WOODS HOLE GROUP FOR EARTH, FROM SPACE
A CLS COMPANY

September 30, 2020 Job No. 2018-0231

Secretary Kathleen Theoharides
Executive Office of Energy and Environmental Affairs
Attn: MEPA Office
100 Cambridge Street, Suite 900
Boston, MA 02114

Sent Via Email: MEPA@mass.gov

Re: **EXPANDED ENVIRONMENTAL NOTIFICATION FORM**
Proposed Beach and Dune Nourishment for Towns of Marshfield and Duxbury, MA
Rexhame Public Beach, Winslow Ave. Beach, Fieldston and Sunrise Beaches, Bay Ave. and Gurnet Road Beaches

Dear Secretary Theoharides,

On behalf of the Towns of Marshfield and Duxbury, we are hereby submitting an electronic copy of an Expanded Environmental Notification Form (EENF) for the above referenced project. Due to the current state of emergency, at this time we are refraining from sending physical copies to MEPA and the distribution list, except for the Mass. Historical Commission. The project is categorically included for preparation of an Environmental Impact Report (EIR) pursuant to 301 CMR 11.03(1)(a)1. and 11.03(3)(a)1.b; however, the Town is requesting that the categorical requirements for the EIR be waived.

Please post this EENF Filing Notification in the next Environmental Monitor.

If you have any questions or require any additional information, please call me at 508-495-6225 or send an email to lfields@woodsholegroup.com.

Sincerely,

Leslie Fields

Leslie Fields
Coastal Geologist/Project Manager

MLF/beg

cc: Distribution List
Greg Guimond, Marshfield Town Planner
Valerie Massard, Duxbury Town Planner

Expanded Environmental Notification Form & Waiver Request

Beach and Dune Nourishment
for Towns of Marshfield & Duxbury, MA


Source: Patriot Ledger
Source: Wicked Local

September 2020

PREPARED FOR:
Secretary Kathleen Theoharides
Executive Office of Energy and Environmental Affairs
Attn: MEPA Office
100 Cambridge Street, Suite 900
Boston, MA 02114

PREPARED BY:
Woods Hole Group, Inc.
A CLS Company
107 Waterhouse Road
Bourne, MA 02532 USA

WOODS HOLE GROUP FOR EARTH, FROM SPACE
A CLS COMPANY

September 30, 2020 Job No. 2018-0231

Secretary Kathleen Theoharides
Executive Office of Energy and Environmental Affairs
Attn: MEPA Office
100 Cambridge Street, Suite 900
Boston, MA 02114

Re: **Request for EIR Waiver & Greenhouse Gas Emissions Policy De Minimis Exemption**
Beach and Dune Nourishment for Towns of Marshfield and Duxbury, MA
Rexhame Public Beach, Winslow Ave. Beach, Fieldston and Sunrise Beaches, and Bay Ave. and Gurnet Road Beaches

Dear Secretary Theoharides,

On behalf of the Towns of Marshfield and Duxbury, we are hereby submitting this Expanded Environmental Notification Form (EENF) with a request for a waiver from the requirement for preparation of an Environmental Impact Report (EIR) for the above referenced project. The project includes beach and/or dune nourishment at four (4) key locations along the Marshfield and Duxbury shorelines. The nourishment will restore sediment to critically eroded beaches and dunes, provide storm damage protection for existing resources and shore protection structures, reduce wave overtopping, and enhance the shorebird habitat and recreational values of the beaches. The Towns are focused on mitigating long-term and severe erosion of the beaches caused by coastal armoring along most of the ocean facing developed shorelines.

The project is categorically included for preparation of an EIR pursuant to 301 CMR 11.03(1)(a)1 and 301 CMR 11.03(3)(a)1.b, as the beach and dune nourishment will directly alter more than 50 acres of land, and a state Permit is needed for the project which will alter more than ten acres of wetland, other than salt marsh or bordering vegetated wetland. Additionally, the engineering design and permitting for the project has been partially funded by the Massachusetts Office of Coastal Zone Management.

Request for Waiver from EIR

The Towns of Marshfield and Duxbury are proposing beach and/or dune nourishment at vulnerable locations along the Towns' east facing shorelines. While 83% of the shoreline in Marshfield contains hard shore protection structures and 91% of the developed shoreline in Duxbury has hard shore protection structures, the beaches in front of the structures are critically eroded. This beach erosion has left the seawalls and revetments vulnerable to undermining and failure, and increased the vulnerability of public, commercial, and residential properties to damaging wave overtopping and flooding. Seawall and revetment damage have increased over the years and with each passing coastal storm the shore protection structures show new signs of failure. With hundreds of properties at risk, the Towns cannot afford to wait, and must act now to permit beach and dune nourishment at these vulnerable east facing shorelines.

The proposed project includes beach and/or dune nourishment over 91 acres at the following four (4) locations: Rexhame Public Beach, Winslow Ave. Beach, Fieldston and Sunrise Beaches, and Bay Ave. and Gurnet Rd. Beaches. The project will increase resiliency to coastal storms and sea level rise by restoring sediment to critically eroded beaches that have been adversely impacted by the shore protection structures and the reduced sediment supply caused by miles of seawalls and revetments. The Towns are currently seeking permits for beach and/or dune nourishment at the four (4) locations, while sources of sediment needed to restore the beaches are being identified, investigated, and permitted under separate efforts. Once permits for the nourishment sites are in place, the Towns will be able to pursue sources of compatible sediment from the upland or from nearby dredging projects looking for beneficial reuse opportunities. With additional investigations, they may also identify an offshore borrow site(s) that could be permitted in the future.

According to the MEPA Regulations (310 CMR 11.11), the Secretary may grant a waiver from any provision of the regulations provided that compliance with the requirements would:

- "result in an undue hardship for the Proponent"
- "not serve to avoid or minimize Damage to the Environment"

The Towns of Marshfield and Duxbury contend that the requirement for preparation of an EIR would result in an undue hardship. The extra time required to prepare the EIR would delay issuance of the permits that would result in lost opportunities for accepting sediment as beneficial reuse from nearby dredging projects. The US Army Corps of Engineers dredges Green Harbor annually and places the dredged material in an offshore disposal site where it is lost from the littoral system. However, once the Towns have sites permitted for beach and/or dune nourishment, they will be able to accept the sediment dredged from Green Harbor for use in restoring their beaches and dunes. Every year that sediment dredged from Green Harbor and other nearby navigation projects like the South River is dumped offshore, or taken away from the Marshfield and Duxbury shoreline, results in a missed opportunity to replenish critically eroded beaches and to enhance shoreline resiliency. Additionally, the requirement to prepare an EIR would result in an undue hardship since the extra review time could lead to missed funding and other cost share opportunities that would be used to offset costs associated with project construction and monitoring.

The project will result in public benefits to the Towns of Marshfield and Duxbury by enhancing storm damage protection, reducing costs associated with emergency response during storms, and minimizing expenditures required for post storm recovery. Without implementation of the proposed resiliency measures, costs over the next 30 years for FEMA repetitive loss claims, repair of damaged shore protection structures and emergency services during storms are projected to be $73.6 and $27.1 million for Marshfield and Duxbury, respectively. By nourishing critically eroded beaches and dunes, the Towns are taking proactive steps to enhance public safety and reduce future costs associated with coastal storms. The Towns feel strongly that a requirement to prepare an EIR would delay realization of the project benefits which would result in an undue hardship for both public and private stakeholders.

Presumptions for categorically included projects are that an EIR is necessary to fully investigate and document existing resources and alternatives, and that there will be a significant impact to the environment as a result of the project. In requesting a Waiver from the requirement to file a mandatory EIR, the Expanded ENF filing includes a project description, a detailed description of the existing environmental conditions, a detailed analysis of alternatives considered and associated impacts, as well as mitigation measures that will be employed to limit environmental impacts. The project site has been studied thoroughly, and the proposed designs were developed expressly to avoid and minimize impacts to the environment, while also achieving the project goals to increase resiliency to coastal storms and sea level rise by restoring sediment to critically eroded beaches and dunes impacted by miles of hard coastal engineering structures.

The Towns of Marshfield and Duxbury believe the planning, investigative and procedural reviews undertaken in the preparation of the Expanded ENF provide an extensive and through investigation of resources, and the resulting project for restoring sediment to critically eroded beaches and dunes will minimize impacts to the natural resources. The project will undergo environmental review during the application processes for local Order of Conditions from Marshfield and Duxbury, Department of Environmental Protection (DEP) Chapter 91 Waterways Permits, Coastal Zone Management Federal Consistency Determinations, and US Army Corps of Engineers Individual Permits. As such, the Towns of Marshfield and Duxbury request that the categorical requirement for an EIR be waived.

Request for Greenhouse Gas Emissions Policy De Minimis Exemption

The MEPA Review process requires under the Greenhouse Gas (GHG) Emissions Policy and Protocol that the emission of greenhouse gases be assessed when determining if a project will result in damage to the environment. The goal of the beach and dune nourishment project for the Towns of Marshfield and Duxbury is to enhance the resiliency of the coastline by restoring sediment to the littoral system. The beach and dune nourishment will reduce risks associated with storm flooding and wave overtopping, provide protection for the existing seawalls and revetments, and enhance the recreational and wildlife habitat values of the sites. The GHG emissions associated with this project will be limited to indirect emissions during the construction period of the project, including the placement and spreading of sand on beaches and dunes at selected sites in the Towns of Marshfield and Duxbury. During construction, the Towns will incorporate alternative measures to avoid and minimize GHG emissions, such as limiting idling and using bio-fuels in off-road construction equipment. Upon completion of the project there will be no further sources of greenhouse gases. This project will contribute to the resiliency of the shoreline in the face of expected sea level rise and increasing severity and frequency of storms. Therefore, in regard to the Revised MEPA Greenhouse Gas Emissions Policy and Protocol, a de minimus exemption from the Policy is requested.

If you have any questions or require any additional information, please contact me at 508-495-6225 or via email at lfields@whgrp.com.

Sincerely,

Leslie Fields

Leslie Fields
Coastal Geologist/Project Manager

MLF/beg

Enclosure

cc: Distribution List
Greg Guimond, Marshfield Town Planner
Valerie Massard, Duxbury Town Planner

WOODS HOLE GROUP
A CLS COMPANY

107 Waterhouse Road
Bourne, MA 02532
Phone: 508-540-8080
Fax: 508-540-1001
e-mail: WHGroup@whgrp.com
www.whgrp.com

Expanded Environmental Notification Form Contents:

Section A

Expanded Environmental Notification Form (EENF) Application and Addendum A

Commonwealth of Massachusetts

Executive Office of Energy and Environmental Affairs
Massachusetts Environmental Policy Act (MEPA) Office

Environmental Notification Form

For Office Use Only

EEA#: ____________________

MEPA Analyst: ______________

The information requested on this form must be completed in order to submit a document electronically for review under the Massachusetts Environmental Policy Act, 301 CMR 11.00.

Project Name: Towns of Marshfield & Duxbury Beach and Dune Nourishment		
Street Address: Various		
Municipality: Marshfield & Duxbury	Watershed: Atlantic Ocean	
Universal Transverse Mercator Coordinates:	Latitude: 42 06' 23.75" N Longitude: 70 39' 19.35" W	
Estimated commencement date: Winter 2023	Estimated completion date: TBD	
Project Type: Beach and Dune Nourishment	Status of project design: 85 %complete	
Proponent: Towns of Marshfield & Duxbury		
Street Address: See attached Addendum A		
Municipality:	State:	Zip Code:
Name of Contact Person: Leslie Fields		
Firm/Agency: Woods Hole Group, Inc.	Street Address: 107 Waterhouse Rd.	
Municipality: Bourne	State: MA	Zip Code: 02532
Phone: 508-495-6240	Fax: 508-540-1001	E-mail: lfields@whgrp.com

Does this project meet or exceed a mandatory EIR threshold (see 301 CMR 11.03)?
☒Yes ☐No

If this is an Expanded Environmental Notification Form (ENF) (see 301 CMR 11.05(7)) or a Notice of Project Change (NPC), are you requesting:

a Single EIR? (see 301 CMR 11.06(8))	☒Yes ☐No
a Special Review Procedure? (see 301CMR 11.09)	☐Yes ☐No
a Waiver of mandatory EIR? (see 301 CMR 11.11)	☒Yes ☐No
a Phase I Waiver? (see 301 CMR 11.11)	☐Yes ☐No

(Note: Greenhouse Gas Emissions analysis must be included in the Expanded ENF.)

Which MEPA review threshold(s) does the project meet or exceed (see 301 CMR 11.03)?

11.03(1)(a)1, 11.03(3)(a)1.b, 11.03(3)(b)1.a, 11.03(3)(b)1.e, 11.03(3)(b)4

Which State Agency Permits will the project require?

DEP Chapter 91 Waterways Permit, CZM Federal Consistency Determination

Identify any financial assistance or land transfer from an Agency of the Commonwealth, including the Agency name and the amount of funding or land area in acres:
CZM CR FY20 Grant for $175,842. Additional grant monies will be sought in the future.

Summary of Project Size & Environmental Impacts	Existing	Change	Total
LAND			
Total site acreage	90.85 acres		
New acres of land altered		72.25 acres = sum of footprints above MLW	
Acres of impervious area	0	0	0
Square feet of new bordering vegetated wetlands alteration		0	
Square feet of new other wetland alteration		18.6 acres = sum of footprints below MLW	
Acres of new non-water dependent use of tidelands or waterways		0	
STRUCTURES			
Gross square footage	N/A	N/A	N/A
Number of housing units	N/A	N/A	N/A
Maximum height (feet)	N/A	N/A	N/A
TRANSPORTATION			
Vehicle trips per day	N/A	N/A	N/A
Parking spaces	N/A	N/A	N/A
WASTEWATER			
Water Use (Gallons per day)	N/A	N/A	N/A
Water withdrawal (GPD)	N/A	N/A	N/A
Wastewater generation/treatment (GPD)	N/A	N/A	N/A
Length of water mains (miles)	N/A	N/A	N/A
Length of sewer mains (miles)	N/A	N/A	N/A

Has this project been filed with MEPA before?
☐ Yes (EEA #___) ☒No

Has any project on this site been filed with MEPA before?
☒ Yes (EEA #'s: **see below**) ☐No

Duxbury Seawalls Phase 1 and Revetment
Ocean Rd. South & North, Cable Hill Way, Gurnet Road, Bay Avenue
Town of Duxbury as Applicant
12/26/2018
EEA No. 15957

Foster Avenue Revetment Improvement = *S end of Sunrise Beach*
Foster Ave. From 2nd Road to 7th Road
Town of Marshfield as Applicant
06/10/2019
EEA No. 16045

Foster Ave Seawall Revetment Project = *N end of Sunrise Beach*
Foster Ave from 5th Rd to Old Beach Rd
Town of Marshfield as Applicant
09/09/2015
EEA No. 15415

Seawall Revetment Project = *Fieldston Beach*
Surf Ave – Between Old Beach Road and Rexhame Road
Town of Marshfield as Applicant
09/05/2012
EEA No. 14956

GENERAL PROJECT INFORMATION – all proponents must fill out this section

PROJECT DESCRIPTION:

Describe the existing conditions and land uses on the project site:

Development in the Towns of Marshfield and northern Duxbury consists of single-family homes and some commercial development on small lots located directly along the shoreline. In Marshfield, this development extends along most of the town's 4.7 miles of east facing shoreline. In Duxbury, the northern 0.80 mile of the shoreline is developed. Over the years seawalls and revetments have been built to protect the properties from ongoing erosion. Within the Town of Marshfield, approximately 82.5% (i.e., 3.9 miles) of the east facing shoreline is armored, and in Duxbury 91.3% (i.e., 0.7 miles) of the developed barrier beach is armored. Most of these seawalls and revetments are publicly owned and maintained. The shore protection structures have caused a loss of sediment to the littoral system, a gradual retreat of the shoreline, and a lowering of the beach elevation. During storms, the public and private infrastructure behind the seawalls and revetments is subject to damage from wave overtopping and flooding and the shore protection structures becoming increasingly compromised.

Describe the proposed project and its programmatic and physical elements:

The Towns of Marshfield and Duxbury applied for and received a CZM Grant in FY20 for $175,842 to fund field data collection, an alternatives analysis, and initial permitting for beach and dune nourishment at suitable beaches. A previous CZM Grant (FY18) ($36,000) funded an evaluation of beneficial reuse opportunities for material dredged annually from Green Harbor by the US Army Corps of Engineers.

The proposed project includes beach and dune nourishment at four (4) locations:

- **Rexhame Public Beach (Marshfield)**
- **Winslow Ave Beach (Marshfield)**
- **Fieldston & Sunrise Beaches (Marshfield)**
- **Bay Ave (Marshfield) and Gurnet Rd (Duxbury) Beaches**

The project triggers the requirement for an Environmental Impact Report (EIR) pursuant to

- **301 CMR 11.03(1) (a)1 as it will directly alter more than 50 acres of land,**
- **301 CMR 11.03(3)(a)1.b as a state Permit is needed for the project and it will alter more than 10**
- **acres of wetland other than salt marsh or bordering vegetated wetland.**

However, a waiver from the requirement for an EIR is being requested pursuant to 301 CMR 11.11. The Towns contend that preparation of an EIR would result in an undue hardship since the extra time Required to prepare an EIR would delay issuance of the permits that would result in lost opportunities for accepting sediment as beneficial reuse from nearby dredging projects. Additionally, the extra review time with an EIR could lead to missed funding and other cost share opportunities that would be used to offset costs associated with project construction and monitoring.

See Sections B, D & E for further details.

NOTE: The project description should summarize both the project's direct and indirect impacts (including construction period impacts) in terms of their magnitude, geographic extent, duration and frequency, and reversibility, as applicable. It should also discuss the infrastructure requirements of the project and the capacity of the municipal and/or regional infrastructure to sustain these requirements into the future.

Describe the on-site project alternatives (and alternative off-site locations, if applicable), considered by the proponent, including at least one feasible alternative that is allowed under current zoning, and the reasons(s) that they were not selected as the preferred alternative:

Alternatives for enhancing shoreline resiliency were evaluated at fourteen (14) different beaches along the Marshfield and northern Duxbury shoreline. Alternatives considered included the following: (a) maintain existing management approach – status quo, (b) enhance and/or enlarge existing seawalls and revetments, (c) offshore breakwaters, (d) beach nourishment, (e) dune nourishment, (f) intertidal boulder field, (g) constructed reefs, and (h) managed retreat.

For beaches where soft, nature-based approaches using beach and dune nourishment were determined to be feasible, engineering designs were evaluated, and a preferred alternative was selected for permitting through this Expanded Environmental Notification Form (EENF). Other hard or hybrid options will require further study and engineering design, and therefore are not included as part of this permitting request. See Section D for further details.

NOTE*: The purpose of the alternatives analysis is to consider what effect changing the parameters and/or siting of a project, or components thereof, will have on the environment, keeping in mind that the objective of the MEPA review process is to avoid or minimize damage to the environment to the greatest extent feasible. Examples of alternative projects include alternative site locations, alternative site uses, and alternative site configurations.*

Summarize the mitigation measures proposed to offset the impacts of the preferred alternative:

Mitigation measures proposed are directed toward avoiding and minimizing impacts during and after construction, and include the following (See Section F for further details):

- **Time of year restrictions will be followed for protection of endangered species.**
- **Equipment access for all beach and dune nourishment will utilize existing beach access ways.**
- **Nourishment footprints have been designed to avoid direct impacts to rocky intertidal resources. Where direct impacts are unavoidable, rocky intertidal habitat will be replicated within the nourishment footprint.**
- **Nourishment sediments compatible with existing beach and dune sediments have been specified.**
- **The nourishment footprint for the Bay Ave beach has been shortened to minimize impacts caused by increased shoaling at Green Harbor. Nourishment sediments at the northern end of Bay Ave will be predominantly cobble and gravel to minimize northerly transport towards the Harbor.**
- **Beach and dune slopes have been designed to meet habitat requirements for threatened and**
- **endangered nesting shorebirds.**
- **Beach grass plantings will only be conducted landward of the dune crest to maintain appropriate shorebird habitat.**

If the project is proposed to be constructed in phases, please describe each phase:

The project will be constructed in phases, as funding and material (i.e., large volumes of sediment for nourishment) are obtained. Once the project is fully permitted, the Towns will be able to receive sediment dredged annually from Green Harbor by the US Army Corps of Engineers. Nourishment materials will be directed to permitted beach areas in need of improved resiliency, or in response to significant erosion following storms.

AREAS OF CRITICAL ENVIRONMENTAL CONCERN:

Is the project within or adjacent to an Area of Critical Environmental Concern?

☐ Yes (Specify__________)

☒ No

if yes, does the ACEC have an approved Resource Management Plan? ___ Yes ___ No;

If yes, describe how the project complies with this plan.

____

Will there be stormwater runoff or discharge to the designated ACEC? ___ Yes ___ No;

If yes, describe and assess the potential impacts of such stormwater runoff/discharge to the designated ACEC.

____

RARE SPECIES:

Does the project site include Estimated and/or Priority Habitat of State-Listed Rare Species? (see http://www.mass.gov/dfwele/dfw/nhesp/regulatory_review/priority_habitat/priority_habitat_home.htm)

☒Yes (Specify: Estimated and Priority Habitat__) ☐No

HISTORICAL /ARCHAEOLOGICAL RESOURCES:
Does the project site include any structure, site or district listed in the State Register of Historic Place or the inventory of Historic and Archaeological Assets of the Commonwealth?
☒Yes (Specify: **See 10 properties, see below**) ☐No

77, 81, 83, 87, 91, 93, 97, 101, 105 & 109 Gurnet Road in Duxbury. These resources are all located landward of the seawall, and therefore are outside the project footprint.

If yes, does the project involve any demolition or destruction of any listed or inventoried historic or archaeological resources? ☐Yes (Specify____) ☒No

WATER RESOURCES:
Is there an Outstanding Resource Water (ORW) on or within a half-mile radius of the project site? _X_Yes ___No; if yes, identify the ORW and its location. _________

South River ORW in Marshfield is located behind the barrier beach and within a half-mile of the proposed nourishments at Rexhame Public Beach and Winslow Ave Beach. Impacts to this ORW are not expected.

(NOTE: Outstanding Resource Waters include Class A public water supplies, their tributaries, and bordering wetlands; active and inactive reservoirs approved by MassDEP; certain waters within Areas of Critical Environmental Concern, and certified vernal pools. Outstanding resource waters are listed in the Surface Water Quality Standards, 314 CMR 4.00.)

Are there any impaired water bodies on or within a half-mile radius of the project site? _X_Yes ___No; if yes, identify the water body and pollutant(s) causing the impairment:

The project sites are not located directly on an impaired water body.

There is, however, an impaired water body within a ½ mile of Rexhame Public Beach and Winslow Ave. Beach in Marshfield: South River. South River is listed as a Category 5 waterbody on MassDEP's 2014 Integrated List of Waters, from the dam at Main Street, Marshfield to confluence with North River/Massachusetts Bay, Marshfield/Scituate. It is listed as impaired for shellfishing due to fecal coliform from municipal separate storm sewer systems (MS4).

There is also an impaired water body within a ½ mile of the Bay Ave. Beach in Marshfield: Green Harbor. Green Harbor is listed as a Category 5 waterbody on MassDEP's 2014 Integrated List of Waters, from the tidegates at Route 139, Marshfield to the mouth of the harbor at Massachusetts Bay/Cape Cod Bay, Marshfield. It is listed as impaired for shellfishing due to fecal coliform from an unknown source.

Is the project within a medium or high stress basin, as established by the Massachusetts Water Resources Commission? ___Yes _X__No

STORMWATER MANAGEMENT:

Generally describe the project's stormwater impacts and measures that the project will take to comply with the standards found in MassDEP's Stormwater Management Regulations:_**N/A**____

MASSACHUSETTS CONTINGENCY PLAN:
Has the project site been, or is it currently being, regulated under M.G.L.c.21E or the Massachusetts Contingency Plan? Yes ___ No _X__ ;
if yes, please describe the current status of the site (including Release Tracking Number (RTN), cleanup phase, and Response Action Outcome classification):_________________

Is there an Activity and Use Limitation (AUL) on any portion of the project site? Yes ___ No _X__;
if yes, describe which portion of the site and how the project will be consistent with the AUL: ___.

Are you aware of any Reportable Conditions at the property that have not yet been assigned an RTN?
Yes ___ No _X__ ; if yes, please describe:_______________

SOLID AND HAZARDOUS WASTE:

If the project will generate solid waste during demolition or construction, describe alternatives considered for re-use, recycling, and disposal of, e.g., asphalt, brick, concrete, gypsum, metal, wood:__**N/A**____

(NOTE: Asphalt pavement, brick, concrete and metal are banned from disposal at Massachusetts landfills and waste combustion facilities and wood is banned from disposal at Massachusetts landfills. See 310 CMR 19.017 for the complete list of banned materials.)

Will your project disturb asbestos containing materials? Yes ___ No _X__ ;
if yes, please consult state asbestos requirements at http://mass.gov/MassDEP/air/asbhom01.htm

Describe anti-idling and other measures to limit emissions from construction equipment:

The Towns of Marshfield and Duxbury will incorporate measures to avoid and minimize Green House Gas emissions during the construction period, such as limiting idling and using bio-fuels in off-road construction equipment.

DESIGNATED WILD AND SCENIC RIVER:

Is this project site located wholly or partially within a defined river corridor of a federally designated Wild and Scenic River or a state designated Scenic River? Yes ___ No _X__ ;
if yes, specify name of river and designation:

If yes, does the project have the potential to impact any of the “outstandingly remarkable” resources of a federally Wild and Scenic River or the stated purpose of a state designated Scenic River?
Yes ___ No ___ ; if yes, specify name of river and designation: _____________;
if yes, will the project will result in any impacts to any of the designated “outstandingly remarkable” resources of the Wild and Scenic River or the stated purposes of a Scenic River.
Yes ___ No ___ ;
if yes,describe the potential impacts to one or more of the “outstandingly remarkable” resources or stated purposes and mitigation measures proposed.

ATTACHMENTS:

1. List of all attachments to this document.
2. U.S.G.S. map (good quality color copy, 8-½ x 11 inches or larger, at a scale of 1:24,000) indicating the project location and boundaries.
3.. Plan, at an appropriate scale, of existing conditions on the project site and its immediate environs, showing all known structures, roadways and parking lots, railroad rights-of-way, wetlands and water bodies, wooded areas, farmland, steep slopes, public open spaces, and major utilities.
4 Plan, at an appropriate scale, depicting environmental constraints on or adjacent to the project site such as Priority and/or Estimated Habitat of state-listed rare species, Areas of Critical Environmental Concern, Chapter 91 jurisdictional areas, Article 97 lands, wetland resource area delineations, water supply protection areas, and historic resources and/or districts.
5. Plan, at an appropriate scale, of proposed conditions upon completion of project (if construction of the project is proposed to be phased, there should be a site plan showing conditions upon the completion of each phase).
6. List of all agencies and persons to whom the proponent circulated the ENF, in accordance with 301 CMR 11.16(2).
7. List of municipal and federal permits and reviews required by the project, as applicable.

LAND SECTION – all proponents must fill out this section

I. Thresholds / Permits

A. Does the project meet or exceed any review thresholds related to **land** (see 301 CMR 11.03(1)
_X__ Yes ___ No; if yes, specify each threshold:

11.03(1)(a)1

II. Impacts and Permits

A. Describe, in acres, the current and proposed character of the project site, as follows:

	Existing	Change	Total
Footprint of buildings			
Internal roadways			
Parking and other paved areas			
Other altered areas			
Undeveloped areas	90.79	0	90.79
Total: Project Site Acreage			

B. Has any part of the project site been in active agricultural use in the last five years?
___ Yes _X__ No; if yes, how many acres of land in agricultural use (with prime state or locally important agricultural soils) will be converted to nonagricultural use?

C. Is any part of the project site currently or proposed to be in active forestry use?
___ Yes _X__ No; if yes, please describe current and proposed forestry activities and indicate whether any part of the site is the subject of a forest management plan approved by the Department of Conservation and Recreation:

D. Does any part of the project involve conversion of land held for natural resources purposes in accordance with Article 97 of the Amendments to the Constitution of the Commonwealth to any purpose not in accordance with Article 97? ___ Yes _X__ No; if yes, describe:

E. Is any part of the project site currently subject to a conservation restriction, preservation restriction, agricultural preservation restriction or watershed preservation restriction? ___ Yes__X_ No; if yes, does the project involve the release or modification of such restriction? ___ Yes ___ No; if yes, describe:

F. Does the project require approval of a new urban redevelopment project or a fundamental change in an existing urban redevelopment project under M.G.L.c.121A? ___ Yes _X__ No; if yes, describe:

G. Does the project require approval of a new urban renewal plan or a major modification of an existing urban renewal plan under M.G.L.c.121B? Yes ___ No _X__; if yes, describe:

III. Consistency

A. Identify the current municipal comprehensive land use plans:

Title: **Town of Marshfield, MA 2015 Master Plan, Date: August 2015**
Title: **Town of Duxbury Master Plan, Date: December 2019**

B. Describe the project's consistency with that plan with regard to:
1) economic development ______________________
2) adequacy of infrastructure ____________________
3) open space impacts __________________________
4) compatibility with adjacent land uses______________

1) **Economic Development** – Economic goals of the MMP include maximizing the benefits of Marshfield's costal location, strengthening downtown commerce, and to support and expand maritime industries and tourism that provide economic benefits. Similarly, economic goals outlined in the DMP include strengthening maritime businesses including tourism, strategically planning for resilience, and maintaining a vibrant coastal economy through climate change. The proposed beach/dune nourishment and cobble berm will help to maintain a valuable coastal habitat and recreation area that attracts both tourists and year-round residents. After visiting the beach, tourists will likely contribute to the local economies of both Marshfield and Duxbury by visiting local restaurants and shops. Habitat restoration efforts will also benefit fisheries and shellfish populations in Marshfield and Duxbury, both of which substantially contribute to the economy. In addition, the proposed nature-based project will provide continued use of beaches within Marshfield and Duxbury by increasing coastal resiliently, thus protecting economic development through tourism as climate change progresses.

2) **Adequacy of Infrastructure** – The MMP emphasizes the significant damage of public infrastructure and private residences that occurs when waves overtop seawalls, which will increase in severity as sea level continues to rise. Also mentioned is the importance of climate change adaption strategies in relation to costal infrastructure. The DMP aims to manage infrastructure to meet current and future needs of the town and to incorporate climate resiliency into planning efforts. Significant overtopping of the seawalls within Marshfield and Duxbury is already a regular occurrence, resulting in significant costs to both towns. The proposed project will improve storm damage protection and augment current management, minimizing damage to infrastructure and cost of repairs. As the proposed project mitigates damage to infrastructure as a result of costal processes that become worse with climate change, the project supports an adaption strategy that accounts for climate change.

3) **Open Space Impacts** – Open Space and Recreation goals of the MMP include maintaining linked lands for wildlife habitat connectivity, providing additional protection to the Green Harbor River watershed areas, and to conserve, protect, and restore valuable shoreline resources. DMP Open Space Goals include protecting Duxbury's water resources, preserving the semi-rural character of the town, and to provide recreation opportunities with minimal impact to the environment. The proposed habitat restoration will preserve current and future use of Marshfield and Duxbury beaches as a recreation area and will maintain a long stretch of connecting coastal beach habitat for wildlife. Beach and dune nourishment will also provide additional habitat for nesting shorebirds. The DMP also aims to take into account the effects of climate change and develop long term strategies for open spaces. The proposed project will help to increase coastal resiliency through habitat restoration, which will help to mitigate the effects of severe storms and flooding on the shorelines of Marshfield and Duxbury. In addition, restoring costal dune and beach habitat will provide storm damage protection for the Green Harbor River watershed.

4) **Compatibility with Adjacent Land Uses** – Adjacent to the Rexhame, Fieldston, Sunrise, and Bay Avenue/Gurnet Road Beaches are a variety of land uses including residential communities, commercial districts, and harbors. All the elements of the proposed project will help maintain the integrity of these beaches, which provides significant storm damage protection to inland areas and to coastal harbors. Storm protection will benefit both Marshfield and Duxbury by decreasing damage to inland commercial, residential, and harbor areas, all of which are likely utilized by tourists. This supports the MMP's goal of protecting the Green Harbor River watershed as well, which is adjacent to the proposed project area.

C. Identify the current Regional Policy Plan of the applicable Regional Planning Agency (RPA)
RPA: Metropolitan Area Planning Council

Title: **MetroFuture, Making a Greater Boston Region, Date: May 2008**

D. Describe the project's consistency with that plan with regard to:
   1) economic development ________________________
   2) adequacy of infrastructure _______________________
   3) open space impacts ____________________________

1) **Economic Development** – Sustainable Growth Patterns goals of the MAPC include small business owners playing a major role in the regional economy through their combined contributions and regional growth guided by proactive planning and resilience to climate change. Both the towns of Marshfield and Duxbury contain many small businesses such as restaurants, cafes, hotels, galleries, shops, etc. adjacent to coastal beaches. The proposed project will help support small businesses by attracting tourists to beaches who will then rely on nearby businesses in the hospitality sector within Marshfield and Duxbury. The proposed project also takes a proactive approach to protecting future growth occurring within residential and commercial sectors of Marshfield and Duxbury by providing increased storm damage protection and resilience to climate change.

2) **Adequacy of Infrastructure** – The proposed project is consistent with MAPC's goals of ensuring the region is prepared for and resilient from climate change. Habitat restoration efforts outlined in the proposed project will restore natural dune and beach habitat which provides natural storm damage protection and minimizes coastal flooding. These nature-based resiliency measures will augment current beach management, mainly consisting of hard structures including seawalls. The proposed project will minimize direct impacts on the seawalls, increasing their longevity and the degree of protection they offer to residential buildings and public infrastructure behind seawalls.

3) **Open Space Impacts** – Energy, Air, Water, and Wildlife goals of the MAPC include sustainably managing water resources, maintaining biodiversity, and creating a network of protected open spaces that provide wildlife habitat and scenic beauty. Community Vitality goals also include maintaining access to community outdoor spaces. By restoring the costal dune and beach habitat, the proposed project will maintain and protect the existing open spaces, wildlife habitat, and scenic beauty of the beaches within Marshfield and Duxbury. This will also help to maintain biodiversity, such as of the many bird species that depend on coastal habitat area for nesting and of shellfish species. In addition, the proposed project will maintain the large expanse of beaches along the shoreline from Marshfield to Duxbury that create a network of wildlife habitat and connectivity

RARE SPECIES SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to **rare species or habitat** (see 301 CMR 11.03(2))? ___ Yes _X__ No; if yes, specify, in quantitative terms:

(NOTE: If you are uncertain, it is recommended that you consult with the Natural Heritage and Endangered Species Program (NHESP) prior to submitting the ENF.)

B. Does the project require any state permits related to **rare species or habitat**? ___ Yes _X_ No

C. Does the project site fall within mapped rare species habitat (Priority or Estimated Habitat?) in the current Massachusetts Natural Heritage Atlas (attach relevant page)? _X__ Yes ___ No.

D. If you answered "No" to all questions A, B and C, proceed to the **Wetlands, Waterways, and Tidelands Section**. If you answered "Yes" to either question A or question B, fill out the remainder of the Rare Species section below.

II. Impacts and Permits

A. Does the project site fall within Priority or Estimated Habitat in the current Massachusetts Natural Heritage Atlas (attach relevant page)? _X__ Yes ___ No. If yes,

1. Have you consulted with the Division of Fisheries and Wildlife Natural Heritage and Endangered Species Program (NHESP)? _X__Yes ___No; if yes, have you received a determination as to whether the project will result in the "take" of a rare species? ___ Yes _X__ No; if yes, attach the letter of determination to this submission.

2. Will the project "take" an endangered, threatened, and/or species of special concern in accordance with M.G.L. c.131A (see also 321 CMR 10.04)? ___ Yes _X__ No; if yes, provide a summary of proposed measures to minimize and mitigate rare species impacts

3. Which rare species are known to occur within the Priority or Estimated Habitat?

Piping Plover and Seabeach Needlegrass at Rexhame Public Beach

Piping Plover and Least Tern at Bay Ave and Gurnet Rd Beaches

See attached response letter from NHESP dated January 30, 2020 in Section L.

4. Has the site been surveyed for rare species in accordance with the Massachusetts Endangered Species Act? _X__ Yes**, (see below)** ___ No

Rexhame Public Beach in Marshfield is within NHESP mapped habitat and is monitored annually by Mass Audubon.

Winslow Ave. Beach, Fieldston and Sunrise Beaches, and Bay Ave. Beach in Marshfield are not currently within NHESP mapped habitat.

The southern end of Gurnet Rd. Beach in Duxbury is currently within NHESP mapped habitat, but not currently monitored. This portion includes the following private properties: 1, 3, 5, 7, 9, 11, 13, 15, 17, 19 and 21 Ocean Road South. The Duxbury Beach Reservation property directly abuts this area and is monitored annually by Mass Audubon.

4. If your project is within Estimated Habitat, have you filed a Notice of Intent or received an Order of Conditions for this project? ___ Yes _X__ No (**to be filed)**; if yes, did you send a copy of the Notice of Intent to the Natural Heritage and Endangered Species Program, in

accordance with the Wetlands Protection Act regulations? ___ Yes ___ No

B. Will the project "take" an endangered, threatened, and/or species of special concern in accordance with M.G.L. c.131A (see also 321 CMR 10.04)? ___ Yes _X__ No; if yes, provide a summary of proposed measures to minimize and mitigate impacts to significant habitat:

WETLANDS, WATERWAYS, AND TIDELANDS SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to **wetlands, waterways, and tidelands** (see 301 CMR 11.03(3))? _X__ Yes ___ No; if yes, specify, in quantitative terms:

11.03(3)(a)1.b – The project will directly alter 6.1 acres of coastal dune, 63.1 acres of coastal beach, 18.6 acres of land under the ocean, and 75.6 acres of land containing shellfish.

11.03(3)(b)1.a – The project will require a Permit from the Commonwealth and will result in alteration to coastal dune and barrier beach resources.

11.03(3)(b)1.e – The project will result in 768,020 cy of fill of within a velocity zone

11.03(3)(b)4 – The project may result in disposal of more than 10,000 cy of dredged material.

B. Does the project require any state permits (or a local Order of Conditions) related to **wetlands, waterways, or tidelands**? _X__ Yes ___ No; if yes, specify which permit:

Marshfield Nourishment:
- **Order of Conditions**
- **Chapter 91 Waterways Permit**
- **CZM Federal Consistency Determination**

Duxbury Nourishment:
- **Order of Conditions**
- **Chapter 91 Waterways Permit**
- **CZM Federal Consistency Determination**

The Towns are planning to get separate state and federal permits after the MEPA process so that they are responsible for their own projects, compliance reporting, and permit tracking.

C. If you answered "No" to both questions A and B, proceed to the **Water Supply Section**. If you answered "Yes" to either question A or question B, fill out the remainder of the Wetlands, Waterways, and Tidelands Section below.

II. Wetlands Impacts and Permits

A. Does the project require a new or amended Order of Conditions under the Wetlands Protection Act (M.G.L. c.131A)? __X_ Yes ___ No; if yes, has a Notice of Intent been filed? ___ Yes _X__ No **(to be filed)**; if yes, list the date and MassDEP file number: ______; if yes, has a local Order of Conditions been issued? ___ Yes ___ No; Was the Order of Conditions appealed? ___ Yes ___ No. Will the project require a Variance from the Wetlands regulations? ___ Yes _X__ No.

B. Describe any proposed permanent or temporary impacts to wetland resource areas located on the project site:

See Section E for further details regarding permanent or temporary impacts.

C. Estimate the extent and type of impact that the project will have on wetland resources, and indicate whether the impacts are temporary or permanent:

Coastal Wetlands	Area (square feet) or Length (linear feet)	Temporary or Permanent Impact?
Land Under the Ocean	_810,216_________	_permanent_________

Designated Port Areas		
Coastal Beaches	2,879,316	permanent
Coastal Dunes	265,280	permanent
Barrier Beaches	3,340,180	permanent
Coastal Banks		permanent
Rocky Intertidal Shores	47,480	
Salt Marshes		
Land Under Salt Ponds		
Land Containing Shellfish	3,292,136	permanent
Fish Runs		
Land Subject to Coastal Storm Flowage	3,954,812	permanent

Inland Wetlands		
Bank (lf)		
Bordering Vegetated Wetlands		
Isolated Vegetated Wetlands		
Land under Water		
Isolated Land Subject to Flooding		
Borderi ng Land Subject to Flooding		
Riverfront Area		

D. Is any part of the project:

1. proposed as a **limited project**? ___ Yes _X__ No; if yes, what is the area (in sf)?____
2. the construction or alteration of a **dam**? ___ Yes _X__ No; if yes, describe:
3. fill or structure in a **velocity zone** or **regulatory floodway**? _X__ Yes ___ No
4. dredging or disposal of dredged material? _X__ Yes ___ No; if yes, describe the volume of dredged material and the proposed disposal site:

   The project proposes up to 768,020 cy of material to be obtained from dredged material, land-based sources, or a combination of both. Disposal sites have been designed for Rexhame Public Beach, Winslow Ave Beach, Fieldston/Sunrise Beaches, and Bay Ave/Gurnet Rd Beaches.

5. a discharge to an **Outstanding Resource Water (ORW)** or an **Area of Critical Environmental Concern (ACEC)**? ___ Yes _X__ No
6. subject to a wetlands restriction order? ___ Yes __X__ No; if yes, identify the area (in sf):
7. located in buffer zones? ___Yes _X__No; if yes, how much (in sf) ______

E. Will the project:

1. be subject to a local wetlands ordinance or bylaw? __X_ Yes ___ No
2. alter any federally-protected wetlands not regulated under state law? ___ Yes _X__ No; if yes, what is the area (sf)?

III. Waterways and Tidelands Impacts and Permits

A. Does the project site contain waterways or tidelands (including filled former tidelands) that are subject to the Waterways Act, M.G.L.c.91? _X__ Yes ___ No; if yes, is there a current Chapter 91 License or Permit affecting the project site? _X__ Yes ___ No; if yes, list the date and license or permit number and provide a copy of the historic map used to determine extent of filled tidelands: **See Section C Figure C-29 for map of historic MHW.**

Town of Duxbury – Ch91 License No. 4235, issued 11/4/1994
Town of Duxbury – Ch91 License No. 6664, issued 7/2/1997

Town of Marshfield – State Contract 962 in January 1947

Town of Marshfield – State Contract 1882 in November 1957
Town of Marshfield – State Contract 2502 in October 1965

C. Does the project require a new or modified license or permit under M.G.L.c.91? _X__ Yes ___ No; if yes, how many acres of the project site subject to M.G.L.c.91 will be for non-water-dependent use? Current _0__ Change _0__ Total _0__
If yes, how many square feet of solid fill or pile-supported structures (in sf)?

D. For non-water-dependent use projects, indicate the following: **N/A**
Area of filled tidelands on the site:____________________
Area of filled tidelands covered by buildings:____________
For portions of site on filled tidelands, list ground floor uses and area of each use: ______________
Does the project include new non-water-dependent uses located over flowed tidelands? Yes ___ No ___
Height of building on filled tidelands________________

Also show the following on a site plan: Mean High Water, Mean Low Water, Water-dependent Use Zone, location of uses within buildings on tidelands, and interior and exterior areas and facilities dedicated for public use, and historic high and historic low water marks.

E. Is the project located on landlocked tidelands? ___ Yes _X_ No; if yes, describe the project's impact on the public's right to access, use and enjoy jurisdictional tidelands and describe measures the project will implement to avoid, minimize or mitigate any adverse impact:

F. Is the project located in an area where low groundwater levels have been identified by a municipality or by a state or federal agency as a threat to building foundations? ___Yes _X_ No; if yes, describe the project's impact on groundwater levels and describe measures the project will implement to avoid, minimize or mitigate any adverse impact:

G. Is the project non-water-dependent **and** located on landlocked tidelands **or** waterways or tidelands subject to the Waterways Act **and** subject to a mandatory EIR? ___ Yes _X__ No;
(NOTE: If yes, then the project will be subject to Public Benefit Review and Determination.)

H. Does the project include dredging? ___ Yes _X__ No; if yes, answer the following questions:
What type of dredging? Improvement ___ Maintenance ___ Both ____
What is the proposed dredge volume, in cubic yards (cys) _________
What is the proposed dredge footprint ____length (ft) ___width (ft)____depth (ft);
Will dredging impact the following resource areas?
Intertidal Yes__ No__; if yes, ___ sq ft
Outstanding Resource Waters Yes__ No__; if yes, ___ sq ft
Other resource area (i.e. shellfish beds, eel grass beds) Yes__ No__; if yes __ sq ft
If yes to any of the above, have you evaluated appropriate and practicable steps to: 1) avoidance; 2) if avoidance is not possible, minimization; 3) if either avoidance or minimize is not possible, mitigation?
If no to any of the above, what information or documentation was used to support this determination?
Provide a comprehensive analysis of practicable alternatives for improvement dredging in accordance with 314 CMR 9.07(1)(b). Physical and chemical data of the sediment shall be included in the comprehensive analysis.
Sediment Characterization
Existing gradation analysis results? __Yes ___No: if yes, provide results.

Existing chemical results for parameters listed in 314 CMR 9.07(2)(b)6? ___Yes ____No; if yes, provide results.

Do you have sufficient information to evaluate feasibility of the following management options for dredged sediment? If yes, check the appropriate option.

Beach Nourishment ___
Unconfined Ocean Disposal ___
Confined Disposal:
Confined Aquatic Disposal (CAD) ___
Confined Disposal Facility (CDF) ___
Landfill Reuse in accordance with COMM-97-001 ___
Shoreline Placement ___
Upland Material Reuse____
In-State landfill disposal____
Out-of-state landfill disposal ____
(NOTE: This information is required for a 401 Water Quality Certification.)

IV. Consistency:

A. Does the project have effects on the coastal resources or uses, and/or is the project located within the Coastal Zone? __X_ Yes ___ No; if yes, describe these effects and the projects consistency with the policies of the Office of Coastal Zone Management:

See CZM Consistency Statement in Section K.

B. Is the project located within an area subject to a Municipal Harbor Plan? _X__ Yes ___ No; if yes, identify the Municipal Harbor Plan and describe the project's consistency with that plan:

The proposed Nature-Based Storm-Damage Protection project consists of large-scale beach and dune nourishment at four (4) beaches along the Marshfield and Duxbury shorelines. Main objectives of the project include significantly contributing to a comprehensive resilience plan for the communities of Marshfield and Duxbury, increased protection for natural resources and shoreline infrastructure, and public outreach and collaboration, all of which are consistent with the Marshfield Harbor, Rivers, and Waterways Management Plan (MHRWMP). Main goals of the MHRWMP include maintaining safe navigation and boating, protecting natural resources, improving public access, and protecting waterfronts that attract tourist and contribute to the local economy.

The proposed project will offer increased protection of natural resources. Beaches along the shoreline of Marshfield and Duxbury have been experiencing ongoing and severe erosion, resulting in landward migration of the shoreline. By significantly increasing the amount of sediment and size of dunes and beaches, the proposed project will help to maintain the existing beach and dune habitat. Marshfield beaches also serve as vital nesting habitat for threatened species, such as the piping plover. The proposed dune nourishment has been designed specifically to maintain dune slopes appropriate for shorebird nesting. Additionally, beach and dune nourishment resulting in decreased erosion will also protect existing salt marsh habitat, such as that around Green River, and preserve ecosystem services provided by salt marshes such as flood mitigation, increased water quality, and erosion prevention. The proposed project will also improve public access to coastal recreation areas, which serve as tourist attractions and thus, contribute to the local economy.

The MHRWMP also aims to prepare Marshfield for the effects of climate change, most notably sea level rise and severe storms. The project will provide a nature-based technique to mitigate storm damage and offer increased protection for coastal infrastructure, both public and private. Decreased storm damage will also result in lower repair costs for both the town and local residents, increasing available funds for other priorities. Collaboration is another main component of the MHRWMP, as well as of the

proposed project. Both the towns of Marshfield and Duxbury prioritized public education and outreach as a part of the proposed project. Public meetings will be held with shorefront property owners and the general public, in addition to meetings with regulatory agencies including the Executive Office of Energy and Environmental Affairs/MEPA Office, Massachusetts Office of Coastal Zone Management (CZM) and the local Conservation Commissions. The proposed project will also operate in compliance with the Massachusetts Department of Environmental Protection (DEP) Wetlands Protection Act, the Marshfield Conservation Commission, and DEP Waterways Chapter 91 regulations, all referenced in the MHRWMP. In addition, the project will have no negative effect on recreational or commercial fishing, the importance of which is emphasized in the MHRWMP.

The Town of Duxbury lacks on official harbors management plan, instead using the Snug Harbor Storm Emergency Plan (SHSEP). However, the proposed project is not located within Snug Harbor and will not affect the emergency measures outlined in the SHSEP, to be taken prior to a storm event.

WATER SUPPLY SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to **water supply** (see 301 CMR 11.03(4))? ___ Yes _X__ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to **water supply**? ___ Yes _X__ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the **Wastewater Section**. If you answered "Yes" to either question A or question B, fill out the remainder of the Water Supply Section below.

II. Impacts and Permits

A. Describe, in gallons per day (gpd), the volume and source of water use for existing and proposed activities at the project site:

	Existing	Change	Total
Municipal or regional water supply	________	________	________
Withdrawal from groundwater	________	________	________
Withdrawal from surface water	________	________	________
Interbasin transfer	________	________	________

(NOTE: Interbasin Transfer approval will be required if the basin and community where the proposed water supply source is located is different from the basin and community where the wastewater from the source will be discharged.)

B. If the source is a municipal or regional supply, has the municipality or region indicated that there is adequate capacity in the system to accommodate the project? ___ Yes ___ No

C. If the project involves a new or expanded withdrawal from a groundwater or surface water source, has a pumping test been conducted? ___ Yes ___ No; if yes, attach a map of the drilling sites and a summary of the alternatives considered and the results. ______________

D. What is the currently permitted withdrawal at the proposed water supply source (in gallons per day)? ______Will the project require an increase in that withdrawal? ___Yes ___No; if yes, then how much of an increase (gpd)? ____________________

E. Does the project site currently contain a water supply well, a drinking water treatment facility, water main, or other water supply facility, or will the project involve construction of a new facility? ___ Yes ___No. If yes, describe existing and proposed water supply facilities at the project site:

	Permitted Flow	Existing Avg Daily Flow	Project Flow	Total
Capacity of water supply well(s) (gpd)	_______	________	________	________
Capacity of water treatment plant (gpd)	_______	________	________	________

F. If the project involves a new interbasin transfer of water, which basins are involved, what is the direction of the transfer, and is the interbasin transfer existing or proposed?

G. Does the project involve:

1. new water service by the Massachusetts Water Resources Authority or other agency of the Commonwealth to a municipality or water district? ___ Yes ___ No
2. a Watershed Protection Act variance? ___ Yes ___ No; if yes, how many acres of alteration?
3. a non-bridged stream crossing 1,000 or less feet upstream of a public surface drinking water supply for purpose of forest harvesting activities? ___ Yes ___ No

III. Consistency

Describe the project's consistency with water conservation plans or other plans to enhance water resources, quality, facilities and services:

WASTEWATER SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to **wastewater** (see 301 CMR 11.03(5))? ___ Yes _X__ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to **wastewater**? ___ Yes _X__ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the **Transportation -- Traffic Generation Section**. If you answered "Yes" to either question A or question B, fill out the remainder of the Wastewater Section below.

II. Impacts and Permits

A. Describe the volume (in gallons per day) and type of disposal of wastewater generation for existing and proposed activities at the project site (calculate according to 310 CMR 15.00 for septic systems or 314 CMR 7.00 for sewer systems):

	Existing	Change	Total
Discharge of sanitary wastewater	________	________	________
Discharge of industrial wastewater	________	________	________
TOTAL	________	________	________

	Existing	Change	Total
Discharge to groundwater	________	________	________
Discharge to outstanding resource water	________	________	________
Discharge to surface water	________	________	________
Discharge to municipal or regional wastewater facility	________	________	________
TOTAL	________	________	________

B. Is the existing collection system at or near its capacity? ___ Yes ___ No; if yes, then describe the measures to be undertaken to accommodate the project's wastewater flows:

C. Is the existing wastewater disposal facility at or near its permitted capacity? ___ Yes___ No; if yes, then describe the measures to be undertaken to accommodate the project's wastewater flows:

D. Does the project site currently contain a wastewater treatment facility, sewer main, or other wastewater disposal facility, or will the project involve construction of a new facility? ___ Yes ___ No; if yes, describe as follows:

	Permitted	Existing Avg Daily Flow	Project Flow	Total
Wastewater treatment plant capacity (in gallons per day)	_______	________	________	________

E. If the project requires an interbasin transfer of wastewater, which basins are involved, what is the direction of the transfer, and is the interbasin transfer existing or new?

(NOTE: Interbasin Transfer approval may be needed if the basin and community where wastewater will be discharged is different from the basin and community where the source of water supply is located.)

F. Does the project involve new sewer service by the Massachusetts Water Resources Authority (MWRA) or other Agency of the Commonwealth to a municipality or sewer district? ___ Yes ___ No

G. Is there an existing facility, or is a new facility proposed at the project site for the storage, treatment, processing, combustion or disposal of sewage sludge, sludge ash, grit, screenings, wastewater reuse (gray water) or other sewage residual materials? ___ Yes ___ No; if yes, what is the capacity (tons per day):

	Existing	Change	Total
Storage	________	________	________
Treatment	________	________	________
Processing	________	________	________
Combustion	________	________	________
Disposal	________	________	________

H. Describe the water conservation measures to be undertaken by the project, and other wastewater mitigation, such as infiltration and inflow removal.

III. Consistency

A. Describe measures that the proponent will take to comply with applicable state, regional, and local plans and policies related to wastewater management:

B. If the project requires a sewer extension permit, is that extension included in a comprehensive wastewater management plan? ___ Yes ___ No; if yes, indicate the EEA number for the plan and whether the project site is within a sewer service area recommended or approved in that plan:

TRANSPORTATION SECTION (TRAFFIC GENERATION)

I. Thresholds / Permit

A. Will the project meet or exceed any review thresholds related to **traffic generation** (see 301 CMR 11.03(6))? ___ Yes _X__ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to **state-controlled roadways**? ___ Yes _X_ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the **Roadways and Other Transportation Facilities Section**. If you answered "Yes" to either question A or question B, fill out the remainder of the Traffic Generation Section below.

II. Traffic Impacts and Permits

A. Describe existing and proposed vehicular traffic generated by activities at the project site:

	Existing	Change	Total
Number of parking spaces	_______	________	_______
Number of vehicle trips per day	________	________	________
ITE Land Use Code(s):	________	________	________

B. What is the estimated average daily traffic on roadways serving the site?

Roadway	Existing	Change	Total
1. ___________________	________	________	________
2. ____________________	________	________	________
3. ____________________	________	________	________

C. If applicable, describe proposed mitigation measures on state-controlled roadways that the project proponent will implement:

D. How will the project implement and/or promote the use of transit, pedestrian and bicycle facilities and services to provide access to and from the project site?

C. Is there a Transportation Management Association (TMA) that provides transportation demand management (TDM) services in the area of the project site? ____ Yes ____ No; if yes, describe if and how will the project will participate in the TMA:

D. Will the project use (or occur in the immediate vicinity of) water, rail, or air transportation facilities? ____ Yes ____ No; if yes, generally describe:

E. If the project will penetrate approach airspace of a nearby airport, has the proponent filed a Massachusetts Aeronautics Commission Airspace Review Form (780 CMR 111.7) and a Notice of Proposed Construction or Alteration with the Federal Aviation Administration (FAA) (CFR Title 14 Part 77.13, forms 7460-1 and 7460-2)?

III. Consistency

Describe measures that the proponent will take to comply with municipal, regional, state, and federal plans and policies related to traffic, transit, pedestrian and bicycle transportation facilities and services:

TRANSPORTATION SECTION (ROADWAYS AND OTHER TRANSPORTATION FACILITIES)

I. Thresholds

A. Will the project meet or exceed any review thresholds related to **roadways or other transportation facilities** (see 301 CMR 11.03(6))? ___ Yes _X__ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to **roadways or other transportation facilities**? ___ Yes _X__ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the **Energy Section**. If you answered "Yes" to either question A or question B, fill out the remainder of the Roadways Section below.

II. Transportation Facility Impacts

A. Describe existing and proposed transportation facilities in the immediate vicinity of the project site:

B. Will the project involve any

1. Alteration of bank or terrain (in linear feet)? ____________
2. Cutting of living public shade trees (number)? ____________
3. Elimination of stone wall (in linear feet)? ____________

III. Consistency -- Describe the project's consistency with other federal, state, regional, and local plans and policies related to traffic, transit, pedestrian and bicycle transportation facilities and services, including consistency with the applicable regional transportation plan and the Transportation Improvements Plan (TIP), the State Bicycle Plan, and the State Pedestrian Plan:

ENERGY SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to **energy** (see 301 CMR 11.03(7))?
___ Yes _X__ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to **energy**? ___ Yes _X__ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the **Air Quality Section**. If you answered "Yes" to either question A or question B, fill out the remainder of the Energy Section below.

II. Impacts and Permits

A. Describe existing and proposed energy generation and transmission facilities at the project site:

	Existing	Change	Total
Capacity of electric generating facility (megawatts)	________	________	________
Length of fuel line (in miles)	________	________	________
Length of transmission lines (in miles)	________	________	________
Capacity of transmission lines (in kilovolts)	________	________	________

B. If the project involves construction or expansion of an electric generating facility, what are:

1. the facility's current and proposed fuel source(s)?
2. the facility's current and proposed cooling source(s)?

C. If the project involves construction of an electrical transmission line, will it be located on a new, unused, or abandoned right of way? ___Yes ___No; if yes, please describe:

D. Describe the project's other impacts on energy facilities and services:

III. Consistency

Describe the project's consistency with state, municipal, regional, and federal plans and policies for enhancing energy facilities and services:

AIR QUALITY SECTION

I. Thresholds

A. Will the project meet or exceed any review thresholds related to **air quality** (see 301 CMR 11.03(8))? ___ Yes _X__ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to **air quality**? ___ Yes _X__ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the **Solid and Hazardous Waste Section**. If you answered "Yes" to either question A or question B, fill out the remainder of the Air Quality Section below.

II. Impacts and Permits

A. Does the project involve construction or modification of a major stationary source (see 310 CMR 7.00, Appendix A)? ___ Yes ___ No; if yes, describe existing and proposed emissions (in tons per day) of:

	Existing	Change	Total
Particulate matter	________	________	________
Carbon monoxide	________	________	________
Sulfur dioxide	________	________	________
Volatile organic compounds	________	________	________
Oxides of nitrogen	________	________	________
Lead	________	________	________
Any hazardous air pollutant	________	________	________
Carbon dioxide	________	________	________

B. Describe the project's other impacts on air resources and air quality, including noise impacts:

III. Consistency

A. Describe the project's consistency with the State Implementation Plan:

B. Describe measures that the proponent will take to comply with other federal, state, regional, and local plans and policies related to air resources and air quality:

SOLID AND HAZARDOUS WASTE SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to **solid or hazardous waste** (see 301 CMR 11.03(9))? ___ Yes _X__ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to **solid and hazardous waste**? ___ Yes _X__ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the **Historical and Archaeological Resources Section**. If you answered "Yes" to either question A or question B, fill out the remainder of the Solid and Hazardous Waste Section below.

II. Impacts and Permits

A. Is there any current or proposed facility at the project site for the storage, treatment, processing, combustion or disposal of solid waste? ___ Yes ___ No; if yes, what is the volume (in tons per day) of the capacity:

	Existing	Change	Total
Storage	________	________	________
Treatment, processing	________	________	________
Combustion	________	________	________
Disposal	________	________	________

B. Is there any current or proposed facility at the project site for the storage, recycling, treatment or disposal of hazardous waste? ___ Yes ___ No; if yes, what is the volume (in tons or gallons per day) of the capacity:

	Existing	Change	Total
Storage	________	________	________
Recycling	________	________	________
Treatment	________	________	________
Disposal	________	________	________

C. If the project will generate solid waste (for example, during demolition or construction), describe alternatives considered for re-use, recycling, and disposal:

D. If the project involves demolition, do any buildings to be demolished contain asbestos?
___ Yes ___ No

E. Describe the project's other solid and hazardous waste impacts (including indirect impacts):

III. Consistency

Describe measures that the proponent will take to comply with the State Solid Waste Master Plan:

HISTORICAL AND ARCHAEOLOGICAL RESOURCES SECTION

I. Thresholds / Impacts

A. Have you consulted with the Massachusetts Historical Commission? ___ Yes __X_ No; if yes, attach correspondence. For project sites involving lands under water, have you consulted with the Massachusetts Board of Underwater Archaeological Resources? ____Yes __X__ No; if yes, attach correspondence

B. Is any part of the project site a historic structure, or a structure within a historic district, in either case listed in the State Register of Historic Places or the Inventory of Historic and Archaeological Assets of the Commonwealth? _X__ Yes ___ No; if yes, does the project involve the demolition of all or any exterior part of such historic structure? ___ Yes _X__ No; if yes, please describe:

C. Is any part of the project site an archaeological site listed in the State Register of Historic Places or the Inventory of Historic and Archaeological Assets of the Commonwealth? ___ Yes _X__ No; if yes, does the project involve the destruction of all or any part of such archaeological site? ___ Yes ___ No; if yes, please describe:

D. If you answered "No" to all parts of both questions A, B and C, proceed to the **Attachments and Certifications** Sections. If you answered "Yes" to any part of either question A or question B, fill out the remainder of the Historical and Archaeological Resources Section below.

II. Impacts

Describe and assess the project's impacts, direct and indirect, on listed or inventoried historical and archaeological resources:

Ten (10) properties in Duxbury along Gurnet Rd are listed on the State Register of Historic Places. These listings refer to the historic buildings on site which are all located landward of the seawalls. All work proposed with this project will be conducted on the ocean side of the seawalls, and therefore no impacts are expected to these historic properties. The project will in fact help to protect the properties from damages caused by wave overtopping and coastal flooding.

III. Consistency

Describe measures that the proponent will take to comply with federal, state, regional, and local plans and policies related to preserving historical and archaeological resources:

Should any unknown submerged cultural resources be encountered during the course of the project, the applicant will take steps to limit adverse affects and notify the BUAR and MHC, as well as other appropriate agencies, immediately in accordance with the BUAR's Policy Guidance for Discovery of Unanticipated Archaeological Resources.

CERTIFICATIONS: Town of Marshfield

1. The Public Notice of Environmental Review has been/will be published in the following newspapers in accordance with 301 CMR 11.15(1):

   (Name) Marshfield Mariner (Date) September 30, 2020

2. This form has been circulated to Agencies and Persons in accordance with 301 CMR 11.16(2).

Signatures:

9/29/2020	Michael A. Maresco	9/30/2020	Leslie Fields
Date	Signature of Responsible Officer or Proponent	Date	Signature of person preparing EENF

Michael A. Maresco, Town Administrator	Leslie Fields
Name (print or type)	Name (print or type)
Town of Marshfield	Woods Hole Group, Inc.
Firm/Agency	Firm/Agency
870 Moraine Street	107 Waterhouse Road
Street	Street
Marshfield, MA 02050	Bourne, MA 02532
Municipality/State/Zip	Municipality/State/Zip
781-834-5563	508-495-6225
Phone	Phone

CERTIFICATIONS: Town of Duxbury

1. The Public Notice of Environmental Review has been/will be published in the following newspapers in accordance with 301 CMR 11.15(1):

   (Name)__Duxbury Clipper________(Date)__September 30, 2020__

2. This form has been circulated to Agencies and Persons in accordance with 301 CMR 11.16(2).

Signatures:

9/28/2020	René J. Read	9/30/2020	Leslie Fields
Date	Signature of Responsible Officer or Proponent	Date	Signature of person preparing EENF

René J. Read, Town Manager	Leslie Fields
Name (print or type)	Name (print or type)
Town of Duxbury	Woods Hole Group, Inc.
Firm/Agency	Firm/Agency
878 Tremont Street	107 Waterhouse Road
Street	Street
Duxbury, MA 02332	Bourne, MA 02532
Municipality/State/Zip	Municipality/State/Zip
781-934-1100 ext. 5401	508-495-6225
Phone	Phone

ADDENDUM – A: Supplement to EENF

Proponents Information:

Town of Marshfield
Michael A. Maresco, Town Administrator
870 Moraine Street
Marshfield, MA 02050

and

Town of Duxbury
René J. Read, Town Manager
878 Tremont Street
Duxbury, MA 02332

****

For parcels included in the proposed project footprints, see Section M for a list of parcel and owner information.

Section B

Summary and Project Description

B. SUMMARY and PROJECT DESCRIPTION

As coastal communities along the South Shore of Massachusetts, the Towns of Marshfield and Duxbury are vulnerable to coastal flooding, erosion, and wave induced damages caused by nor'easters and hurricanes. Development in the Towns of Marshfield and Duxbury during the early 20th century led to a pattern of single-family homes and some commercial development on small lots located directly along the shoreline. In Marshfield, this development extends along most of the town's 4.7 miles of east facing shoreline. In Duxbury, the northern 0.80 mile of the shoreline is developed, while the southern portion of the barrier beach, down to Gurnet Point, is undeveloped and owned by the Duxbury Beach Reservation. Over the years seawalls and revetments were built to protect the properties from ongoing erosion. Within the Town of Marshfield, approximately 82.5% (i.e., 3.9 miles) of the east facing shoreline is armored, and in Duxbury 91.3% (i.e., 0.7 miles) of the developed barrier beach is armored. Most of these seawalls and revetments are publicly owned and maintained.

Long-term erosion of the beaches in front of the shore protection structures has caused a gradual retreat of the shoreline, and in many places the bases of the structures are inundated at high tide. A significant portion of the Marshfield shoreline was identified as a coastal erosion hot spot in the 2018 State Hazard Mitigation and Climate Adaptation Plan, where the combination of erosion, storm surge, flooding and waves have caused significant damage to buildings and infrastructure. With continued erosion and no possibility for landward retreat of the shoreline, the elevation of the beach in front of the structures has begun to lower. This has resulted in exposure of many of the seawalls and revetments, where in some cases there is between 5 and 9 feet of vertical wall exposed to the open ocean. During storms, the lower beach elevations allow deeper water along the shoreline and larger waves to penetrate inland, where they encounter the hard seawalls and revetments. In turn, the higher wave energy during storms increases the potential for beach scour, overtopping, wave-induced damages to infrastructure and upland flooding.

Because of this vulnerability, the local governments have taken an active role in the management of their shorelines. Current practices include repair and maintenance of existing shore protection structures, elevating buildings, buying out property owners, and regulating development in high hazards areas. While the current management approach takes steps to address the immediate needs of the community, it does nothing to restore sediment to critically eroded beaches or to make the shoreline more resilient to the impacts of climate change. The current project to permit beach and dune nourishment at critically eroded shorelines in the Towns of Marshfield and Duxbury is being proposed to augment existing management practices. The project incorporates resilient strategies for shore protection that will mitigate the effects of climate change, improve storm damage protection, reduce wave overtopping, restore sediment to the littoral system and provide protection for existing shore protection structures.

Alternatives for enhancing shoreline resiliency were evaluated at fourteen (14) different beaches along the Marshfield and Duxbury coastline. Given the long history of hardened shore protection structures, the alternatives assessment focused on addressing the reduced sediment supply to the beaches using soft engineering methods such as beach and dune nourishment. At some locations however, soft engineering was not feasible due to sediment transport patterns and the presence of sensitive coastal resources. At these locations, combinations of hard, hybrid and soft methods were evaluated. For these locations additional engineering design will be required before the towns can proceed with permitting. For the remaining sites where soft engineering methods were considered feasible, alternative designs for beach and/or dune nourishment were developed and evaluated for performance, environmental impacts and cost. The impact assessment was then used to select a preferred alternative for permitting.

Beach and/or dune nourishment is being proposed at the following four (4) locations:

- **Rexhame Public Beach** – The preferred alternative (Rexhame Public – Alt 1) includes nourishment to enhance the resiliency of the existing dune. The crest of the dune will be increased to an elevation of 28 ft NAVD88 and a width of 30 ft. The seaward facing side of the dune nourishment will slope at 1V:5H to meet natural grades along the beach. The dune nourishment design calls for 47,240 cubic yards of sand and will provide protection of the existing dunes during storms up to the 50-yr event.

- **Winslow Ave. Beach** – The preferred alternative for Winslow Ave. Beach (Winslow – Alt2) includes nourishment to enhance the resiliency of the existing cobble dune. The crest of the dune will be increased to an elevation of 17 ft NAVD88 and a width of 40 ft. The sides of the dune will slope at 1V:7H to meet natural grades along the beach. The design calls for 17,850 cubic yards of mixed sand and cobble and will provide protection from flooding during storms up to the 10-yr event.

- **Fieldston and Sunrise Beaches** – The preferred alternative for the Fieldston and Sunrise area (Fieldston/Sunrise – Alt 2) includes beach and dune nourishment to minimize wave overtopping and provide protection for the existing seawalls. The design incudes a 30 ft wide dune crest at elevation 13 ft NAVD88 and seaward facing slopes of 1V:5H. The beach nourishment will have a 90 ft wide berm at elevation 9.5 ft NAVD88, sloping at 1V:12H to natural grades in the nearshore. The design calls for 389,770 cubic yards of mixed sand and gravel. Protection from wave overtopping is provided during a 10-yr storm event and renourishment intervals are estimated to range from 3.5 to 7.0 years.

- **Bay Ave. and Gurnet Rd. Beaches** – The preferred alternative for the Bay Ave. and Gurnet Rd. area (Bay Ave/Gurnet Rd – Alt 1) includes beach and dune nourishment to minimize wave overtopping and provide protection for the existing shore protection structures. The design includes a 20 ft wide dune crest at elevation 11 ft NAVD88 and seaward facing slopes of 1V:5H. The beach nourishment will have an 85 ft wide berm at elevation 8.0 ft NAVD88, sloping at 1V:20H to natural grades in the nearshore. The design calls for 313,160 cubic yards of mixed sand and gravel. Protection from wave overtopping is provided during a 10-yr storm event and renourishment intervals are estimated to range from 3.0 to 6.5 years.

The Towns are currently seeking permits for beach and/or dune nourishment at the four (4) locations, while sources of sediment needed to restore the beaches are being identified, investigated, and permitted under separate efforts. Once permits for the nourishment sites are in place, the Towns will be able to pursue sources of compatible sediment from the upland or from nearby dredging projects looking for beneficial reuse opportunities. This approach has been used successfully for a number of beaches on Cape Cod, where nourishment sites are permitted and then when beach compatible sand is dredged from navigation channels, it can be beneficially used for nourishment. With additional investigations, Marshfield and Duxbury may also identify an offshore borrow site(s) that could be permitted in the future.

The Beach and Dune Nourishment project for the Towns of Marshfield and Duxbury will require the following local, state, and federal permits:

- Executive Office of Energy and Environmental Affairs: Certificate from the Secretary of Energy and Environmental Affairs on the Expanded Environmental Notification Form
- Executive Office of Energy and Environmental Affairs: Final Record of Decision from the Secretary of Energy and Environmental Affairs
- Marshfield Conservation Commission/Massachusetts Endangered Species Act: Order of Conditions
- Duxbury Conservation Commission/ Massachusetts Endangered Species Act: Order of Conditions
- Massachusetts Department of Environmental Protection/Waterways Division: Chapter 91 Permit
- Massachusetts Coastal Zone Management: Federal Consistency Determination
- U.S. Army Corps of Engineers: Individual Permits

This Expanded Environmental Notification Form (EENF) is the first application filed for the project which will initiate environmental review. All other applications will be submitted once the Massachusetts Environmental Policy Act (MEPA) review process is complete. The project will not require a land transfer. The Project has received $175,842 in grant funding from the Massachusetts Coastal Zone Management Coastal Resiliency Program. Project construction is estimated to range from $0.54 million for the smallest project at Winslow Ave. Beach to $11.69 million for the largest project at Fieldston and Sunrise Beaches. A combination of local, state, and federal funding will likely be sought for construction funding.

A total of eleven (11) alternatives were evaluated at the four (4) sites selected for beach and/or dune nourishment as summarized below. A detailed description of the alternatives considered is provided in Section D.

Rexhame Public Beach

Rexhame Public – Alt 1: dune nourishment; 47,240 cubic yards
Rexhame Public – Alt 2: dune + beach nourishment; 82,570 cubic yards
Rexhame Public – Alt 3: beach nourishment; 129,000 cubic yards

Winslow Ave. Beach

Winslow – Alt 1: dune nourishment; 11,200 cubic yards
Winslow – Alt 2: dune nourishment; 17,850 cubic yards

Fieldston and Sunrise Beaches

Fieldston/Sunrise – Alt 1: dune + beach nourishment; 339,350 cubic yards
Fieldston/Sunrise – Alt 2: dune + beach nourishment; 389,770 cubic yards
Fieldston/Sunrise – Alt 3: beach nourishment; 409,100 cubic yards

Bay Ave. and Gurnet Rd. Beaches

Bay Ave/Gurnet Rd – Alt 1: dune + beach nourishment; 313,160 cubic yards
Bay Ave/Gurnet Rd – Alt2: dune + beach nourishment; 511,030 cubic yards
Bay Ave/Gurnet Rd – Alt 3: beach nourishment; 527,740 cubic yards

Environmental impacts associated with each alternative were evaluated and are discussed in Section E. Findings from the evaluation of environmental impacts were used to select a preferred alternative that achieves the goals for each site and avoids and/or minimizes adverse environmental impacts. Table B-1 provides a summary of the preferred alternative selected for each site with associated resource area impacts and other selection criteria. Changes to wetland resources (within the project footprints) for each beach, are summarized in Tables B-2 through B-5.

Table B-1. Summary of Preferred Alternatives with Direct Resource Area Impacts and Other Selection Criteria.

Beach Site	Area of Impact (acres)								Other Selection Criteria for Preferred Alternative
	Land Under the Ocean	Coastal Beaches	Coastal Dunes	Barrier Beaches	Land Containing Shellfish	Rocky Intertidal Shore	Land Subject to Coastal Storm Flowage	Estimated Habitats of Rare Wildlife	
Rexhame Public Beach									
Rexhame Public - Alt 1	--	2.41	2.93	5.34	--	--	5.34	5.34	Dune only alternative (Rexhame Public - Alt 1) provides similar level of protection as beach nourishment alternatives, with smaller volume and area of impact to existing resources. Service life of beach nourishment alternatives indicates the need for frequent renourishment.
Winslow Ave. Beach									
Winslow – Alt 2	--	1.49	3.16	2.90	--	--	4.65	--	The larger dune nourishment alternative (Winslow - Alt 2) provides increased storm damage protection without a significant increase in volume over the smaller dune alternative.
Fieldston & Sunrise Beaches									
Fieldston/Sunrise – Alt 2	2.40	28.10	--	18.14	29.4	1.09	30.50	--	The Fieldston/Sunrise – Alt 2 beach and dune nourishment alternative performs better than, or similar to the other alternatives, with a smaller area of impact to existing resources.
Bay Ave. & Gurnet Rd. Beaches									
Bay Ave/Gurnet Rd – Alt 1	16.20	34.10	--	50.30	46.20	--	50.30	23.52	The Bay Ave/Gurnet Rd – Alt 1 beach and dune nourishment alternative shows less berm scarping than the other alternatives and requires a significantly smaller volume of material.

Table B-2. Summary of Changes to Wetland Resources with Rexhame Public – Alt 1.

Resource Area	Existing Area in Footprint (acres)	Change in Area (acres)	Proposed Area Remaining in Footprint (acres)
Land Under the Ocean	0	0	0
Coastal Beach	2.41	-2.41	0
Coastal Dune	2.93	+2.41	5.34
Barrier Beach	5.34	0	5.34
Land Containing Shellfish	0	0	0
Rocky Intertidal Shore	0	0	0
Land Subject to Coastal Storm Flowage	5.34	0	5.34
Estimated Habitats of Rare Wildlife	5.34	0	5.34

Table B-3. Summary of Changes to Wetland Resources with Winslow – Alt 2.

Resource Area	Existing Area in Footprint (acres)	Change in Area (acres)	Proposed Area Remaining in Footprint (acres)
Land Under the Ocean	0	0	0
Coastal Beach	1.49	-1.49	0
Coastal Dune	3.16	+1.49	4.65
Barrier Beach	2.90	0	2.90
Land Containing Shellfish	0	0	0
Rocky Intertidal Shore	0	0	0
Land Subject to Coastal Storm Flowage	4.65	0	4.65
Estimated Habitats of Rare Wildlife	0	0	0

Table B-4. Summary of Changes to Wetland Resources with Fieldston/Sunrise – Alt 2.

Resource Area	Existing Area in Footprint (acres)	Change in Area (acres)	Proposed Area Remaining in Footprint (acres)
Land Under the Ocean	2.40	-2.20	0.20
Coastal Beach	28.10	-1.36	26.74
Coastal Dune	0	+3.59	3.59
Barrier Beach	18.14	0	18.14
Land Containing Shellfish	29.40	-18.80	10.60
Rocky Intertidal Shore	1.09	0	1.09
Land Subject to Coastal Storm Flowage	30.50	0	30.50
Estimated Habitats of Rare Wildlife	0	0	0

Table B-5. Summary of Changes to Wetland Resources with Bay Ave/Gurnet Rd – Alt 1.

Resource Area	Existing Area in Footprint (acres)	Change in Area (acres)	Proposed Area Remaining in Footprint (acres)
Land Under the Ocean	16.20	-9.68	6.52
Coastal Beach	34.10	+5.20	39.30
Coastal Dune	0	+4.50	4.50
Barrier Beach	50.30	0	50.30
Land Containing Shellfish	46.20	-18.98	27.22
Rocky Intertidal Shore	0	0	0
Land Subject to Coastal Storm Flowage	50.30	0	50.30
Estimated Habitats of Rare Wildlife	23.52	0	23.52

The project will adhere to the following mitigation measures to avoid and/or minimize environmental impacts during and following construction.

- Pre-construction onsite meetings will be held with the selected contractors, project engineer and Towns of Marshfield and Duxbury to discuss project requirements.
- Boundaries of the beach and/or dune nourishment will be clearly marked prior to construction.
- Construction access to the beach sites will be limited to existing beach access points adjacent or within the proposed nourishment areas.
- Nourishment footprints have been designed to avoid direct impacts to rocky intertidal resources. Where direct impacts are unavoidable, rocky intertidal habitat will be replicated at the appropriate location with the nourishment footprint.
- The nourishment footprint for the Bay Ave beach has been shortened to minimize impacts caused by increased shoaling at Green Harbor. Further, nourishment sediments at the northern end of Bay Ave will be predominantly cobble and gravel to minimize northerly transport towards the Harbor.
- Time of year restrictions as determined by the regulatory agencies will be followed for all work to protect endangered species and sensitive coastal resources
- Storage of all fuels, hydraulic oil, etc. in a locked storage trailer or removed off site daily
- Vehicles/equipment will be refueled away from the beaches and stormwater systems
- Implementation of a post construction monitoring and plan
- Shorebird inventory, mapping and monitoring in all areas currently mapped as by NHESP as estimated and priority habitat, along with surveillance surveys in nourished areas not currently mapped by NHESP.
- Installation of protective fencing and signage as necessary to protect nesting shorebirds.

Section C

Existing Environment

C. EXISTING ENVIRONMENT

1.0 Existing Environment

1.1 Tides, Storm Surge and Sea Level Rise

Tides along the Marshfield and Duxbury coastline are semi diurnal, with two high and two low tides of about the same height each day. The mean tide range is approximately 9.1 ft. Specific tidal datums for the open coast of Marshfield and Duxbury are presented in Table C-1. Also shown in Table 1 are key storm surge elevations for this stretch of shoreline. The tidal datum elevations were obtained from NOAA (2020a) and surge elevations for the 10-, 50-, and 100-yr return period storms were obtained from the Federal Emergency Management Agency's (FEMA) Flood Insurance Study (2016).

Table C-1. Tidal Datums and Storm Surge Elevations for the Marshfield and Duxbury Shoreline.

Tidal Datum or Flood Condition	Elevation (ft, NAVD88)
Tidal Flood 100-Year Return	9.50
Tidal Flood 50-Year Return	9.10
Tidal Flood 10-Year Return	8.30
High Tide Line (HTL)	6.50
Mean Higher High Water (MHHW)	4.52
Mean High Water (MHW)	4.08
NAVD88	0.00
Mean Low Water (MLW)	-5.00
Mean Lower Low Water (MLLW)	-5.35

Moving into the 21st century and beyond, it is likely that other long-term processes such as sea level rise will have a significant effect on evolution of the coastlines in the Towns of Marshfield and Duxbury. Long-term measurements in Boston Harbor show that relative sea level, or the elevation of the sea with respect to the land, has been rising at an average of 2.83 mm per year, or 0.93 feet per century (Figure C-1).

The Intergovernmental Panel on Climate Change (IPCC) has spent considerable time and energy reviewing and analyzing the current state of knowledge of past and future changes in sea level in relation to climate change. Taking this information, the United States Army Corps of Engineers (USACE) developed guidance for incorporating sea-level change considerations in civil works programs (USACE, 2009, 2011). Using this information, a sea level rise scenario of 2.0 ft projected to occur in 2070 was used during resiliency planning for the Marshfield and Duxbury shorelines. This long-range planning is applicable when considering the effects of sea level rise on coastal engineering structures, such as seawalls and revetment, as these structures typically have a 50-yr design life. However, non-structural projects, such as beach and/or dune nourishment, typically have a much shorter design life (i.e., 5 to 10 years). For these types of projects, the effects of sea level rise are not typically considered during the design process since adjustments to the design can be incorporated as needed prior to renourishment.

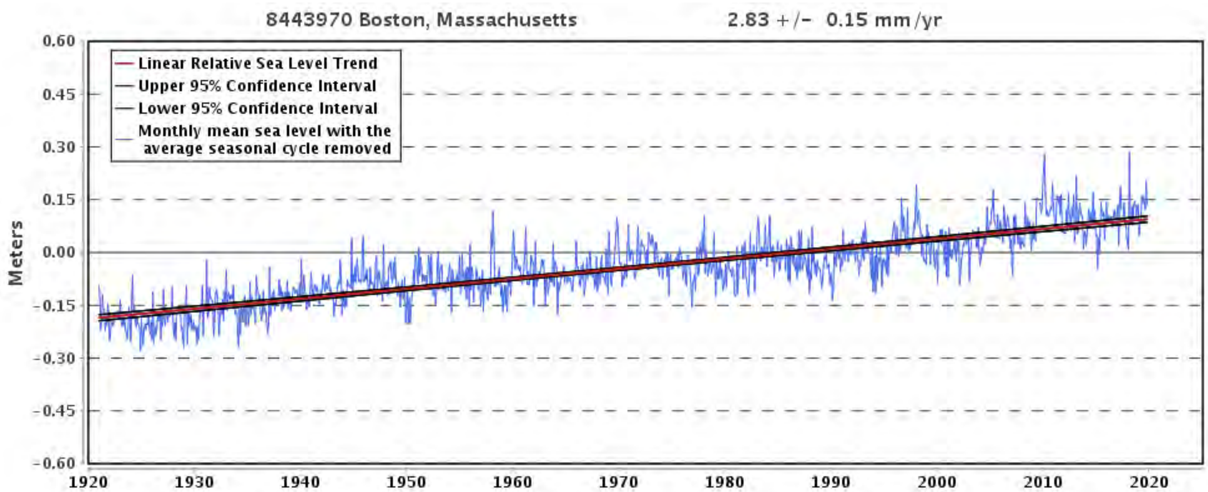


Figure C-1. Long-term mean sea level data for NOAA's Boston Harbor tide gage (NOAA, 2020b).

1.2. Bathymetry

A detailed bathymetric survey of the seafloor offshore of Marshfield and northern Duxbury was performed by the Woods Hole Group on November 7 and December 7, 2019. The Town of Marshfield Harbormaster's office supplied the survey vessel and boat captain. The survey area covered approximately 28,550 ft (8.7 km) in the longshore direction and extended offshore approximately 3,280 ft (1 km) from water depths of 9.8 to 40 ft NAVD88. Survey transects were spaced at 100-ft intervals.

The survey vessel was conducted using the Town of Marshfield's 31 ft SAFE boat equipped with an over-the side transducer mount and a power supply for survey electronics. A Trimble R8 RTK GPS with HYPACK 2019 survey software was used for navigation. Soundings were taken with a Teledyne Odom Echosounder single beam precision echosounder with a 200 kHz 8-degree transducer. Data were recorded by HYPACK acquisition software as time-stamped ASCII text values embedded with RTK position/tide data. The depth sounder incorporated transducer draft corrections, calibration for speed of sound through water and gain control. During post-processing of data, the soundings were referenced to the vertical geodetic datum NAVD88.

Data collected during the survey is presented in Figure C-2. Shallow areas are signified by blues and greens, whereas deeper areas are signified by oranges and reds. Notable features from this survey include nearshore bars with gradual slopes in the Rexhame Beach area and along the entire beach south of Green Harbor. Shallower water depths are also present directly offshore of Brant Rock. A deeper shore parallel trough, defined by the -40 ft NAVD88 contour, is located offshore of the Winslow Ave., Sunrise, and Fieldston Beaches. An area of deeper offshore bathymetry also exists offshore of the beaches at the southern end of the project area.

Bathymetric data shown in Figure C-2 will be combined with beach profile data collected as part of the 2019 CZM grant funded project (see Section 1.3), as well as publicly available data from the US Geological Survey (USGS) CoNED Topobathymetric Model (USGS, 2016).

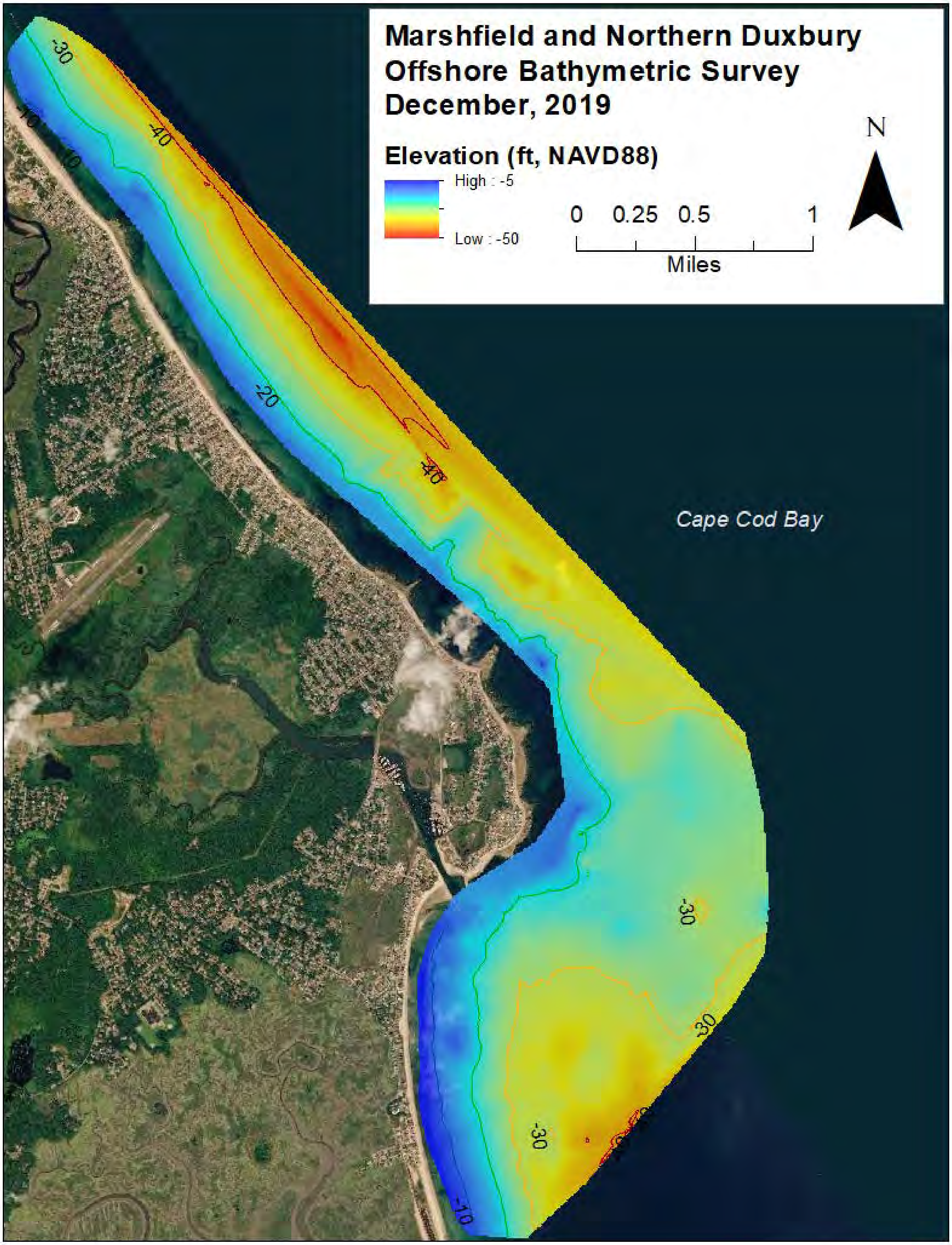


Figure C-2. Bathymetric survey data collected for the study area offshore of Marshfield and northern Duxbury in November and December 2019.

1.3. Beach Topography

The topography of the beaches along the Marshfield and northern Duxbury shorelines was surveyed by the Town of Marshfield and the Woods Hole Group. A total of twenty-three (23) shore normal transects were surveyed at the locations shown in Figure C-3. The Town of Marshfield collected data at transects 8 through 17 in October 2019, and the Woods Hole Group collected data at transects 1 through 7 and 18 through 23 in November 2019. Data were collected along each transect using an RTK GPS, starting at the landward end behind the coastal dunes or engineering structures, and extending seaward to wading depth. The surveys were conducted during the period three (3) hours before and after low tide, and most of the surveys extended to MLW, or beyond. Horizontal coordinates were referenced to the Massachusetts Mainland State Plane Coordinate System, NAD 83 ft, and elevations were referenced to the vertical data NAVD88 ft. Transect data for the Brant Rock area were derived from a 2010 topographic LiDAR and bathymetric data set developed by the US Army Corps of Engineers.

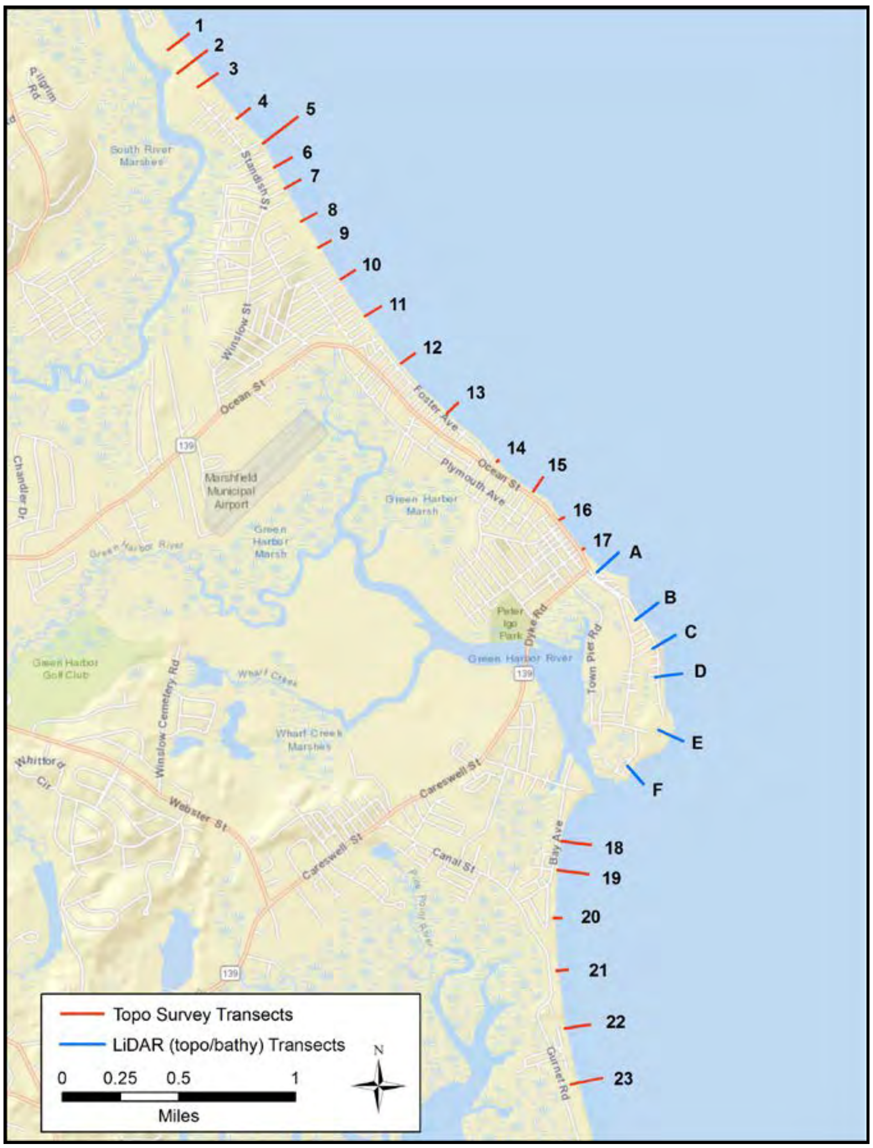


Figure C-3. Locations of topographic survey transects.

Most of the beaches along the northern part of Marshfield are backed by seawalls and/or revetments (Figure C-4). The only exceptions to this are sections of Rexhame Beach (Transects 1-3) and the Winslow Avenue beaches (Transects 8-9) that have naturally occurring dunes and no shore protection structures. The Rexhame Beach dunes are sandy features that extend to the banks of the South River on the western side of the barrier beach. The primary dune is approximately 125 ft wide and reaches a maximum elevation of 27 ft NAVD88 (Figure C-5a). Dunes at the Winslow Avenue beaches are generally low-lying features composed of cobble. The dunes are 140 to 200 ft wide and reach a maximum elevation of 15 ft NAVD88 (Figure C-5b). All of the other beaches north of Brant Rock are backed by seawalls and/or revetments (Figure C-6a-d). Crest elevations of the coastal engineering structures range from 16.0 to 26.6 ft NAVD88, and generally increase from north to south. In most locations, the beach elevations in front of the structures are significantly lower than the crest, leaving the face of the structures exposed to elevated water levels and waves during storms.

The average width of the high tide beach (between MHW and the toe of the dune or shore protection structure) in the Rexhame area is 150 ft (Figure C-4). A distinct narrowing of the high tide beach occurs south of Jackson Street (Transect 5) where a submerged ledge extends seaward from the beach. South of this point the high tide beach gradually narrows to less than 50 ft wide. In some locations in the Ocean Bluff area high tide extends to the shore protection structures, and there is virtually no high tide beach. The intertidal beach (between MHW and MLW) in the Rexhame area ranges between 100 and 150 ft. Beaches further to the south have extensive intertidal flats, with widths between 200 and 350 ft. Intertidal beaches between Ocean Bluff and Brant Rock are significantly narrower as the beach topography slopes steeply towards the east.

Most of the beaches in the project area south of Green Harbor are also backed by seawalls (Figure C-7). The only exceptions occur along the 650 ft long stretch of beach immediately south of Green Harbor (north of Transect 18), and a 350 ft stretch of beach at the end of Bay Road in the Town of Duxbury (south of Transect 20). The area closest to Green Harbor is characterized by wide coastal dune, beach and intertidal resources that are protected and anchored by the southern jetty at the harbor (Figure C-8a). The area at the end of Bay Ave contains a sandy dune approximately 100 ft wide that is fronted by a gently sloping coastal beach. All other sections of the beach are anchored by seawalls and/or revetments. Crest elevations of the walls are generally lower to the south of Green Harbor, ranging from 7.7 to 16.0 ft NAVD88 (Figure C-8b-8d). Lower beach elevations immediately in front of the structures leave 5 to 10 ft of the structures exposed to elevated water levels and waves during storms.

The average width of the high tide beach is less than 50 ft between Transects 18 and 22 (Figure C-7). Further to the south on the Duxbury Beach Reservation property (Transect 23) the high tide beach increases to over 100 ft wide. The intertidal beach along this stretch of the project area is relatively wide, ranging from 185 to 280 ft.

Beach profile data for all transects surveyed are shown on the engineering plans entitled "Plan of Beach and Dune Nourishment Sites, Prepared for Towns of Marshfield and Duxbury, MA", Sheets 1-6, dated 09/23/2020, (see Section O).

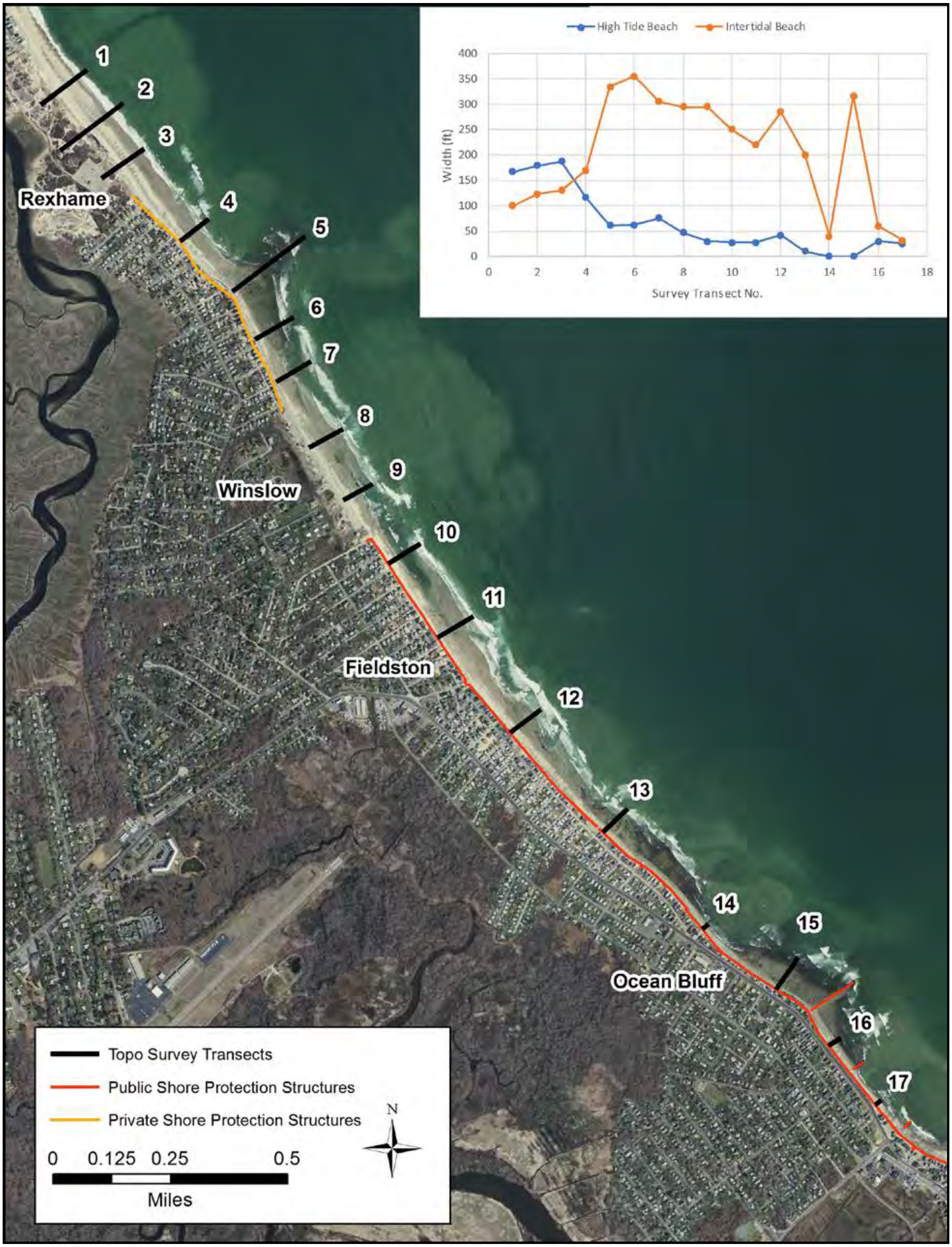


Figure C-4. Survey transects north of Brant Rock showing existing shore protection structures and widths of high tide and intertidal beaches.

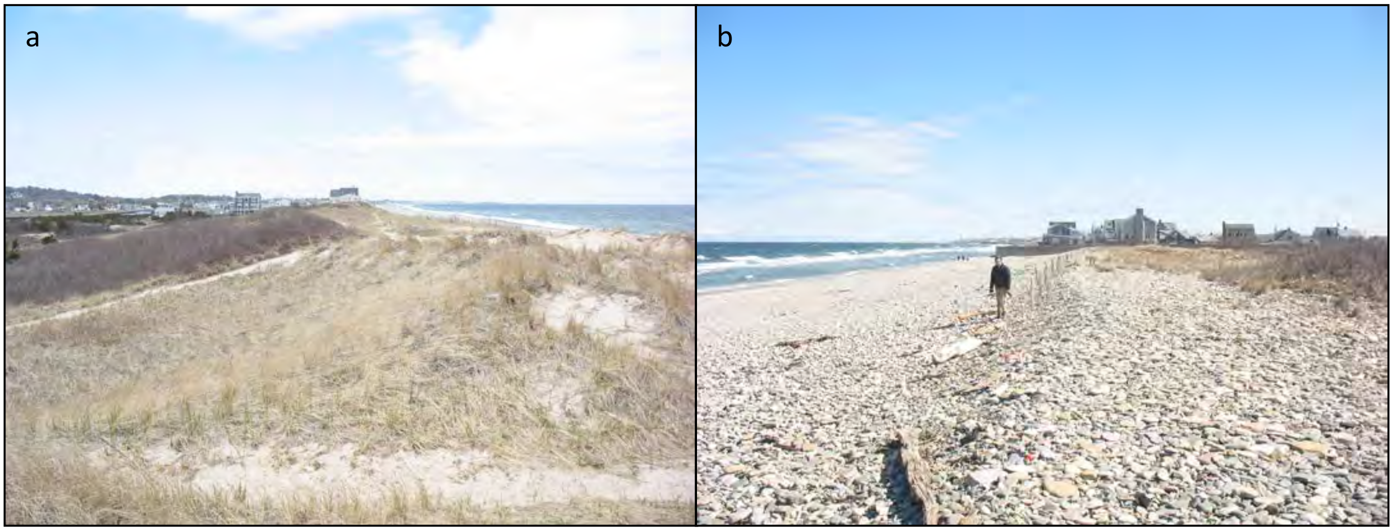


Figure C-5. Photos of primary coastal dune at Rexhame Beach (a) and cobble dune at Winslow Avenue beach (b).

Figure C-6. Photos of coastal engineering structures and coastal beach at Rexhame (a), Fieldston (b), Sunrise (c) and Ocean Bluff (d).

Figure C-7. Survey transects south of Green Harbor showing existing shore protection structures and widths of high tide and intertidal beaches.

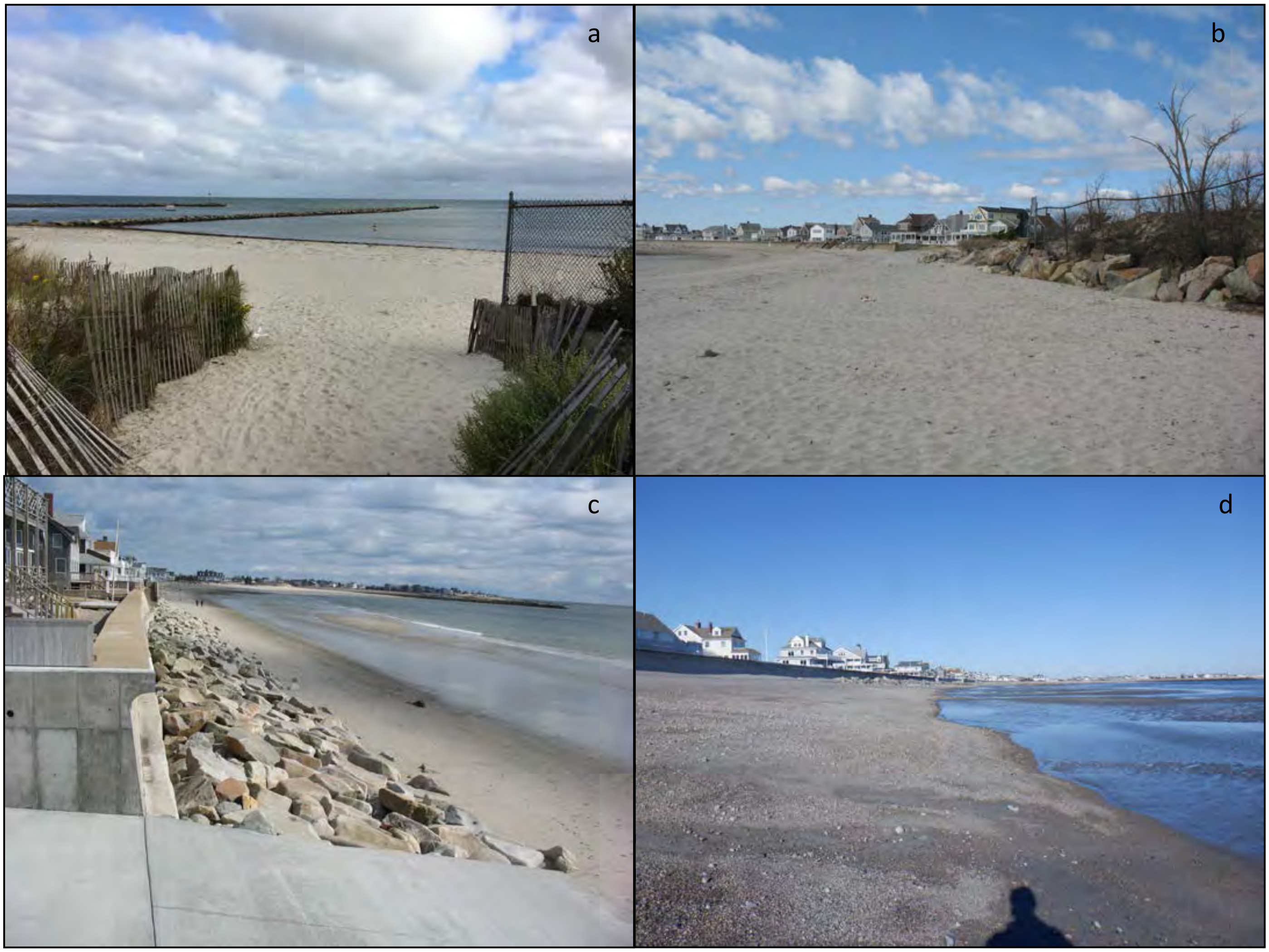


Figure C-8. Photos of dune and beach south of Green Harbor (a), and coastal engineering structures and coastal beach along Bay Ave. (b-c), and along Gurnet Rd. in Duxbury (d).

1.4 Sediments

Information on sediment characteristics along the Marshfield and northern Duxbury coastline was obtained from a series of twenty-three (23) sediment samples collected throughout the project area. In addition, sediment data from previous work on the Marshfield Beach Management Plan (WHG, 2018) and a 2017 CZM funded grant project looking at beneficial reuse of dredged materials from Green Harbor were reviewed and summarized to gain a better understanding of changes in sediment characteristics over time. Figure C-9 shows the locations of the sediment samples from the three (3) studies. Larger scale maps showing sample IDs and locations for the northern, middle, and southern sections of the project area provided in Figures C-10, C-11, and C-12.

Sediment samples collected in Dec. 2019 were a combination of surface grabs and larger volume samples (i.e., 15 gallons). The larger volume samples were collected in areas were the beach was composed of a mixed grain size ranging from cobble down to fine-grained sand. By collecting a larger sample volume, it was possible to include the cobbles and coarser-grained material in the sample, and therefore develop a more representative grain size distribution for the beach. A total of six (6) large volume samples were collected, and at each location, a standard grab sample was also collected. By having co-located samples from the large volume and the standard grabs, it was possible to develop a grain size envelope that characterized the range of sediment sizes on the beach. In addition to the co-located samples (large volume and standard grabs), another eleven (11) standard grab samples were collected to characterize the sandier portions of the beach. To define cross-shore changes in sediment composition, samples were collected from the dunes (where present), MHW line and the mid tide line.

Sediment samples from the previous studies consisted of standard surface grabs collected from the mid tide line. Specific sampling locations were selected in the field to be representative of the average grain size condition at each sampling location. The only exception was the Green Harbor Channel sample, which was collected as a grab sample from a dredged material stockpile located on the north side of Green Harbor. This sample was collected to characterize the sediments dredged annually from the navigation channel at Green Harbor.

The sediment data provide insight on the local wave energy along the beach. For example, areas that have a higher percentage of coarse grain material (gravel or cobble) are more likely to experience higher wave energy conditions during storms. Table C-2 provides summary statistics for the project area beaches and dunes based on sediment samples collected between Aug. 2017 and Dec. 2019.

In general, the beaches are composed of a mixture of gravel and sand. Percentages of gravel range from 0.0 to 93%, and for sand the percentages range from 3.0 to 99.8% (Table C-2). The average D_{50} of the standard beach samples is 3.1 mm (granule); however, when the large volume samples are considered, the D_{50} increases to 6.5 mm (pebble). The average D_{50} for the dune sediments is 0.33 mm (medium sand). Laboratory results for the 2019, 2018 and 2017 samples are provided in Section K.

The distribution of grain size between the earlier 2017/2018 sampling and the 2019 sampling of standard and large volume samples is shown in Figure C-13. The data show a wide range of grain size between cobble and fine sand, with most areas containing a mixture of gravel and coarse to medium sand.

Temporal changes in beach composition have been reported by Town of Marshfield and Duxbury staff, and by Woods Hole Group scientists; however, they are not necessarily represented in the data presented herein. Observations indicate that winter storms tend to remove sand from the high tide beach and portions of the intertidal flats, leaving the coarser grained cobble and gravel behind. Sandier sediments are then restored to portions of the beach during the calmer weather summer and fall seasons.

Figure C-9. Sediment samples collected along the Marshfield and northern Duxbury beaches between Aug. 2017 and Dec. 2019.

Figure C-10. **Sediment samples collected along the northern beach of Marshfield between Aug. 2017 and Jan. 2019.**

Figure C-11. Sediment samples collected along the central beaches of Marshfield between Aug. 2017 and Jan. 2019.

Figure C-12. Sediment samples collected along the beaches of southern Marshfield and northern Duxbury between Aug. 2017 and Jan. 2019.

Table C-2. Summary Grain Size Statistics for Project Area Beaches.

Sample ID	D_{50} (mm)	% Cobble	% Gravel	% Sand	% Silt & Clay
Beach & Dune Samples (listed north to south)					
Rexhame Beach	0.32	0	0.3	99.4	0.3
01-DU-SAN	0.35	0	0.0	99.8	0.2
02-MTL-SAN	8.70	0	83.0	16.9	0.1
02-MTL-COB	14.40	4	93.0	3.0	0.0
03-MHW-SAN	0.55	0	1.0	98.9	0.1
04-MTL-SAN	7.50	0	71.0	28.9	0.1
05-MHW-SAN	0.50	0	20.0	79.9	0.1
06-MTL-SAN	0.53	0	37.0	62.6	0.4
07-DU-SAN	0.30	0	0.0	99.9	0.1
08-MTL-SAN	6.9	0	77.0	22.9	0.1
08-MTL-COB	19.0	4	90.0	6.0	0.0
09-MTL-SAN	1.14	0	41.0	58.8	0.2
10-MTL-SAN	4.00	0	70.0	29.8	0.2
10-MTL-COB	11.4	11	82.0	7.0	0.0
Sunrise/Fieldston	0.37	0	10.8	88.5	0.7
11-MTL-SAN	5.7	0	65.0	34.7	0.3
12-MTL-SAN	0.25	0	2.0	97.3	0.7
9th Street	3.36	0	11.4	87.9	0.7
12-MTL-COB	32.00	34	53.0	13.0	0.0
13-MTL-SAN	5.90	0	78.0	21.9	0.1
Brant Rock	0.42	0	39.8	59.8	0.4
Green Harbor	0.37	0	0.5	99.0	0.5
Pearl Street	4.87	0	8.9	90.5	0.6
14-MTL-COB	13.40	4	68.0	28.0	0.0
14-MTL-SAN	0.34	0	22.0	77.9	0.1
15-MTL-SAN	1.76	0	36.0	63.9	0.1
16-MTL-COB	13.10	10	89.0	1.0	0.0
16-MTL-SAN	1.75	0	40.0	59.9	0.1
17-MTL-SAN	0.23	0	0.0	99.9	0.1
Average	**6.5**	**1.5**	**50.0**	**48.3**	**0.1**

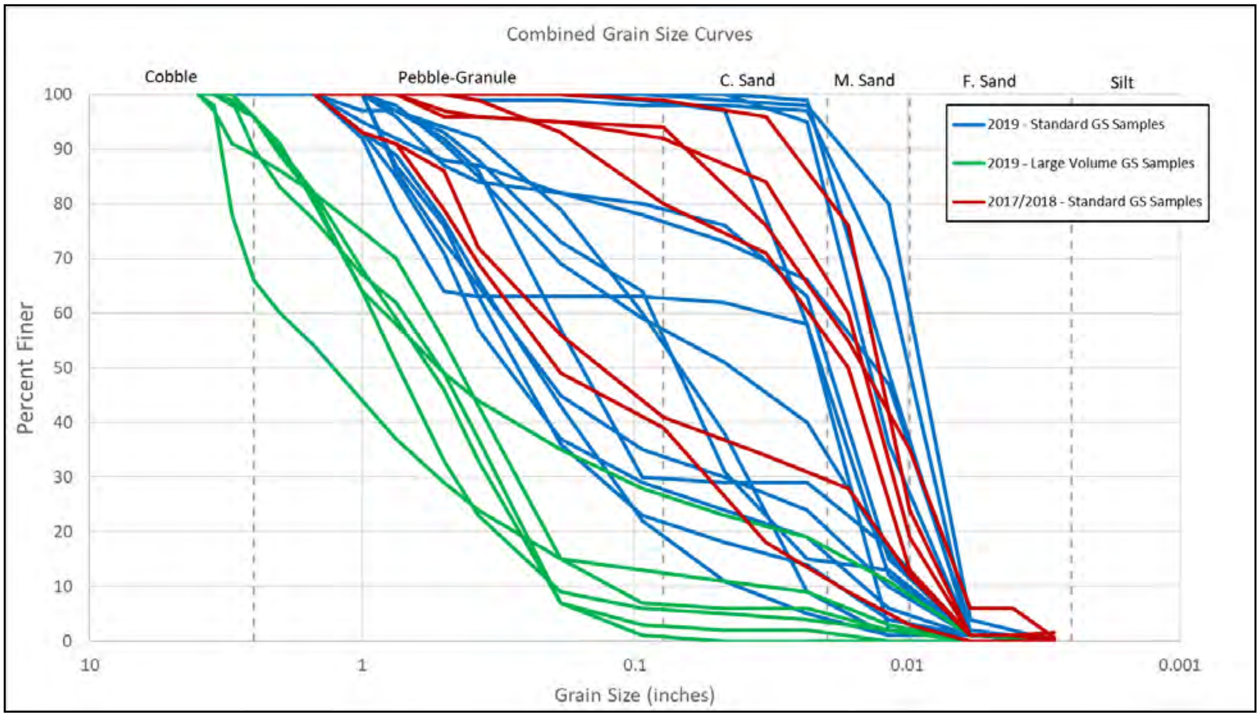


Figure C-13. Combined grain size curves for samples collected in 2017, 2018 and 2019 throughout the Marshfield and Duxbury beaches.

1.5 Shoreline Change

Information on historical shoreline change along the project area coastline was obtained from the Massachusetts Shoreline Change Project (MSCP), 2018 Update (Himmelstoss, et. al., 2019). The MSCP compiled relative positions of shorelines between 1844 and 2014 for all seaward facing coastal areas within the Commonwealth of Massachusetts. The MSCP included shoreline positions in the Marshfield and Duxbury study area for the following years: 1848/1858, 1951/1952, 1978, 1994, 2000, 2001, 2008, 2011 and 2014.

Both long- and short-term rates of shoreline change were determined by fitting a least squares regression line to the shoreline positions measured at a series of shore normal transects. Long-term rates were computed using all nine (9) shorelines between 1948/1858 and 2014 (Figure C-14), while the short-term rates were computed using the seven (7) shorelines between 1978 and 2014 (Figure

15). The slopes of the regression lines at each transect are the rates of shoreline change. Negative values indicate erosion and positive values indicate accretion, with rates of change shown in ft/yr. Figure C-16 shows the error bars associated with the short-term rates of change.

The long-term rates of change shown in Figure C-14 indicate areas of erosion less than 2 ft/yr in the Rexhame, Winslow Ave., and Fieldston Beach areas. Erosion is also indicated in South Brant Rock, Bay Ave, and along the southern end of Gurnet Rd. Beaches. Areas between Sunrise Beach and Brant Rock show accretion at rates of 2 ft/yr and less.

The short-term rates of change shown in Figures C-15 and C-16 are more indicative of existing conditions since they cover the time period after most of the seawalls and revetments were installed.

The short-term data generally indicate accretion less than 2 ft/yr at the northern and southern ends of the project area (Rexhame and Gurnet Rd Beaches). Most shoreline areas in between indicate erosion at rates between 0 and 2 ft/yr. The error bars for the short-term rates of change shown in Figure C-16 suggest significant uncertainty with the rates of change at the northern end of the project area between Rexhame Public Beach and Fieldston Beach. Moving south, there is a clear trend of erosion at Sunrise Beach, Ocean Bluff and the Brant Rock areas. Between Brant Rock and Green Harbor the rates of change and associated errors are relatively small, suggesting a relatively stable shoreline with little erosion or accretion. South of Green Harbor, rates of erosion are greatest in the Bay Ave Beach area, and gradually decrease towards the south along Gurnet Rd. Beaches beyond the study area on the Duxbury Beach Reservation property show a trend of accretion over the short-term.

In many places along the project coastline, the ability of the shoreline to retreat has been impacted by the construction of seawalls and revetments. Prior to this time the shoreline was able to retreat, but once the hard structures were encountered, continued landward migration was halted. Currently, locations where MHW is at the seawall, thereby inhibiting further landward horizontal erosion, include Fieldston and Sunrise Beaches, Ocean Bluff and Hewitt's Point Beaches, the Brant Rock area, and beaches along Bay Ave and Gurnet Rd. In these locations, there has been vertical lowering of the beach face as storm waves interact with the seawalls and sediment is pulled offshore.

Figures C-17 through C-20 show longitudinal profiles of the beach elevation (north to south) at distances of 75 and 175 ft seaward of the coastal dunes (where present) or shore protection structures. Figures C-17 and C-18 include the Marshfield shoreline north of Green Harbor, and Figures C-19 and C-20 include the Marshfield and Duxbury shorelines south of Green Harbor. The beach elevations were derived from publicly available LiDAR data collected between 2000 and 2014.

The data show a significant lowering of the high tide beach for sections of the shoreline with hardened shore protection structures (Figure C-17). The beach elevation drops 10 to 12 ft between Rexhame Public Beach and the Ocean Bluff area. Changes in beach elevation are less pronounced along the low tide beach; however, the data indicate a clear lowering of the beach elevation between 2000 and 2010/2014 for the shoreline between Winslow Ave and Sunrise Beach (Figure C-18). To the south of Green Harbor, both the high and low tide beach elevations are lowest in the Bay Ave. Beach area, which is armored with hard shore protection structures (Figures C-19-C-20).

While the beach lowering in areas of the shoreline with shore protection structures is not reflected in the shoreline change data it, continues to have a negative impact on the beach resource. The associated loss of beach volume impacts nearshore wave dynamics, as greater water depths allow larger waves to propagate onshore. The increased wave energy associated with the larger waves results in additional scouring in front of the seawalls and overtopping of the structures.

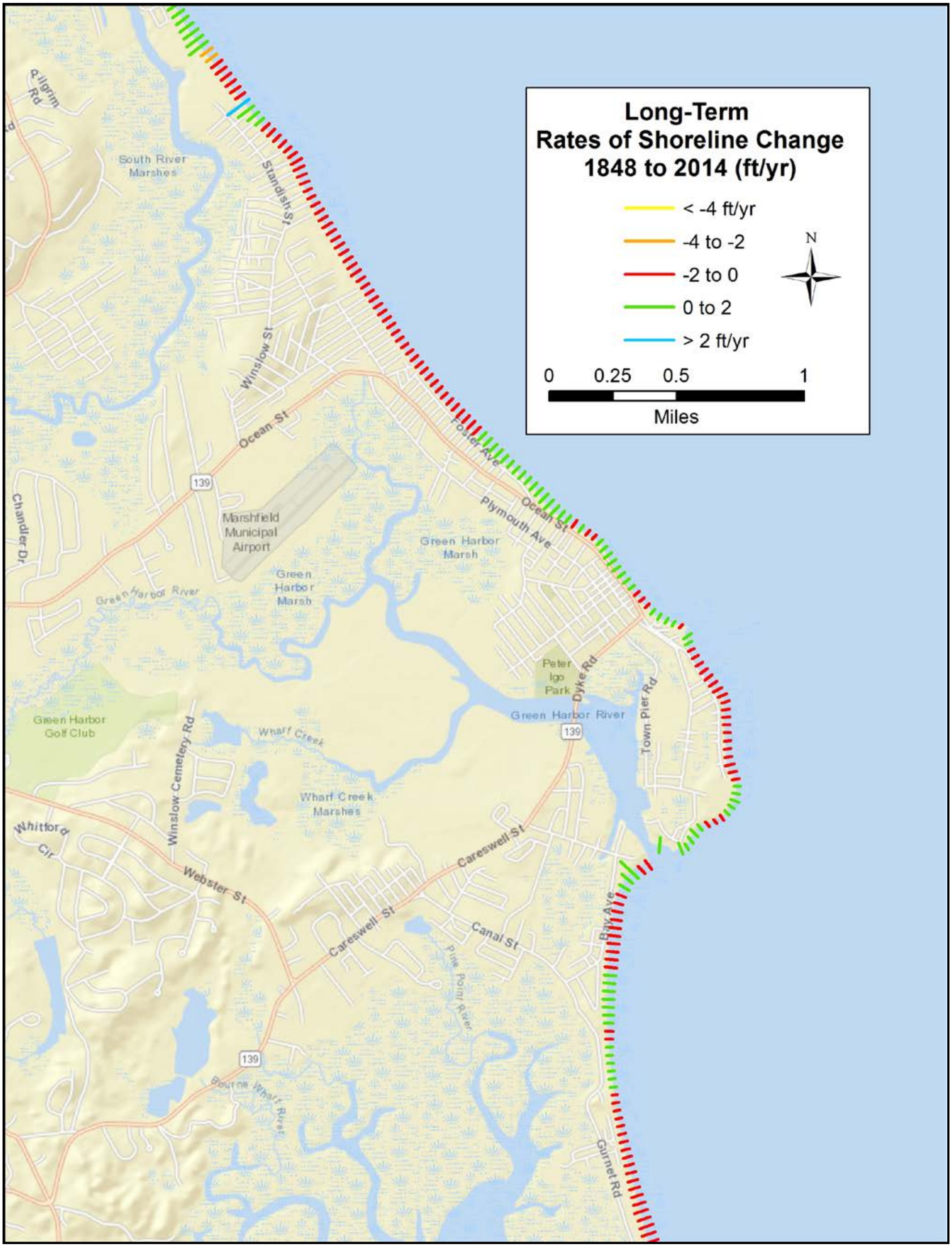


Figure C-14. Long-term linear regression rates of shoreline change for the project area.

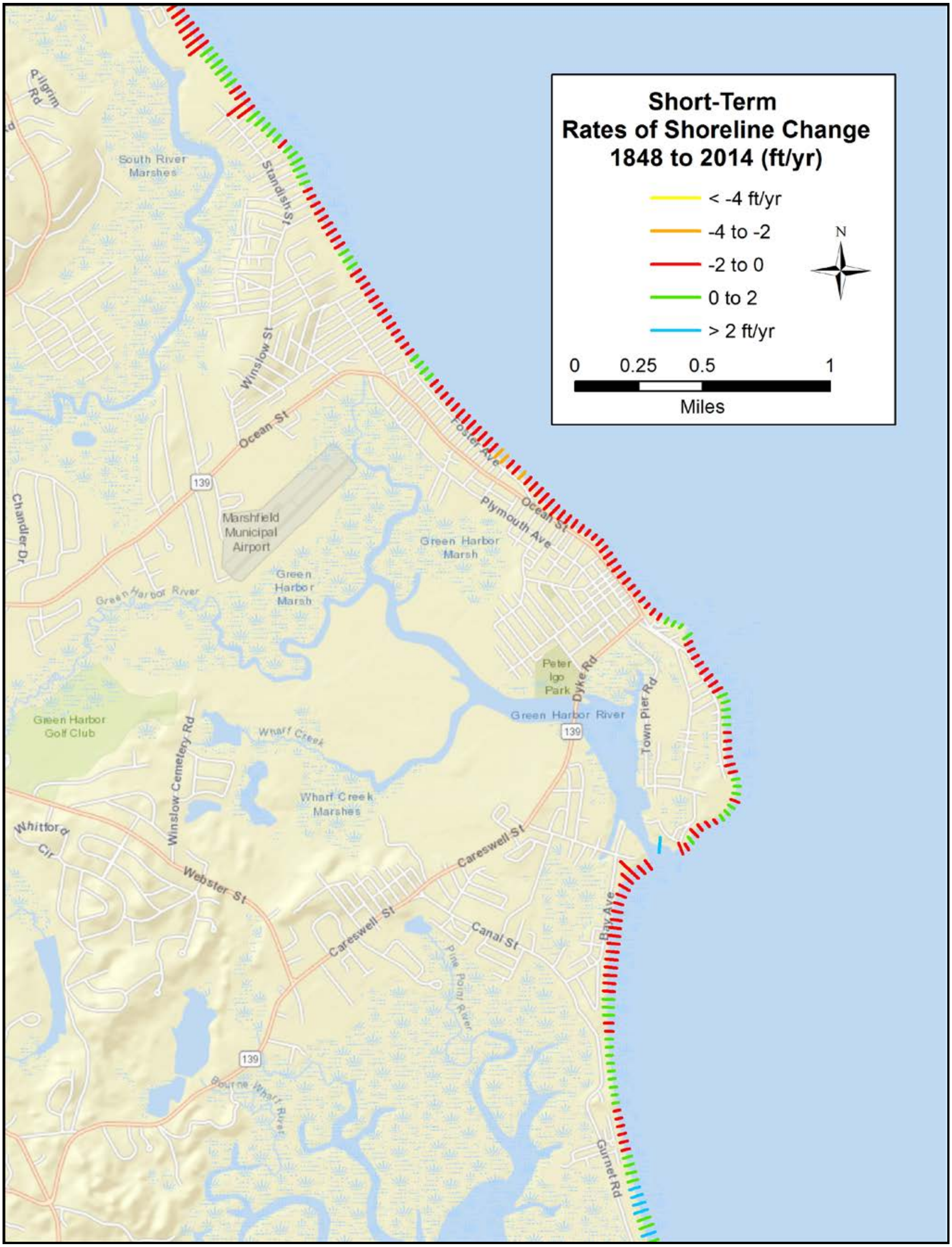


Figure C-15. Short-term linear regression rates of shoreline change for the project area.

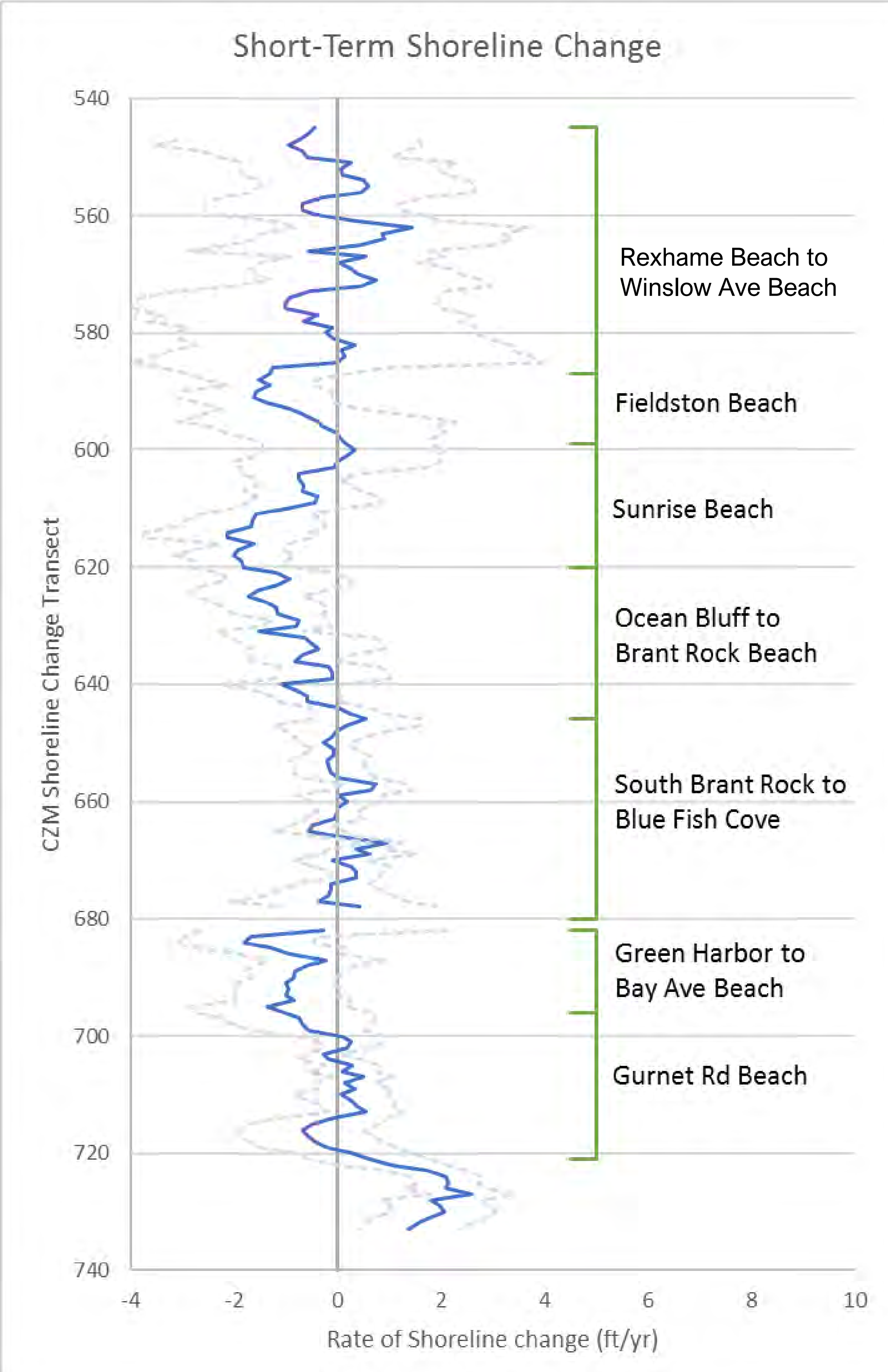


Figure C-16. Long-term linear regression rates of change with 90% confidence intervals as a function of distance from north to south along the Marshfield coastline.

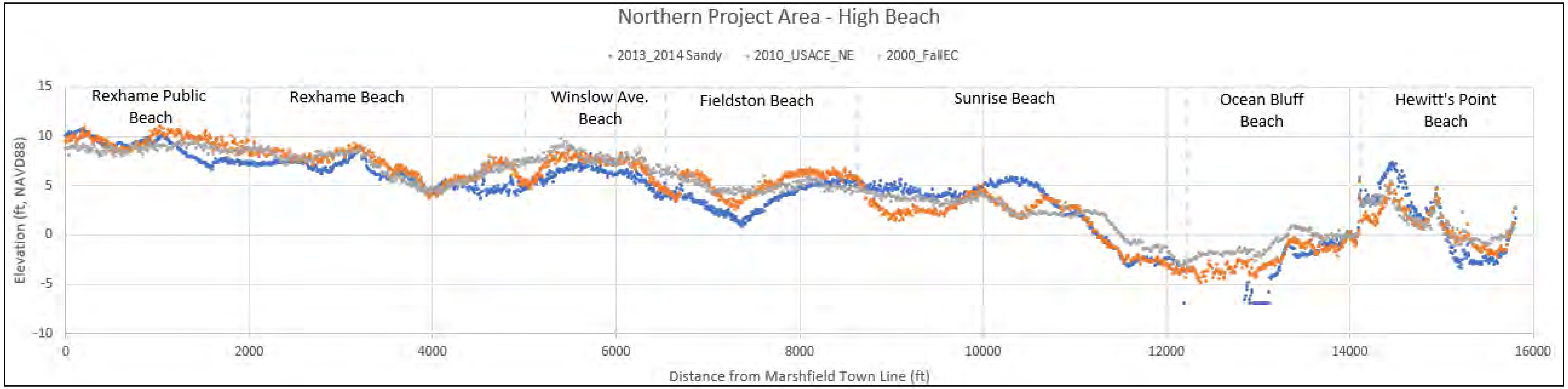


Figure C-17. Comparison of beach elevations from 2000 to 2014 between Rexhame Public Beach and Hewitt's Point Beach for a location 75 ft seaward of coastal dunes or shore protection structures.

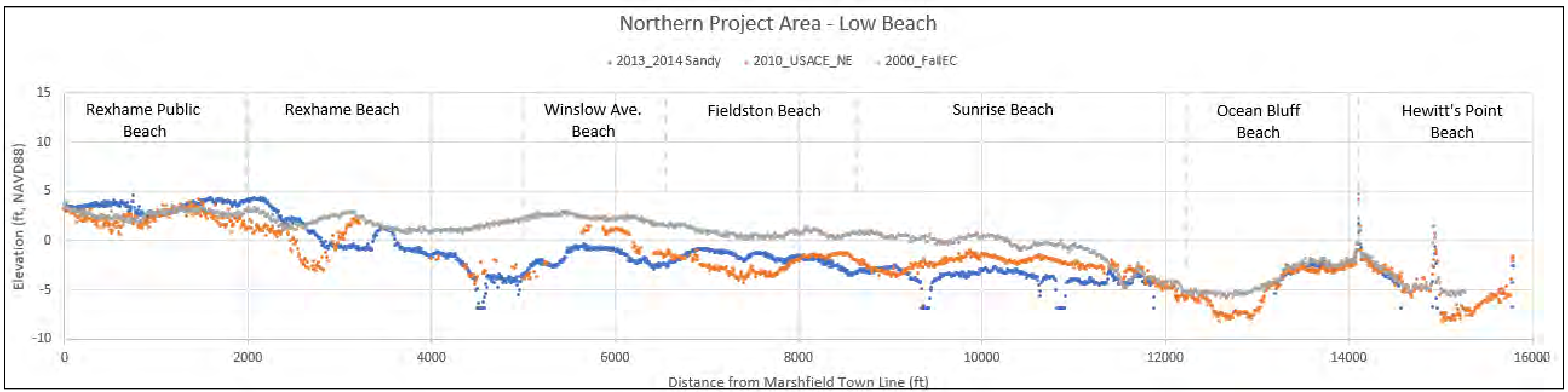


Figure C-18. Comparison of beach elevations from 2000 to 2014 between Rexhame Public Beach and Hewitt's Point Beach for a location 175 ft seaward of coastal dunes or shore protection structures.

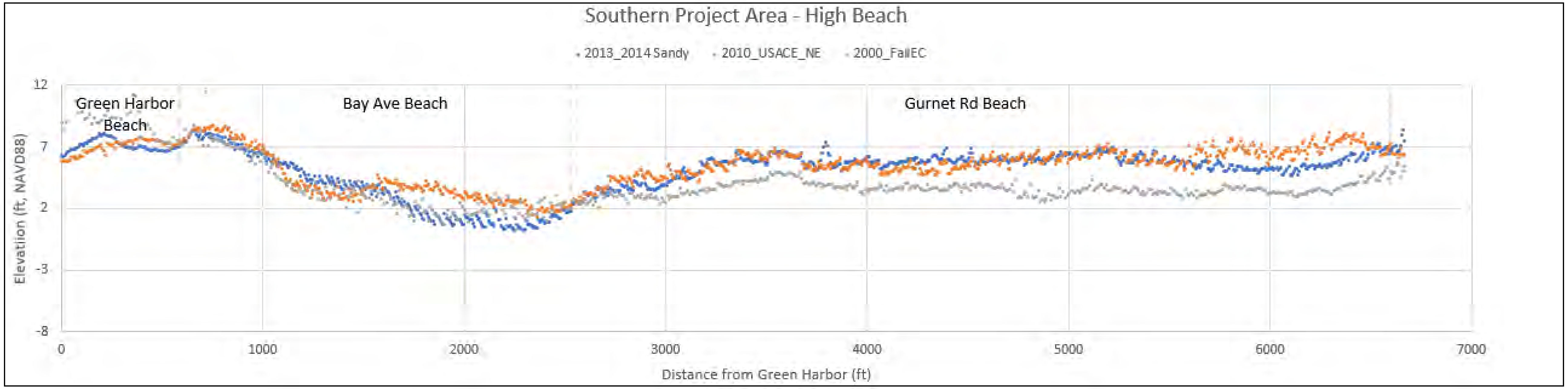


Figure C-19. Comparison of beach elevations from 2000 to 2014 between Green Harbor Beach and Gurnet Rd Beach for a location 75 ft seaward of coastal dunes or shore protection structures.

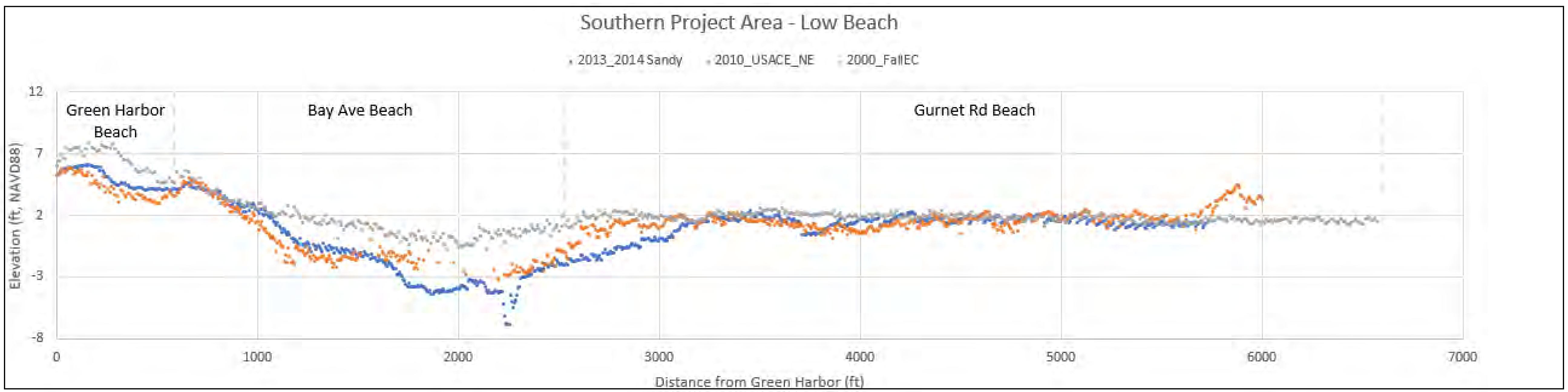


Figure C-20. Comparison of beach elevations from 2000 to 2014 between Green Harbor Beach and Gurnet Rd Beach for a location 175 ft seaward of coastal dunes or shore protection structures.

1.6 Wave Climatology

To accurately characterize sediment fluxes along a coastline to inform beach nourishment or erosion mitigation structural design, the offshore wave climate, and how energy is transferred into the near-shore zone, must be first understood. Wave transformation modeling is a powerful tool for providing information as to how an offshore packet of waves interacts with complex nearshore bathymetry as it reaches the shoreline. The level of interaction with the near-shore zone determines how much energy remains in the wave packet when it reaches the shore. The remaining wave energy that is distributed along the shoreline is indicative of the amount of sediment transport, and the direction of that sediment transport, that will occur.

Wave transformation modeling was previously conducted by Woods Hole Group for the coast of Duxbury, MA (Woods Hole Group, 2016). The goal of the current modeling effort was to extend the wave transformation model northward to include the coast of Marshfield, MA, using newly collected bathymetry data that accurately captures the irregular nearshore features off the coast of Marshfield. From these wave transformation model results, a sediment transport model was developed in order to characterize sediment fluxes and divergence on the Marshfield coastline. This report describes the wave model development, results for average annual conditions and results for extreme events along the Marshfield, MA coastline.

CMS-Wave version 3.2 (Lin et al, 2011), a spectral wave model, was chosen to model wave transformation processes for the Marshfield region. CMS-Wave, (formerly known as WABED, Wave-Action Balance Equation Diffraction) is a 2-dimensional, finite-difference, steady-state nearshore spectral wave model that solves the wave-action balance equation (Mase, 2001) on a uniform or non-uniform cartesian grid. The wave-action balance equation (eq. 1,2) is as follows:

$$\frac{\partial(C_x N)}{\partial x} + \frac{\partial(C_y N)}{\partial y} + \frac{\partial(C_\theta N)}{\partial \theta} = \frac{\kappa}{2\sigma}\left[\left(CC_g \cos^2\theta N_y\right)_y - \frac{CC_g}{2}\cos^2\theta N_{yy}\right] - \varepsilon_b N - S \tag{1}$$

where

$$N = \frac{E(\sigma,\theta)}{\sigma} \tag{2}$$

CMS-Wave has the capability to model and resolve wave processes such as wave refraction, diffraction, breaking, shoaling and interaction with shoreline structures (Lin et al., 2012). The spectral wave model runs as part of the Coastal Modeling System (CMS) developed by the Coastal Inlets Program of the U.S. Army Corps of Engineers (USACE) Research and Development Center (ERDC) and the USACE Coastal Hydraulics Laboratory (CHL). For this modeling effort, CMS-WAVE was run in half-plane mode where only waves directed onshore are simulated, which was deemed suitable for this application.

The bathymetric source for the offshore region of Marshfield is the 2016 USGS CoNED (1887-2016) New England topobathymetric digital elevation model, extracted relative to NAVD88 from NOAA's Data access viewer (https://coast.noaa.gov/dataviewer/#/lidar/search). For the nearshore region of Marshfield (out to a depth of approximately 40 feet), bathymetric data collected by Woods Hole Group in November 2019 were merged with the offshore data and interpolated to the grid to improve the local detail of the model's bathymetry.

The wave modeling was conducted using nested grid approach that included two grids (Table C-3). The first was a regional-scale, 50-m resolution parent grid, which covered the region of Marshfield and extended seaward to the 56-meter depth contour (Figure C-21), which coincided with the general location and depth of the USACE Wave Information Study (WIS) station 63060 in Massachusetts Bay. The second grid was a local scale grid, which was nested within the parent grid and included the Marshfield shoreline and extended to just offshore of Brant Point (Figure C-22). The resolution of this child grid was 10-meters, which was determined sufficient for both capturing necessary shoreline detail as well as remaining computationally efficient.

Table C-3. Grid Information Used for Wave Transformation Modeling.

Details	Regional-Scale Parent Grid	Local-Scale Child Grid
Grid Type	Uniform cartesian	Uniform cartesian
Resolution	50 m	10 m
X origin (MA State Plane Meters)	280634.27	269709.02
Y origin (MA State Plane Meters)	885628.69	878706.45
Grid Orientation	202.08 °	202.08 °
Depth at Boundary	56 m	12 m
Length of Seaward Boundary (km)	16.43 km	11.29 km

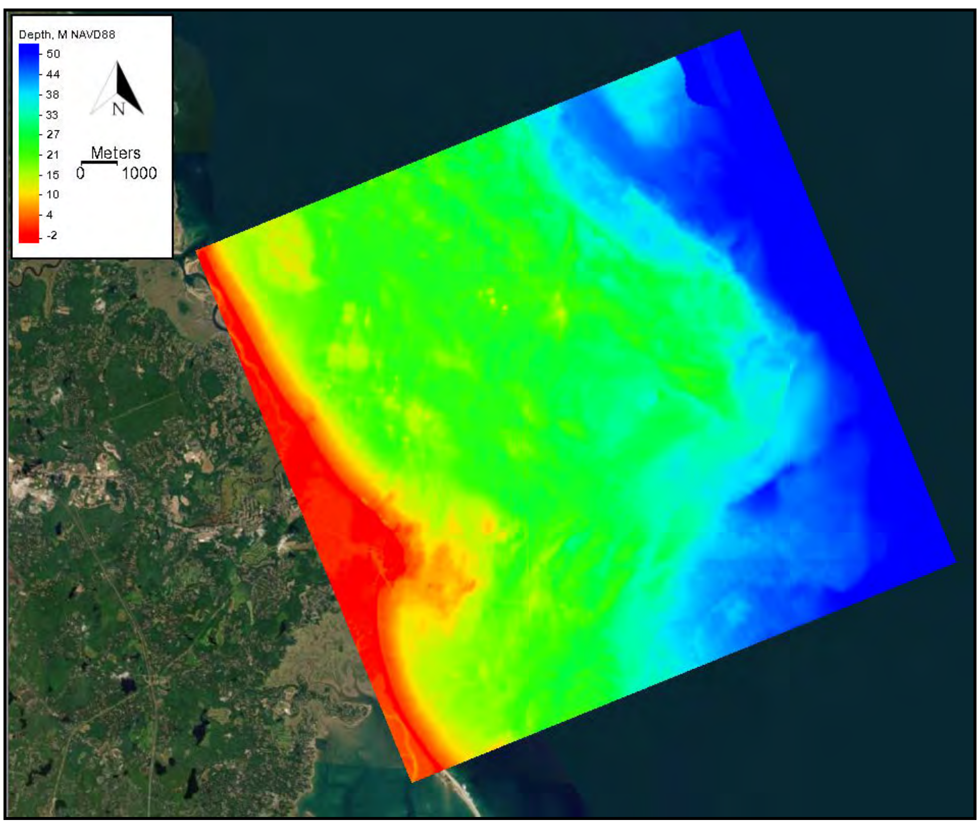


Figure C-21. Full extent of the 50-meter resolution parent grid.

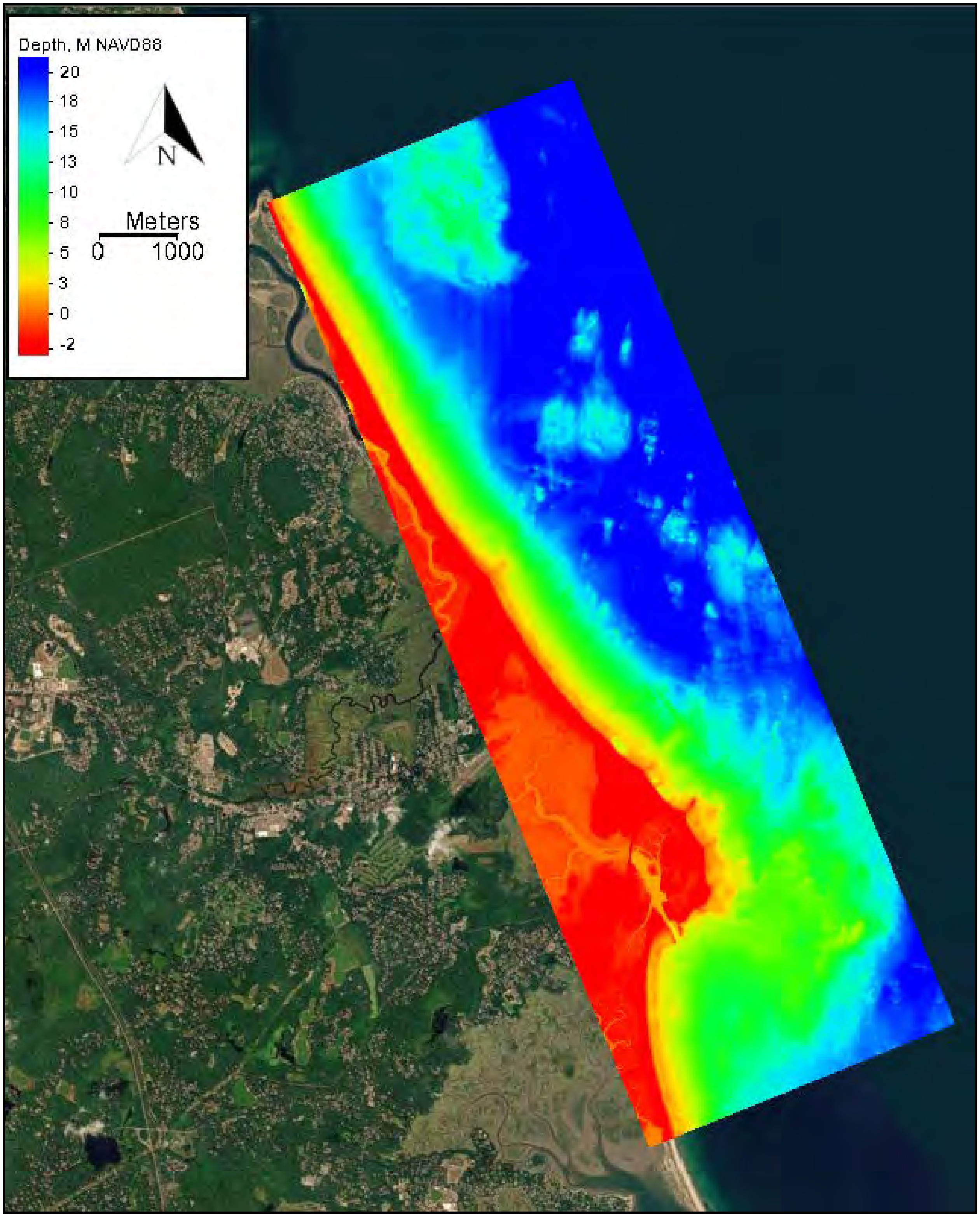


Figure C-22. The full extent of the 10-meter resolution nested grid.

There are two potential sources for wave data in the Marshfield offshore region of Massachusetts Bay. The first is from the National Oceanic and Atmospheric Administration's National Data Buoy Center (NOAA NDBC) station 44013. The second is the WIS station 63060. WIS information is produced from a hindcast wave model (WISWAVE) that predicts the local wave climate based on local and regional wind conditions (Resio and Tracy, 1983). WIS is a reasonable and widely used option when considering long-term average annual conditions. The locations of the two data buoys is presented in Figure C-23.

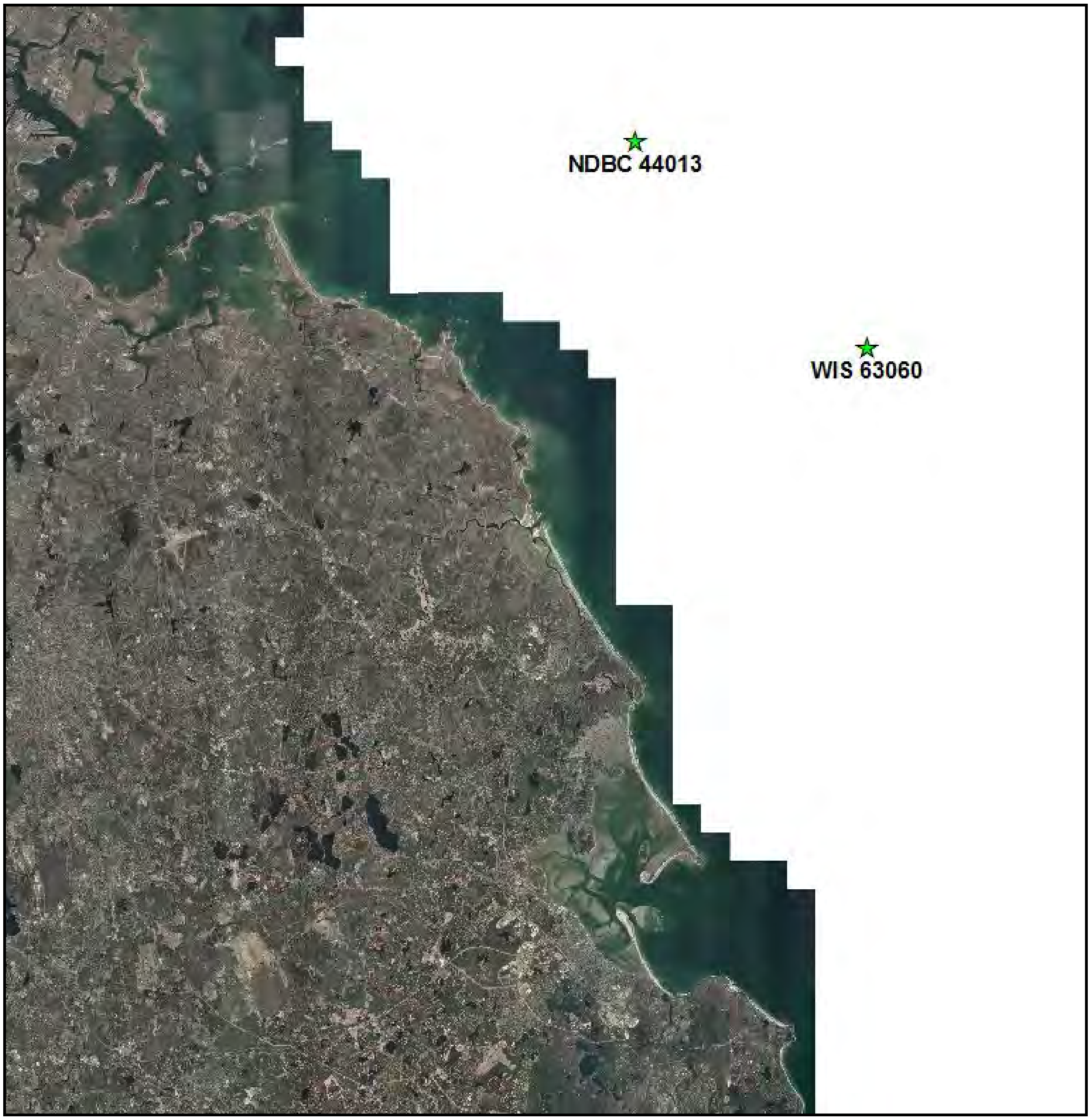


Figure C-23. Locations of offshore wave buoys in the vicinity of Marshfield, MA.

Due to the proximity and matching depth of the seaward boundary of this model, WIS station 63060 was chosen to develop offshore boundary conditions for the wave transformation model. The 33-year hourly averaged wave information from WIS station 63060 is presented as a wave rose in Figure C-24. These data were subdivided into 22.5-degree directional bins to develop representative spectral inputs for the wave model. Table C-4 presents the analysis results of the 33- year dataset used to create the average annual conditions for the wave transformation modeling for Marshfield, MA. The results show the highest wave energy arrives from the NE directional bin (44.5 to 68 degrees) while the most frequent waves arrive from the E-ESE (90.5 to 113 degrees).

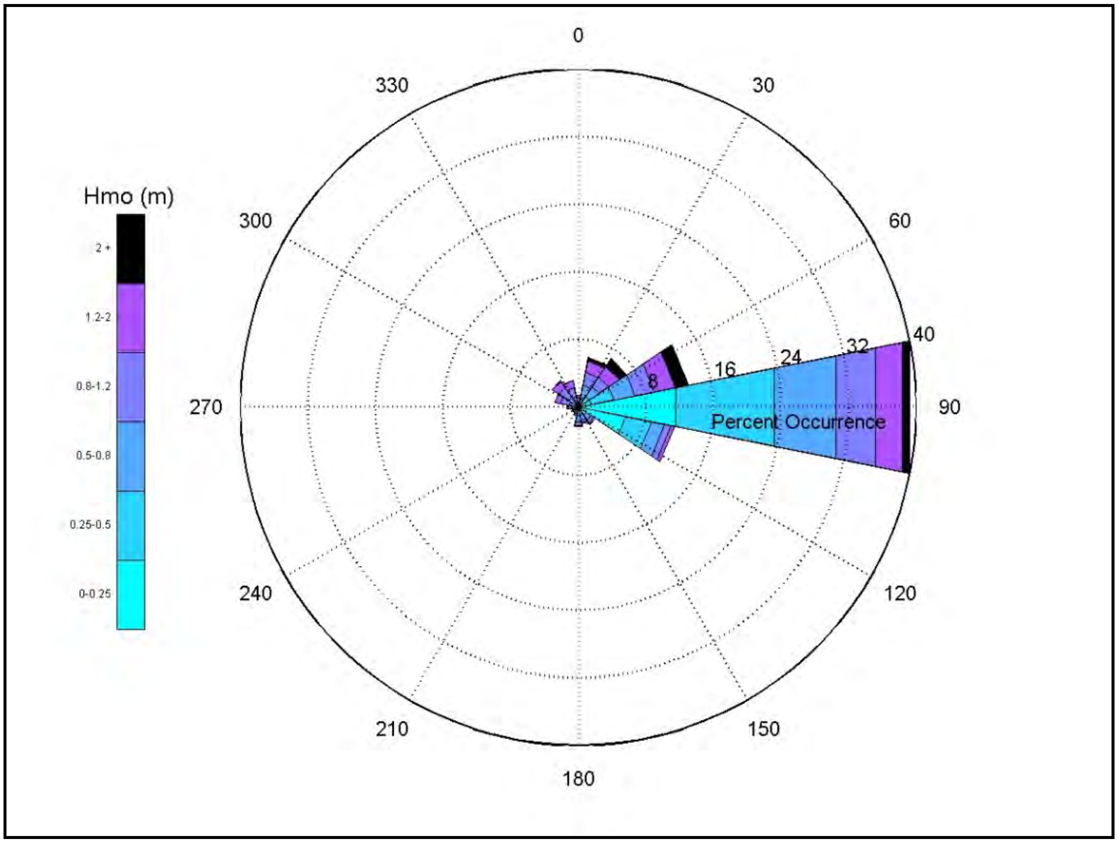


Figure C-24. 33-year hourly averaged wave heights and directions from WIS station 63030.

Table C-4. Input Conditions and Directional Bin Scenarios for the Wave Transformation Modeling.

Directional Bin (0°=N)	Approach Direction	Percent Occurrence	Sig. Wave Height (m)	Peak Period (sec)	Peak Direction (0°=N)
338 to 0.5	NNW	3.10	0.98	4.56	349.17
0.5 to 23.0	N - NNE	3.60	0.99	4.84	12.15
23.0 to 44.5	NNE-NE	5.50	1.14	5.35	34.96
44.5 to 68	NE	8.50	1.20	6.16	57.22
68.0 to 90.5	NE-E	27.70	0.76	7.84	81.31
90.5 to 113.0	E- ESE	30.0	0.43	7.58	98.99
113.0 to 135.5	SE	3.30	0.63	5.29	122.64
135.5 to 158.0	SSE	2.20	0.62	4.54	146.38
Calm	--	16.10	--	--	--

Extreme Event Modeling - High waves and increased sediment transport on open coastlines most often occur during high energy, or storm events. USACE has completed as part of the WIS project a series of analyses for extreme event return periods at station 63060. The results of these extreme event return-period analyses are presented in Figure C-25. For this modeling effort, two high energy return-period scenarios were chosen to use as inputs into the wave transformation model, details of which are presented in Table C-5. The wave heights and for these two scenarios were chosen from the return period analysis of the 33-year wave hindcast at station 63060. The wave period corresponding to each high-energy wave height was derived using the relationship between peak wave height and wave period for storm events. The wave direction was calculated as the mean wave direction of all storms used in the WIS station 63060 return-period analysis. Storm surge elevations corresponding for each scenario were collected from USACE's Tidal Flood Profiles of the New England Coast (USACE, 1988).

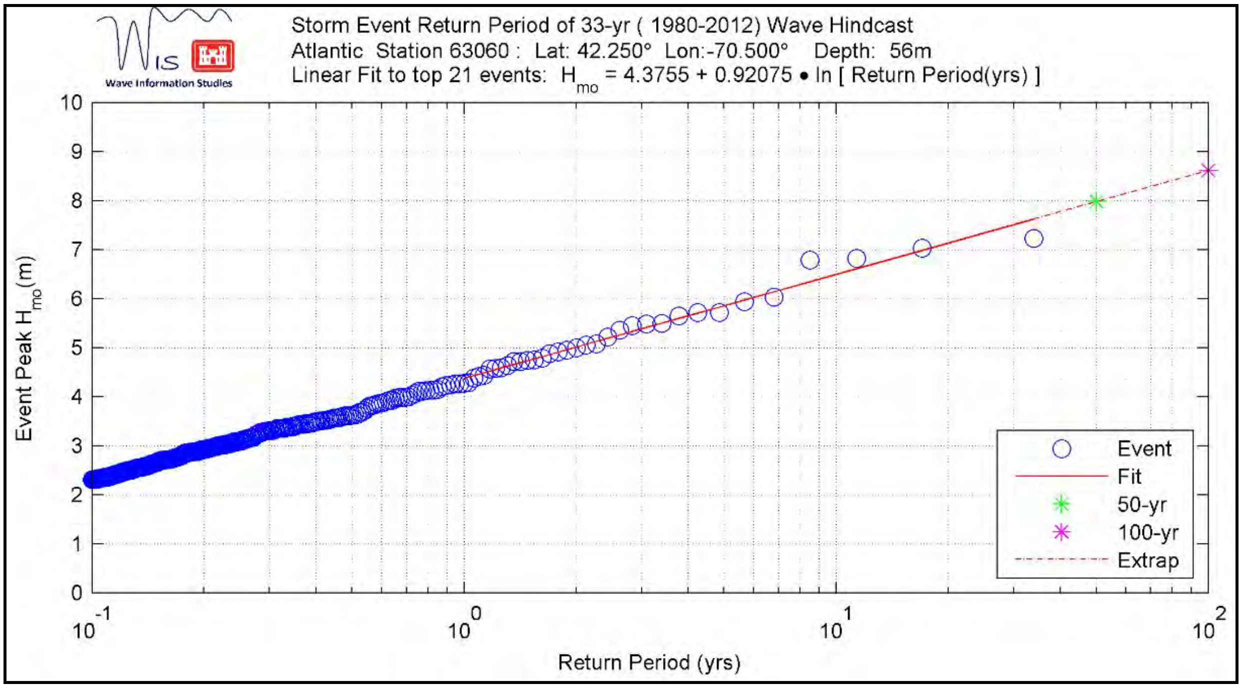


Figure C-25. Storm event return periods for the 33-year dataset at WIS Station 63060 (USACE, 2012).

Table C-5. Wave Input Conditions for High Energy Events.

Event	Storm Surge [m_NAVD88]	Wave Height [m]	Wave Period [sec]	Wave Direction [0°=N]
10-Year	2.47	6.5	12.0	55.4
50-Year	2.77	8.0	13.3	55.4

Model Validation - Before modeling average annual and extreme storm conditions, the wave model performance was first evaluated by running the model and comparing the results to a wave ADCP that was deployed by Woods Hole Group in May-June 2015. Time-series of significant wave height (m), period (s) and wave direction (degrees) output from the model were compared with the ADCP measurements are presented in Figure C-26. Considerable noise (high-frequency oscillations) is present in the ADCP data for wave period and direction during periods of low wave energy, which is expected. The model can capture key high energy events as well as reasonably predict during calm periods but tends to over-predict wave heights at the location of the ADCP. This can be attributed to the spatially constant wind forcing in the model from a single point offshore. The wind inputs from the NDBC buoy may not be fully representative of the winds occurring at the ADCP location, which explains the increased wave heights. Visually however, the model follows the trend of the observations well and captures periods of high and low energy. This indicates reasonable model-data fit, which demonstrates the model is sufficient for characterizing wave transformation processes in the region.

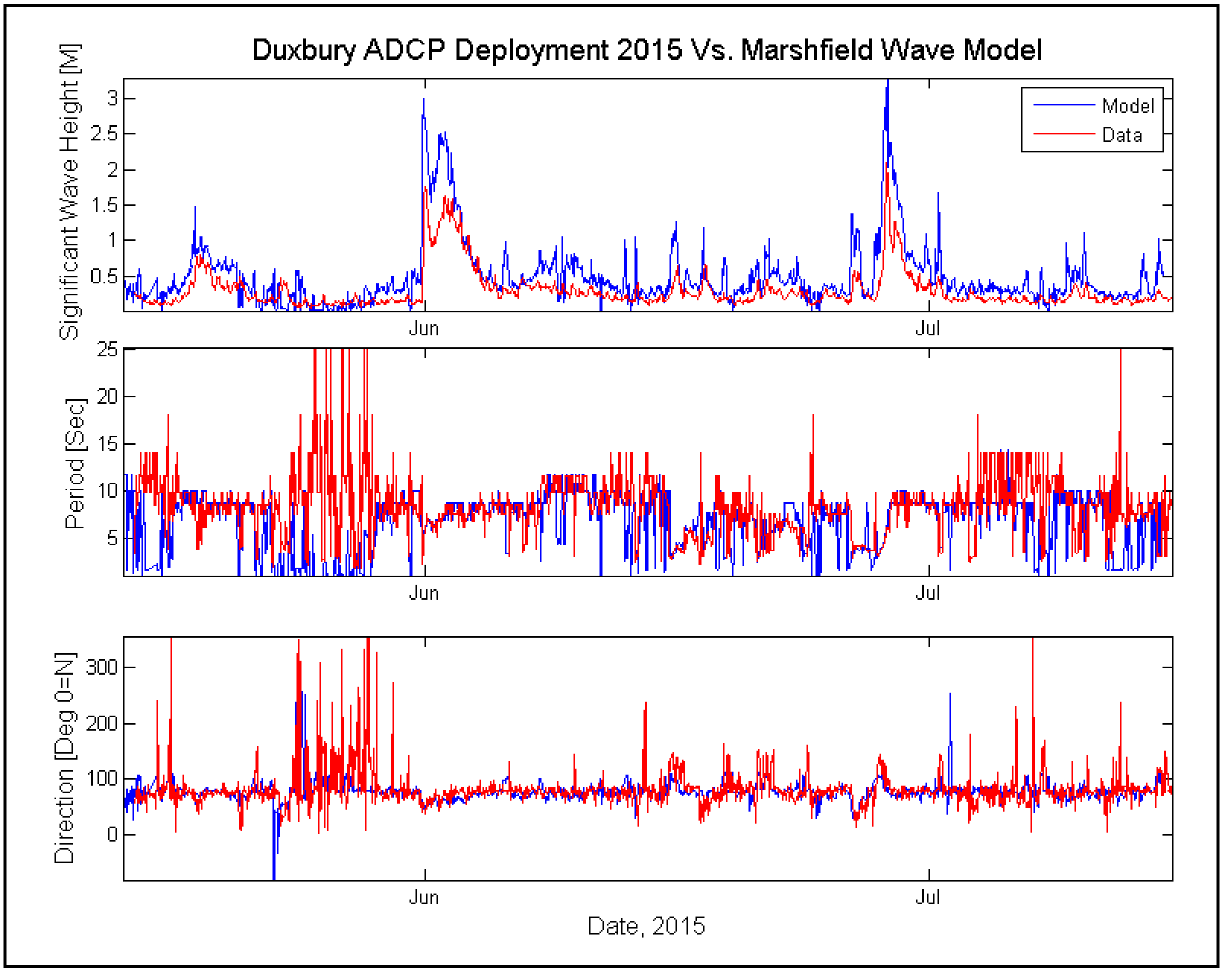


Figure C-26. Observational data collected from an ADCP deployed in May 2015 compared to CMS-Wave model output for wave direction, wave period and significant wave height for the verification run. Model output is represented in red, and the ADCP observational data is represented in blue.

Wave transformation model simulations were performed for each of the average annual and storm conditions listed in Tables C-4 and C-5. An example of the CMS-Wave model output for one of the more energetic directional bins (44.5 to 68 degrees) is shown in Figure C-27. Figures showing the model results for all conditions simulated are included in Section J.

The wave model results shown in Figure C-27 are for waves arriving from NE–ENE and indicate wave heights are larger along the sections of the shoreline due to energy focusing. The increases in wave height appear to occur where waves refract around shallow rocky formations in the nearshore or in the vicinity of shoreline structures (groins).

A close-up view of the wave model results around Brant Rock is shown as an inset in Figure C-27. This is an area of significant wave energy as the nearshore bathymetric features cause waves to shoal, refract, and diffract in this region.

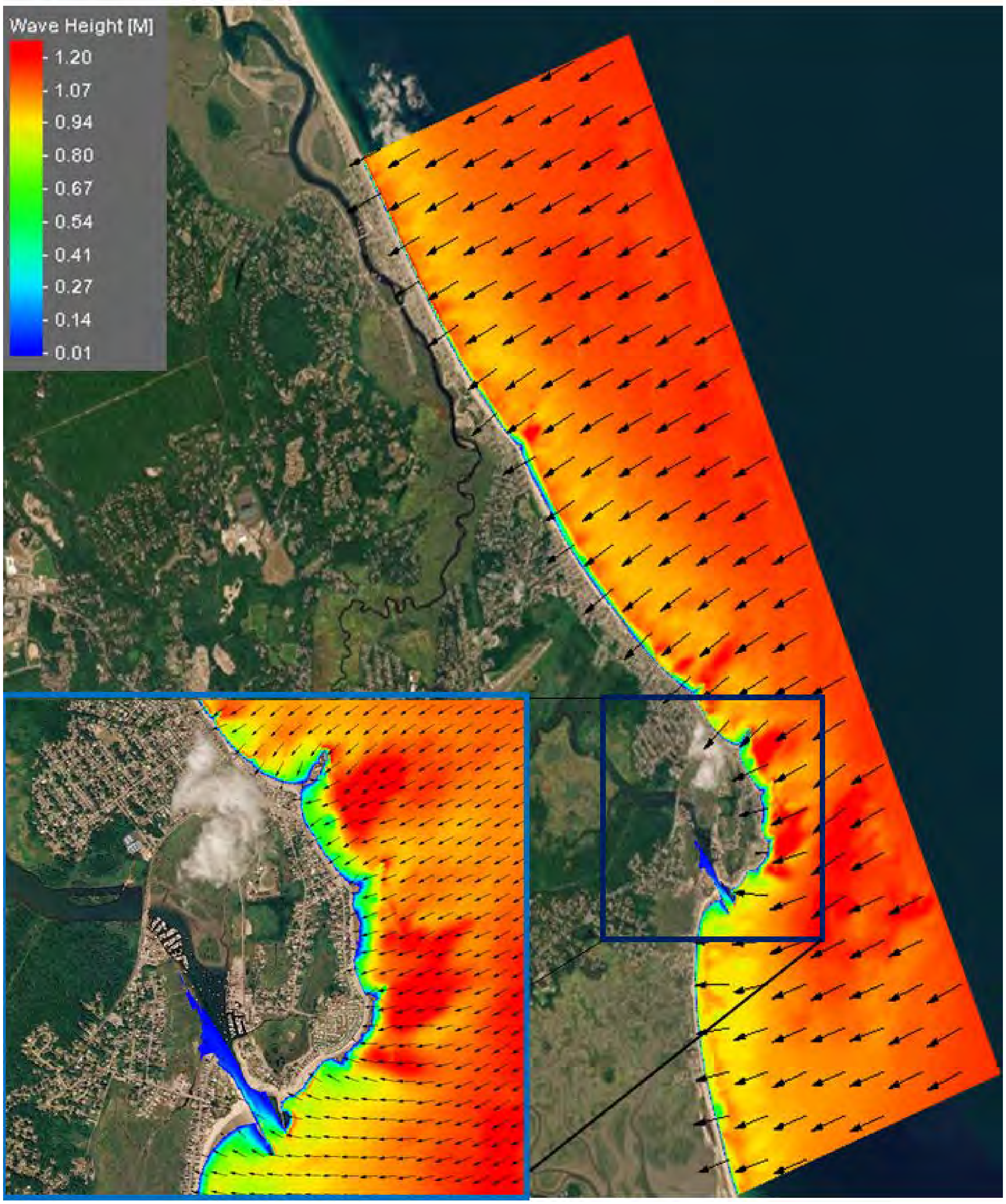


Figure C-27. Results of the local wave model for the NE-ENE approach direction (44.5° to 68.0 ° [N = 0°]).

1.7 Sediment Transport

An understanding of how waves interact with the complex nearshore bathymetry is important to determine estimates of sediment movement in the nearshore region. The results of the transformation-scale wave modeling conducted for Marshfield, therefore, act as the key input for alongshore sediment transport modeling and evaluation of beach nourishment activities. The intent of the sediment transport modeling is to represent the alongshore currents and sediment transport driven by breaking waves in the surf zone. The model provides estimates of sediment flux to identify trends of erosion and accretion along the shoreline. This section describes the development of the physical process-based sediment transport model for Marshfield and northern Duxbury, the model inputs, and results of the sediment transport modeling.

To accurately model sediment transport processes along the Marshfield and northern Duxbury coastline, the characteristics of the naturally occurring sediments on the beach must first be identified. Grain size characterization is also important for the design of beach nourishment and erosion mitigation alternatives developed as part of this study.

The grain size information for the sediment transport modeling were sourced from the sediment sampling that was completed in December 2019 by Woods Hole Group (Table C-1). During this sampling effort 26 surface grab samples were collected at the dune and the mean tide line. Further information regarding this sediment sampling effort is discussed in Section 1.4 above.

The coastline extending southward from the northern Marshfield border to the outer beach in Duxbury is characterized by a mixture of gravel and sand with isolated areas of larger grained sediments. The average sediment type for the Marshfield coastline is a granular sand with a D50 (median grain-size) of 2.65 mm. The smallest D50 occurs for a predominantly sand sample at station 12-MTL-SAN, with a value of 0.25 mm. The largest D50 occurs for a predominantly cobble sample at station 12-MTL-COB, with a value of 32 mm. The median sand grain size for the beach is 1.75 mm occurring at station 16-MTL-SAN and the median gravel/pebble grain size is 19 mm occurring at station 8-MTL-COB. These values were used as the representative grain-sizes for sand and cobble, respectively, in the mixed-grain size sediment transport analysis.

Sediment transport in the coastal zone is characterized by the interaction between onshore wave energy and nearshore features together with sediment grain size and available sediment supply. Modeling sediment transport in the coastal zone numerically involves solving the physics of wave energy and sediment transport with simplifying assumptions. The sediment transport model used for this modeling effort is a process-based model which identifies patterns of regional sediment transport in the presence of a time-varying wave field. Due to the mixed-granular characteristics of the natural sediments occurring on the Marshfield coastline, a sediment transport approach that incorporates multiple grain sizes, along with their relative contributions, was developed and utilized for this modeling effort. This approach is described in the following sections.

The sediment transport model used to simulate sediment fluxes on the Marshfield coastline was a process-based numerical model which solves the steady-state, depth averaged mass and momentum equations, coupled with the calculations for long-shore sediment transport adopted from the methodology developed by Haas and Hanes (2004).

The sediment transport model used a series of cells covering the section of beach and surf zone where wave-induced sediment transport occurs. Based on the wave model results, a cell can either accumulate sediment or lose sediment as the wave energy is applied. Cells that gain more sediment than they lose are described as accreting (sediment is converging in the cell), whereas cells that lose more sediment than they gain are described as eroding (sediment is diverging in the cell). A cell that loses the same amount of sediment that it gains is described as stable, indicating no accretion or erosion is occurring.

A high-resolution bathymetric grid was generated using the nearshore bathymetry/topography from the transformation-scale wave model (CMS-WAVE) for Marshfield and northern Duxbury. The grid for the sediment transport model was the higher resolution local grid of the wave transformation model with 10-meter cells spanning 11.29 km in the along-shore direction and 3.4 km in the onshore direction. Results from the wave transformation model for both average annual conditions and the high-energy events were used as input to the high-resolution sediment transport model. Table C-6 presents the information for the grid used in sediment transport model. The orientation of the grid was altered for the portion of shoreline south of Green Harbor to more accurately represent a shore-normal orientation.

Table C-6. Grid Information for Sediment Transport Model

Details	Sediment Modeling Grid
Grid Type	Uniform cartesian
Resolution	10 m
Scale	Local
X origin (MA State Plane Meters)	269709.02
Y origin (MA State Plane Meters)	878706.45
Grid Orientation	202.08 °
Depth at Boundary	12 m
Length of Seaward Boundary (km)	11.29 km

To identify erosional and accretional patterns on specific sections of the Marshfield and northern Duxbury coastline, sediment transport trends were characterized using modeled rates and direction of sediment transport. The model computed the sediment flux, a representation of the rate of sediment moving along the coastline, in cubic meters per year. Positive and negative fluxes indicate the direction of sediment movement relative to the model's grid orientation. It is important to note that the model computes the potential for sediment transport. The calculations assume that sediment is infinitely available for transport, and therefore model overpredicts rates of transport along stretches of shoreline that are sediment starved.

The transformation-scale wave model results discussed in Section 1.6 above were used as input into the sediment transport model. Sediment transport was first evaluated for average annual conditions by simulating each average directional wave case (Figure C-28). This was completed using both the representative sand grain size, as well as the representative cobble grain size. The results from these cases were then combined to produce an annual pattern of sediment transport (Table C-7). Finally, storms were evaluated in order to determine the episodic transport which occurs during extreme storm events.

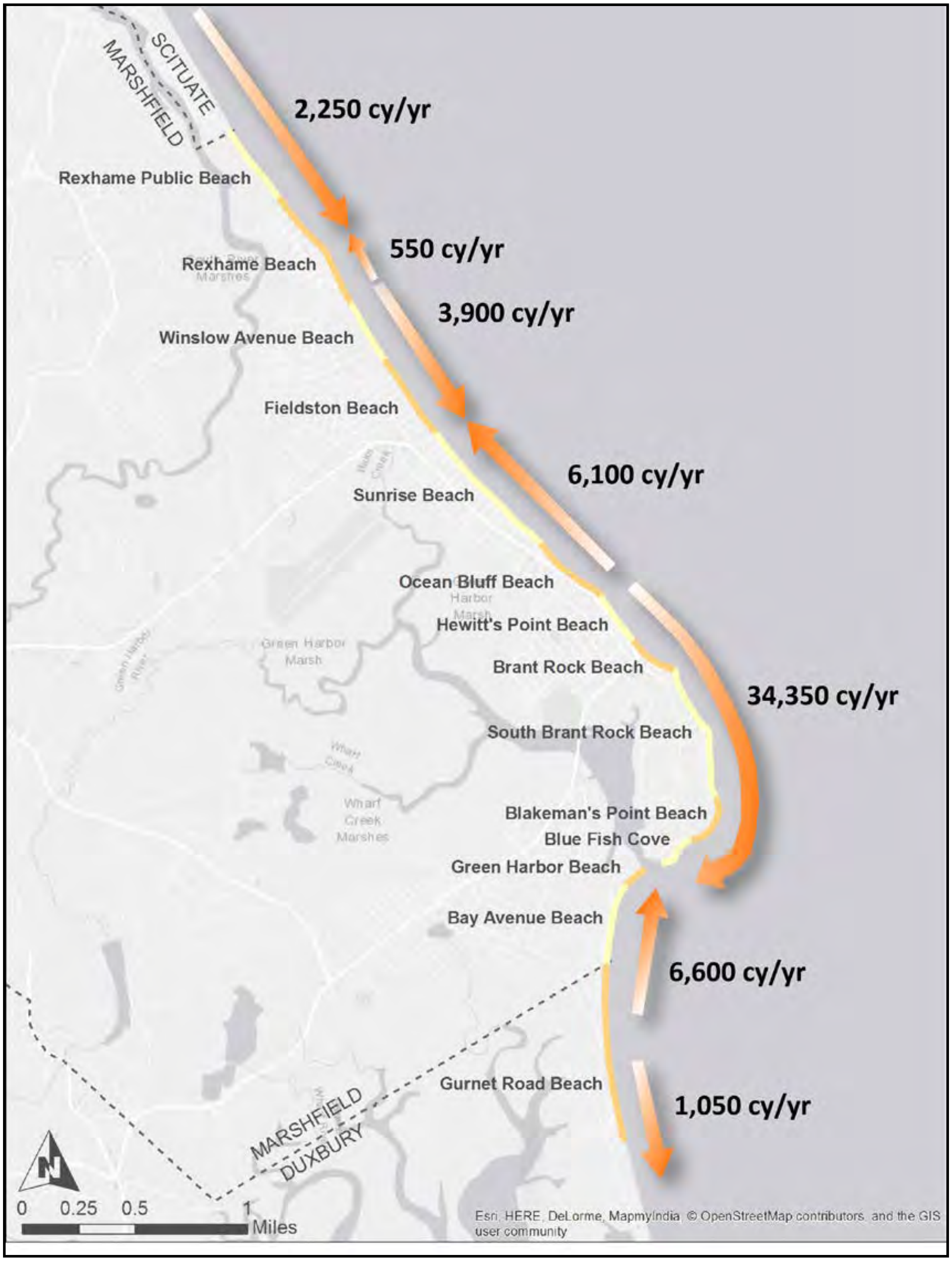


Figure C-28. Sediment transport from the average annual wave bin condition.

Table C-7. Table of Sediment Transport Results for Average Annual Conditions.

Beach	Sediment Flux (cu yards/year)	Direction
Rexhame Beach (North)	2,250	Southward
Rexhame Beach (South)	550	Northward
Winslow Avenue Beach/Fieldston	3,900	Southward
Sunrise/Ocean Bluff	6,100	Northward
Green Harbor Beach/Bay Ave Beach	6,600	Northward
North Duxbury	1,050	Southward

1.8 Regulated Environmental Resources

1.8.1 Land Under the Ocean (310 CMR 10.25)

Land Under the Ocean resource extends from the MLW line seaward to the boundary of the Marshfield and Duxbury jurisdictions. Nearshore areas of Land Under the Ocean are significant to the protection of the following interests: water circulation, distribution of sediment grain size, water quality, finfish habitat, and important food for wildlife. Essential Fish Habitat (EFH) resources documented by the National Marine Fisheries Service (NMFS) to be in Land Under the Ocean in the vicinity of the project site are described in the following section. Eelgrass resources have not been mapped in the waters offshore of the project area.

Essential Fish Habitat (EFH)

Thirty-one federally-managed species have designated Essential Fish Habitat (EFH) in the project area (https://www.habitat.noaa.gov/application/efhmapper/index.html). Table C-8 lists these species by life stage. The project area also lies within a Habitat Areas of Particular Concern (HAPC) for juvenile cod and may also be an HAPC for summer flounder.

Most of the species with EFH in the project area are present from spring through fall, so wintertime construction windows would provide protection from direct effects on species (but not on their habitat). However, winter flounder may be present in winter, and they spawn inshore during late winter and early spring, so this species, and its spawning habitat would be directly affected. Similarly, shellfish including sea scallop and surf clams are present year-round and, if present within the project area, would be vulnerable to direct impacts from project construction.

Habitat preferences for EFH species are provided in Table C-9. Habitat preferences among species range from shallow sandy areas to rocky mid-depth areas to deepwater marine. Because the project area has a mix of sand, gravel and cobble, most substrate types are represented. Construction activity will cause habitat alteration (alteration in water depths, placement of sand in intertidal areas). This will cause temporary impacts to habitat for any species whose habitat overlaps with the project area. Impacts to EFH will be assessed in conjunction with the federal project permitting.

Table C-8. Species with Designated EFH in the Project Area by Life Stage.

Species	Eggs	Larvae	Juveniles	Adults
New England Management Council Species				
Atlantic Sea Scallop (*Placopecten magellanicus*)	X	X	X	X
Atlantic Wolffish (*Anarhichas lupus*)	X	X	X	X
Haddock (*Melanogrammus aeglefinus)*			X	
Winter Flounder (*Pseudopleuronectes americanus*)	X	X	X	X
Little Skate (*Leucoraja erinacea*)	Not well known	No larval stage	X	X
Ocean Pout (*Macrozoarces americanus*)	X		X	X
Atlantic Herring (*Clupea harengus*)		X	X	X
Atlantic Cod (*Gadus morhua*)	X	X	X	X
Pollock (*Pollachius virens*)		X	X	X
Red Hake (*Urophycis chuss*)	X	X	X	X
Silver Hake (*Merluccius bilinearis*)	X	X		X
Yellowtail Flounder (*Limanda ferruginea*)	X	X	X	X
Monkfish (*Lophius americanus*)	X	X		
White Hake (*Urophycis tenuis*)	X	X	X	X
Windowpane Flounder (*Scophthalmus aquosus*)	X	X	X	X
Winter Skate (*Leucoraja ocellata*)	Not well known	No larval stage	X	X
American Plaice (*Hippoglossoides platessoides*)	X	X	X	X
Thorny Skate (*Amblyraja radiata*)			X	
Secretarial Management Species				
Bluefin Tuna (*Thunnus thynnus*)				X
Basking Shark (*Cetorhinus maximus*)	No egg stage	No larval stage	X	X
White Shark (*Carcharodon carcharias)*	No egg stage	No larval stage	X	X
Sand Tiger Shark (*Carcharias taurus*)	No egg stage	No larval stage	X	
Mid-Atlantic Management Council Species				
Northern Shortfin Squid (*Illex illecebrosus*)				X
Longfin Inshore Squid (*Doryteuthis pealeii*)			X	X
Bluefish (*Pomatomus saltatrix*)			X	X
Atlantic Butterfish (*Peprilus triacanthus*)	X		X	X
Spiny Dogfish (*Squalus acanthias*)			X[1]	X
Atlantic Surfclam (*Spisula solidissima*)			X	X
Summer Flounder (*Paralichthys dentatus*)		X		X
Scup (*Stenotomus chrysops*)			X	X
Black Sea Bass (*Centropristis striata*)				X
NEFMC Habitat Areas of Particular Concern				
Inshore 20m Juvenile Cod				
Summer Flounder (Likely)				

Table C-9. Habitats Used by EFH Species in the Project Area.

Species	Comment
New England Management Council Species	
Atlantic Sea Scallop (*Placopecten magellanicus*)	Commercially valued shellfish, common offshore in medium and fine-grained sands, temperatures less than 77F (25C). Adults and juveniles occur all year. Spawning occurs in late Sept -o early October (MA DMF, 2011) Adults can survive in salinities as low as 12.5ppt but more commonly are found in waters above 28ppt. (NMFS/NERO, 2001)
Atlantic Wolffish (*Anarhichas lupus*)	Demersal fish preferring complex habitats with large stones and rocks that provide shelter and resting sites. Occasionally seen in soft sediments including sand and mud. Adults and juveniles could be present any time. Spawning occurs in late summer. Found at depths of 20-240 m in the Gulf of Maine; also found at shallower depths in more northern areas. (NMFS/NEFMC 2009)
Haddock (*Melanogrammus aeglefinus)*	Eggs and juveniles occur in water column and epipelagic zone; juveniles and adults are demersal benthivores. Haddock feed and spawn on sand, rock, gravel and mud. In winter adults prefer deeper waters and move shoreward in summer. When summer temperatures reach 10-11C they move to colder deeper waters. (NOAA, 2005a)
Winter Flounder (*Pseudopleuronectes americanus*)	Demersal species. Adults migrate inshore in fall and early winter, spawn in late winter and early spring when temperatures are less than about 3.5-5.5C, then leave inshore areas after spawning (although some adults remain inshore year-round). Eggs are demersal, adhesive, found at water temps of 10C or less and in salinities ranging from 10-30ppt. Larvae are initially planktonic but become bottom oriented as metamorphosis approaches. Young of the Year (YOY) develop inshore in shallow water for the first year and then move to deeper waters. Substrate includes mud to sand or gravel for eggs, larvae and YOY; adults occur on mud, sand, cobble, rocks and boulder (NOAA, 1999a)
Little Skate (*Leucoraja erinacea*)	Substrate preferences are sand or gravelly bottoms but also found on mud. Skates remain buried in depressions during the day and are more active at night. They move onshore/offshore with seasonal temperature changes. Temperature range is 1-21C; most are found between 2-15C. (NOAA, 2003a)
Ocean Pout (*Macrozoarces americanus*)	Demersal fish in all life stages. Spawning in water <50m in late summer – fall; adults make nests in holes, crevices, etc. Spawning occurs on rough bottom areas. Preferred substrate for adults is variable, sand, gravel, rough bottom but rarely mud. Depths variable 1-300+m but prefer 15-110m. Preferred temperature <10 C for spawning and eggs; Adults and Juveniles occur at temperatures 2-14C, mostly 2-10C. (NOAA, 1999b)
Atlantic Herring (*Clupea harengus*)	Pelagic species but spawns on bottom. Occurs inshore and offshore in summer and fall; Diel vertical migration; depths to about 300m; mostly <80m in fall and shallower in spring. Pre-spawning aggregations more abundant over gravel and sand. Eggs demersal, egg “beds” in coastal water and offshore banks with strong bottom currents and coarse substrate; depths 5-90m. Adults most abundant at 27-35 ppt salinity. (NOAA, 2005b)
Atlantic Cod (*Gadus morhua*)	Occupies mixed areas of water column. Larvae and eggs generally at surface but move deeper with age. Larvae migrate vertically in reaction to light. Adults are mostly on bottom during the day and move up into the water column at night. Found on various substrate but adults prefer rocky, pebbly, gravelly areas and avoid finer sediments. Juveniles use vegetation for predator avoidance. Salinities mostly 30-35ppt; adults generally found in temperatures <10C; younger life stages occur in cool water, mostly 4-8C although juveniles are more tolerant of temperature extremes from 6-20C. (NOAA, 1999c)
Pollock (*Pollachius virens*)	Pelagic schooling species. Often found on inshore and offshore banks. Adults are unselective for bottom type, associated with sediments ranging from gravels to clay. Occurs at depths from 15-300+m, but mostly 75-175m. Temperature range 0-14C but preferred range is 6-8C. (NOAA, 1999d)
Red Hake (*Urophycis chuss*)	Demersal species. Migrates inshore in spring and summer to spawn, and offshore in fall. Preference for soft sand or muddy substrates. Preferred temperature 5-12C. Juveniles seek shelter from predators in sea scallop beds. (NOAA, 2018)
Silver Hake (*Merluccius bilinearis*)	Demersal species. Migrates inshore in spring and summer to spawn, and offshore in fall. Preference for soft sand or muddy substrates. Preferred temperature 7-10C. (NOAA, 2018). Silver hake occur on substrates from gravel to fine silt and clay but are mainly associated with finer sediments (NOAA, 1999e)
Yellowtail Flounder (*Limanda ferruginea*)	Demersal species, prefers sand or sand and mud substrate. Spawning occurs in March through August at temperatures of 5-12C. Temperature range approximately 2-18C. Found at depths of 10-1200m; adults concentrated at depths of 37-73m. Salinity range approximately 32-33.5ppt. (NOAA, 1999f)
Monkfish (*Lophius americanus*)	Demersal piscivores found from inshore to depths of 900m. Seasonal onshore offshore migrations occur and are related to spawning and food availability. (NOAA, 2016) Substrates include sand-shell mix, algae covered rocks, hard sand, pebbly gravel or mud. Eggs and juveniles are found in the water column at depths 15-1000 and temperatures >18C. (NOAA, 1998)
White Hake (*Urophycis tenuis*)	Demersal species, prefers muddy and fine-grained sandy substrates. Eggs and larvae are planktonic, occurring in depths of 10-250 m. Juveniles become pelagic and occur inshore at depths of 5-75 m in spring and autumn when temps are 4-19C. Adults occur inshore and offshore, to depths of 350m. Prey on shrimp, crustaceans, fish including their own young. May occur in project area year round. (NOAA, 1999g)
Windowpane Flounder (*Scophthalmus aquosus*)	Demersal fish, occurring in nearshore bays and estuaries to depths of 75m. Prefers muddy or fine sandy substrate. Preys on polychaetas, crustaceans, small fishes. Temperature range 4-19C in inshore MA waters. (NOAA, 1999h)
Winter Skate (*Leucoraja ocellata*)	Substrate preferences are sand or gravelly bottoms but also found on mud. Skates remain buried in depressions during the day and are more active at night. They move onshore/offshore with seasonal temperature changes. Generally caught at depths from shoreline to 370m. Temperature range is -1 to 20C (NOAA, 2003b)
American Plaice (*Hippoglossoides platessoides*)	Demersal species but eggs and larvae are pelagic. Substrates include fine sand and gravel. Temperature range 2-17C. Salinity range 20-32+ throughout range. Occurs inshore and offshore. (NOAA, 1999i)
Thorny Skate (*Amblyraja radiata*)	Found on a wide range of substrates including sand, gravel, broken shell, pebbles and soft mud. Found at depths of 18-1200m. Temperature range is -1 to 14C. Salinity 31-36ppt. Opportunistic feeder on most abundant and available prey including bivalves, squid, polychaetas, zooplankton. (NOAA, 2003c)

Secretarial Management Species	
Bluefin Tuna (*Thunnus thynnus*)	Long lived, top predator, pelagic fish. Eggs pelagic. Spawning occurs mid-April to June, mainly in the Gulf of Mexico. Occurs in New England during summer. Feeds on fish, squid and crustaceans. (NOAA, undated online information *https://www.fisheries.noaa.gov/species/western-atlantic-bluefin-tuna*)
Basking Shark (*Cetorhinus maximus*)	Migratory coastal pelagic species found in all temperature areas. Slow moving, filter feeder. Occurs in New England during summer months. (*https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/cetorhinus-maximus/*)
White Shark (*Carcharodon carcharias)*	Migratory epipelagic species found in coastal and offshore areas along the continental shelf and islands. Occurs in summer in New England. Feeds on fish, marine mammals, other sharks. (*https://www.nefsc.noaa.gov/nefsc/Narragansett/sharks/white-shark.html*)
Sand Tiger Shark (*Carcharias taurus*)	Migratory species found in surf zone, coastal waters and shallow bays to outer continental shelf. Generally bottom dwelling. (*https://www.nefsc.noaa.gov/nefsc/Narragansett/sharks/sandtiger-shark.html*)
Mid-Atlantic Management Council Species	
Northern Shortfin Squid (*Illex illecebrosus*)	Occurs in water column over various sediment types including sand-silt. Avoids areas inhabited by anemones. Found at temperatures 3.5-20C, salinity generally 30-36.5ppt. In coastal waters during spring and summer. Migrates off continental shelf in fall. (NOAA, 2004)
Longfin Inshore Squid (*Doryteuthis pealeii*)	Occurs in water column over mud or sandy mud at temperatures 9-21C, salinity generally 30-34 ppt. In coastal waters during spring and summer. Migrates offshore to deeper waters in winter. Occurs in Gulf of Maine from March to October. When inshore is found at depths to 180m (NOAA, 2005c)
Bluefish (*Pomatomus saltatrix*)	Pelagic species. Adults generally oceanic nearshore to well offshore over continental shelf. In summer juveniles are found near shorelines or in tidal creeks, also open bay or channel waters Can occur in surf zone. Mostly found over sand substrates but some mud, silt, clay. Also uses areas with seagrass, marsh vegetation. Occurs in New England during summer, in water temperatures 14-30C. Prefers ocean salinities. Sight feeder, preys on other fish mainly.(NOAA, 2006)
Atlantic Butterfish (*Peprilus triacanthus*)	Eggs are pelagic, occurring in surface waters from continental shelf to estuaries and bays; Juveniles and adults found from surface to depth in waters to 330m. Common in inshore areas including the surf zone. Schools found over sandy, sandy-silt, and muddy substrates. Temperatures 4-26C. Salinities 3-37 ppt. (NOAA, 1999j)
Spiny Dogfish (*Squalus acanthias*)	Epibenthic species but does move through the water column. Occurs in coastal and offshore waters to 3,0000ft, usually near bottom waters at temperatures 6-11C. (*https://www.nefsc.noaa.gov/nefsc/Narragansett/sharks/spiny-dogfish.html*) Although, they can tolerate brackish water they prefer full strength seawater and do not enter freshwater habitats; Found north of Cape Cod in summer and move to Long Island area in fall and farther south in winter (*https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/squalus-acanthias/)*
Atlantic Surfclam (*Spisula solidissima*)	Commercially valued shellfish occurring in nearshore and offshore areas. Adults burrow in medium to coarse sand and gravel substrates, also found in silty to fine sand. Does not burrow in mud. Spawning occurs from 19.5-30C; Salinities 14-52 ppt in lab studies. (NOAA, 1999k)
Summer Flounder (*Paralichthys dentatus*)	Demersal fish. Adults occur in a variety of substrates including sand and mud, seagrass beds, and marsh creeks. Adults migrate inshore in April-June, often found in high salinity portions of estuaries. Opportunistic feeders, with fish and crustaceans making up most of the diet (NOAA, 1999l)
Scup (*Stenotomus chrysops*)	Pelagic species occurring in mid-to deepwater parts of the water column during winter, shallower in summer. Found in New England during warmer months. Adults spawn during spring and summer in inshore areas from Delaware Bay to Southern New England (not as far north as project area). Juveniles and adults are found on a variety of substrates from fine to silty sand or mud; also found over mussel beds, rocks and other structures. Temperature tolerance >7 to 27C. (NOAA, 1999m)
Black Sea Bass (*Centropristis striata*)	Demersal species associated with structurally complex habitats, including rocky reef, cobble and rock fields, and exposed stiff clay. Over winters offshore at depths of 30-400m. Moves inshore during spring and offshore in fall. Temperatures 3-21C but mostly found at 9-12C. Salinity 32-36ppt. Depths 1-400m. (NOAA, 2007)

1.8.2 Coastal Beaches (310 CMR 10.27)

The coastal beach includes those unconsolidated sediments subject to wave, tidal and coastal storm action that form the gently sloping shores of the project area, including nearshore tidal flats. The coastal beach extends from the mean low water line (MLW) landward to the seaward toe of the coastal dune or coastal engineering structures. The coastal beach in the project area is shown in Figures C-29 and C-30. Delineations for coastal beach were made using a combination of data from the Woods Hole Group topographic survey and MassGIS data. A description of the beach is provided in Section 1.3 above. Cross-sections of the beach resource are included in the Engineering Plans entitled "Plan of Beach and Dune Nourishment Sites, Prepared for Towns of Marshfield and Duxbury, MA", Sheets 1-6, dated 09/23/2020, (see Section O).

1.8.3 Coastal Dunes (310 CMR 10.28)

Coastal dunes include natural hills, mounds or ridges of sediment landward of the coastal beach, that have been deposited by wind action, storm overwash, or man-made dune restoration projects. The locations of coastal dunes in the project area are shown in Figures C-29 and C-30 and a description is provided in Section 1.3 above. Delineations for coastal dune were made using a combination of data from the Woods Hole Group topographic survey and MassGIS data.

1.8.4 Barrier Beaches (310 CMR 10.29)

Barrier beaches are narrow low-lying strips of land that generally consist of coastal beaches and coastal dunes. Barrier beaches extend roughly parallel to the trend of the coast and are separated from the mainland by a narrow body of fresh, brackish or saline water, or a marsh system. The delineation for barrier beaches for the project area was obtained from MassGIS and is shown in Figures C-29 and C-30. Portions of the project area at Rexhame Public Beach are located within Historic MHW or Filled Tidelands per 310 CMR 9.04(2) (Figure C-29). Rexhame Public Beach is the site of an historic tidal inlet that formed during the 1898 Portland Gale. Closure of the inlet took place naturally.

Figure C-29. Coastal beach, dune, barrier beach resources and historic MHW in northern end of project.

Figure C-30. Coastal beach, dune and barrier beach resources in southern end of project.

1.8.5 Rocky Intertidal Shores (310 CMR 10.31)

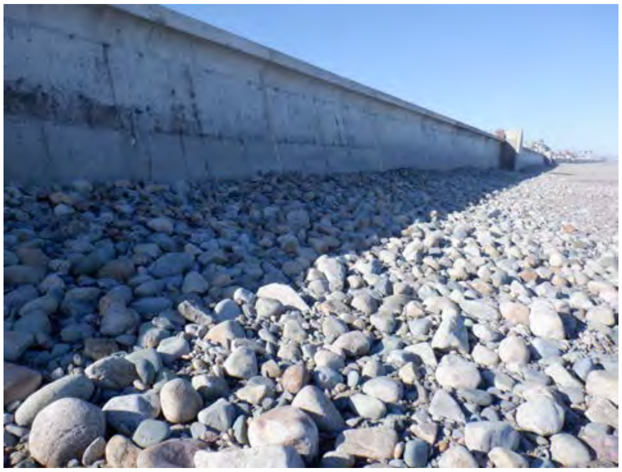
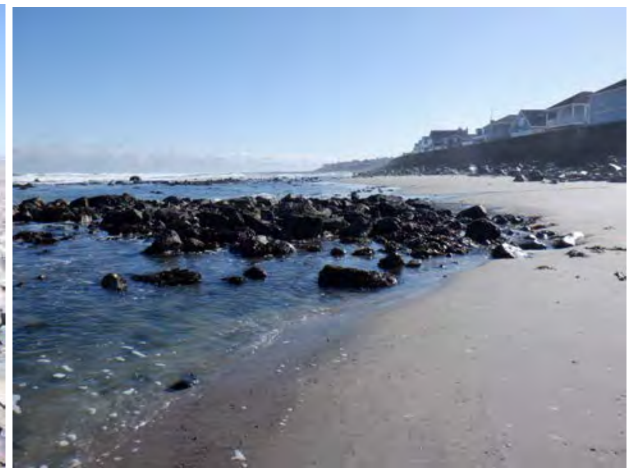
To assess the intertidal habitat throughout the project area, a rocky intertidal shore survey was conducted on November 19 and 21, 2019. The survey was conducted around the time of low tide. The southern portion of the project area, consisting of approximately 1.25 miles south of Green Harbor, was surveyed on November 19, while the northern portion of the project area, approximately 3.5 miles from Brant Rock to the Scituate Town line, was surveyed on November 21. There is an approximately 0.75 mile shoreline area between Brant Rock and Green Harbor that was not surveyed; this area is known to be predominantly rocky intertidal shore and is outside of the proposed project area. In the 4.75 miles of ocean facing beach that was surveyed, six (6) discrete areas of rocky intertidal shore were discovered (Figure C-31). These areas range in size from 10,028 sq ft to more than 600,000 sq ft in area, summing to a total area of 1,244,070 sq ft (28.5 acres) rocky intertidal shore within the proposed project area.

The main characteristics of the six (6) surveyed rocky intertidal shore areas are described below (from north to south):

1. Rexhame: The rocky intertidal shore area in the Old Rexhame area stretches from approximately Jackson Street to Atlantic Street and comprises 232,733 sq ft (5.3 acres). It is characterized by large boulders, tide pools, and attached fauna and macroalgae.

2. Sunrise Beach: There are two (2) surveyed rocky intertidal shore areas along Sunrise Beach. The first extends from approximately 9th Road to 5th Road and is 47,343 sq ft (1.1 acres). This area is substantially different that the other rocky intertidal shore areas delineated as part of this project, as it consists of ocean rounded boulders piled up at the base of the seawall. With rock greater than 10 inches in diameter (i.e., boulders) located below the MHW line, this area technically meets the definition of rocky intertidal shore. However, given the lack of attached biota, and the roundness of the stones – indicating that the wave action in this area is strong enough to move these boulders around, it is unlikely that this area provides the same habitat functions as the other mapped rocky intertidal shore areas along the beach. The second rocky intertidal shore area along Sunrise Beach is just offshore Brook Street and is 68,665 sq ft (1.6

acres). This area is located lower on the beach and is characterized by significant quantities of attached macroalgae.

3. Brant Rock: The most significant rocky intertidal shore areas were mapped in the Brant Rock Beach area. Two discrete sections of rocky intertidal shore were identified in this area. The first extends from approximately Chickatawbut Avenue to Samoset Avenue and is 247,522 sq ft (5.7 acres). This area is characterized by large boulders, tide pools, and attached fauna and macroalgae. The second area is centered around the large Brant Rock groin, and encompasses the large bedrock outcrops that comprise Brant Rock itself; this area extended from just north of the Brant Rock groin to the southern extend of the survey area at approximately Bradford Street. Note that this is not the southern terminus of the rocky intertidal shore habitat, as the survey did not extend further to the south beyond the limits of the areas planned for beach nourishment.


4. Green Harbor: There was only one small (10,028 sq ft; 0.2 acres) area of rocky intertidal shore mapped south of the Green Harbor entrance. This area consisted of small, scattered boulders (boulders are defined as having a dimeter greater than 10 inches), with attached fauna and macroalgae.

5. Duxbury: No rocky intertidal shore was observed in the Duxbury portion of the survey area.

Figure C-31. Mapped rocky intertidal shore habitat within the proposed project area.

1.8.6 Land Containing Shellfish (310 CR 10.34)

A shellfish survey was conducted in the nearshore subtidal areas offshore of Marshfield and Duxbury on January 22 and 23, 2020. The purpose of the work was to document shellfish resources, particularly surf clams, in the nearshore area in the vicinity of the proposed project.

The survey was done by towing a hydraulic dredge along transect lines approximately parallel to the shoreline in waters ranging from approximately -10 to -22 ft MLLW. A total of 18 tows of approximately ¼ mile length were conducted along the Marshfield and Duxbury shoreline. A commercial grade hydraulic clam dredge measuring 15 in wide and 12 in high was used to collect surf clams and other species. The dredge was equipped with a 2.5 in mesh and was operated from the 31 ft JC Sportfisher Dawn Treader, operated by Marine Imaging Technologies of Bourne, MA (Figure C-32).

Figure C-32. Vessel used for shellfish survey (a) and hydraulic dredge used to sample shellfish (b).

The survey area and actual towed lines are illustrated in Figure C-33. A total of eight planned tows were not completed. Five of these (tows 13, 16, 17, 18 and 19) were not conducted due to excessively rocky substrate and associated potential for damage to the equipment. One tow (10) was moved inland to avoid rocky substrate at the target area but was not conducted because the substrate in the new area was too uneven to safely tow the dredge.

Two planned tows (tows 20 and 21) were not completed for two reasons: trawling in this area posed a risk to the equipment, and the substrate was unfavorable to surf clams. Tows 20 and 21 were located in the vicinity of the former disposal area near the entrance channel to Green Harbor. One tow in this area was attempted (tow 20), but the first attempt resulted in equipment breakage (hydraulic hose rupture) and returned three boulders, approximately 12-16" in diameter, along with a gray clay in the damaged hose and adhered to the dredge. A second attempt resulted in removal of the door latch on the dredge. At this time trawling in this area ceased because of the dangerous nature of trawling in this area, as well as the unfavorable substrate for surf clams (clay with large boulders). Three tows (6, 11, 15) were completed, but cut short due to rocky substrate shown on sidescan sonar in real time.

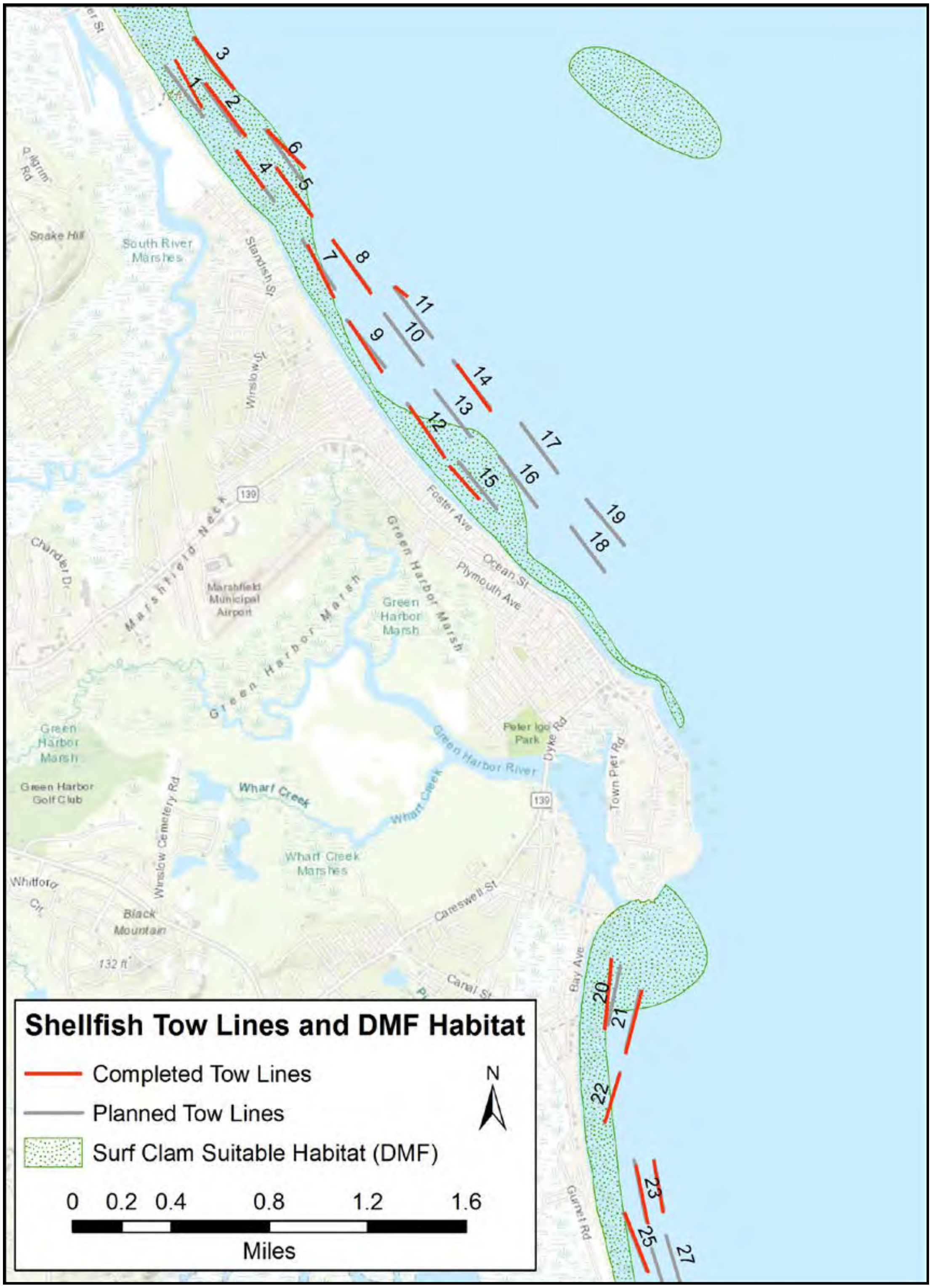


Figure C-33. Map showing locations of planned and complete shellfish survey tow lines.

Shellfish and other species were collected were identified and classified as juveniles and adults. Surf clams were classified in three categories: >3", 3 – 5", and > 5". Other species were measured, fish as longest length, and crabs as carapace width. Species obtained during the tows included:

- Surf Clam (*Spisula solidissima*)
- Cancer crab (*Cancer irroratus*)
- Winter flounder (*Pseudopleuronectes americanus*)

Due to the 2.5 in size of the mesh in the dredge, some juveniles may have been present but not retained in the dredge. However, one very small (0.5 in) juvenile surf clam was found beneath the dredge during transit between tows, likely caught in rocks or sediment that was occasionally present in or on the edges of the dredge when hauled in. Some of the clams came up damaged due to crushing of shell on contact with the dredge blade. Figure C-34 shows species obtained in select tows 5, 2, and 14). Table C-10 provides species and the size of individuals obtained in each tow.

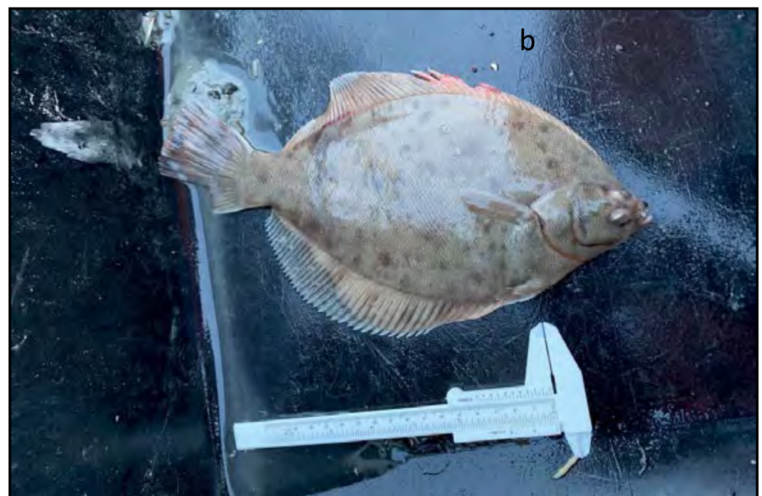


Figure 34. Surf clams (a), flounder (b) and cancer crab (c) collected during tows 5, 14, and 2, respectively.

Table C-10. Habitats Used by EFH Species in the Project Area.

Tow #	Surf Clams >3"	Surf Clams 3 - 5"	Surf Clams >5"	Other Species & Size	Notes
1					No animals. 2 rocks (2-4")
2	1 (just under 3")			1 Cancer crab (3" carapace width)	Lots of rocks and gravel in dredge
3					No animals. Many rocks (at least 30 rocks) and gravel. Rocks 1-2" mostly; some up to 3.5"
4	4				No rocks
5	4	2			Few rocks
6					No animals. Stopped tow early because of rock/boulders on sidescan indicating dangerous area for towing equipment
7	1	1			Rocks in dredge
8	1	1			Rocks and gravel in dredge
9					No animals. Rocks and gravel in dredge
10					After 2 attempts tow was abandoned
11					Few rocks. No animals. Cut tow short due to excessive rocky area on sidescan, indicating risk to equipment
12					No animals. 1 rock in dredge (4")
13					Too rocky to trawl
14				Windowpane flounder (9")	Few rocks in dredge
15		1			Dredge retrieved with large amounts of peat
16					Too rocky to trawl
17					Too rocky to trawl
18					Too rocky to trawl
19					Too rocky to trawl
20					Dredge got caught up on rocks. Stopped tow. Found 3 large rocks (12 - 16") in dredge. Fine clay/silt on sizes / top of dredge. On second attempt the dredge door handle became dislodged. Abandoned this tow
21					Tow not attempted. Adjacent to disposal site, and to tow #20 which has unfavorable substrate (boulders and clay) for clams
22					Nothing in dredge. Checked to ensure working correctly
23					No animals. No rocks. Dredge working correctly
24					No animals. No rocks. Dredge working correctly
25		1			
Totals	**11**	**6**		**2**	

The surf clam survey was conducted as planned, with the exception of certain tows which were impossible to conduct due to unfavorable substrate and associated risk of damage to equipment. Numbers of surf clams and other species were low. Low numbers of surf clams could be associated with the precise spatial extent of sampling during the tows. Specifically, the dredge penetrates only about 6-10 in into the sediment. Surf clams may burrow deeper into sediment during winter due to colder temperatures at the sediment-water interface. Additionally, there may be more clams in shallower water, closer to the intertidal. These very shallow areas were not sampled due to time constraints and lack of adequate water depth for safe sampling.

1.8.7 Estimated Habitats of Rare Wildlife (310 CMR 10.37)

According to the Massachusetts Natural Heritage & Endangered Species Program (NHESP), Division of Fisheries & Wildlife, portions of the project area are located within estimated and priority habitat for state-listed rare species. The northern end of the project area around Rexhame Beach is located within priority and estimated habitat for the Piping Plover and Seabeach Needlegrass, both with threatened state status (Figure C-35). The southern end of the project area falls within priority and estimated habitat for the Piping Plover and Least Tern (Figure C-36). The Least Tern has a state status as a species of special concern. These species are protected under the Massachusetts Endangered Species Act and its implementing regulations (321 CMR 10.00), as well as the Wetlands Protection Act and its implementing regulations (310 CMR 10.00). A letter from NHESP dated Jan. 30, 2020 listing the protected species in the project area is provided in Section L.

1.8.9 Land Subject to Coastal Storm Flowage (310 CMR 10.57)

Land subject to coastal storm flowage is land subject to any inundation caused by coastal storms up to and including that caused by the 100-year storm, surge of record, or storm of record, whichever is greater, and includes both V zones (velocity zones or areas of wave action), and A zones (the extent of the quantifiable 100-year coastal floodplain). The entire project area is mapped on the FEMA Flood Insurance Rate Maps (FIRM) as being in land subject to coastal storm flowage.

1.9 Historic and Archaeological Resources

While archeological resources are not generally known to exist in the project area, the Town of Duxbury has ten (10) historic homes along Gurnet Rd. that are in the project area. Consultation with Massachusetts Historical Commission (MHC) and the Bureau of Underwater Archeological Research (BUAR) will be performed as part of the permitting process.

Figure C-35. Massachusetts NHESP estimated and priority habitat areas for the northern project area.

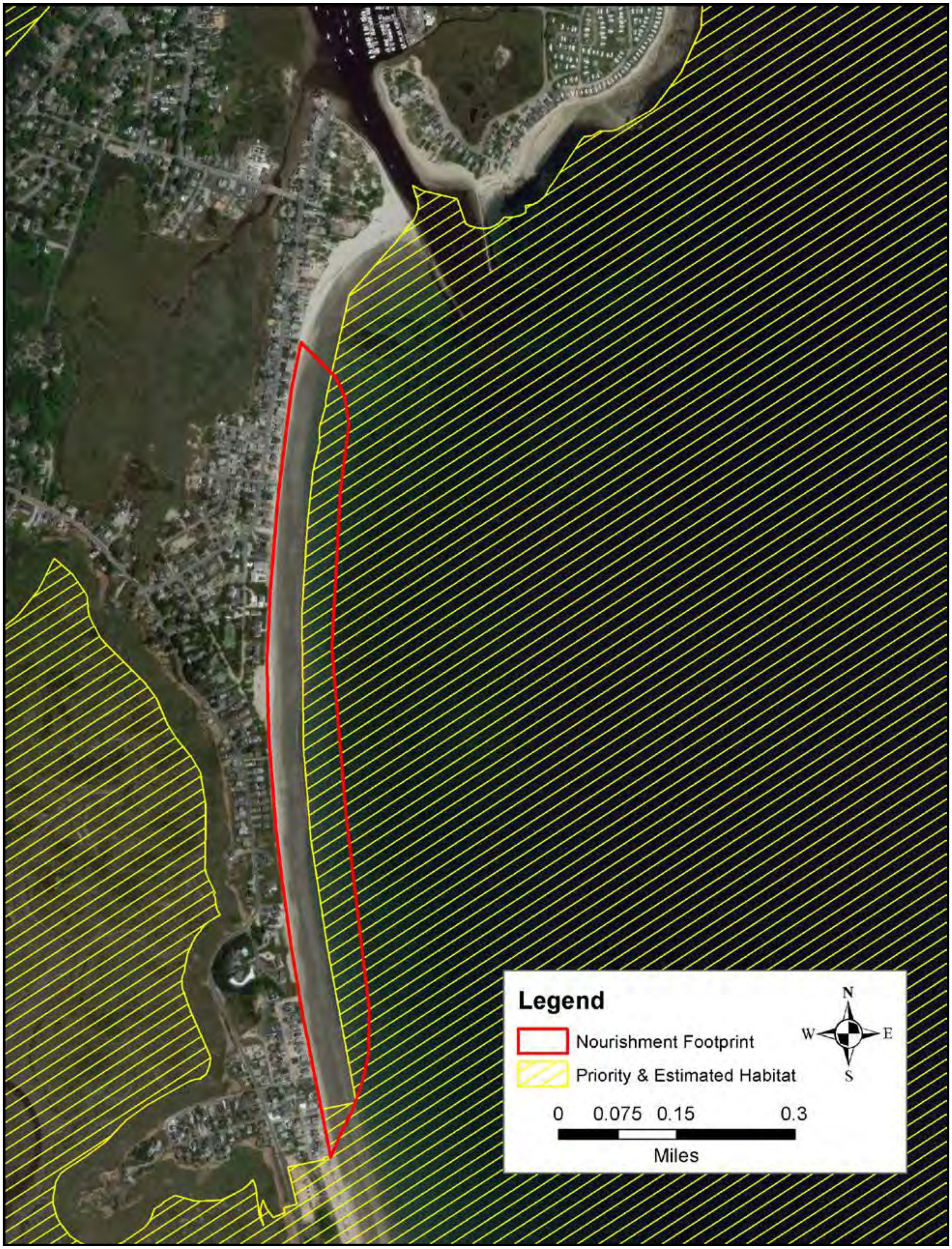


Figure C- 36. Massachusetts NHESP estimated and priority habitat areas for the southern project area.

1.10 Property Ownership

Review of the Marshfield and Duxbury assessors' databases indicate that that very few shorefront properties are owned by the municipalities (Figure C-37). Despite this fact, the towns provide public beach services at the following locations: Rexhame, Winslow Avenue, Fieldston, Sunrise, Brant Rock, and Green Harbor Beach, and Duxbury Beach. In the event that public agencies (i.e., towns, state, or federal govt.) fund the implementation of beach/dune nourishment on privately owned beaches, it will be necessary to secure the appropriate easements from the property owners. The easements would grant in perpetuity a public on-foot right-of-passage along and across the shore of the coastline between the mean high-water line and the entire nourished area. As part of the planning process for publicly funded beach nourishment, the town has drafted sample "Beach Nourishment Easement", "Release of Land Damage", and "Notification Letters" that were sent to all affected property owners in the event of a nourishment project. A list of affected property owners is provided in Section M.

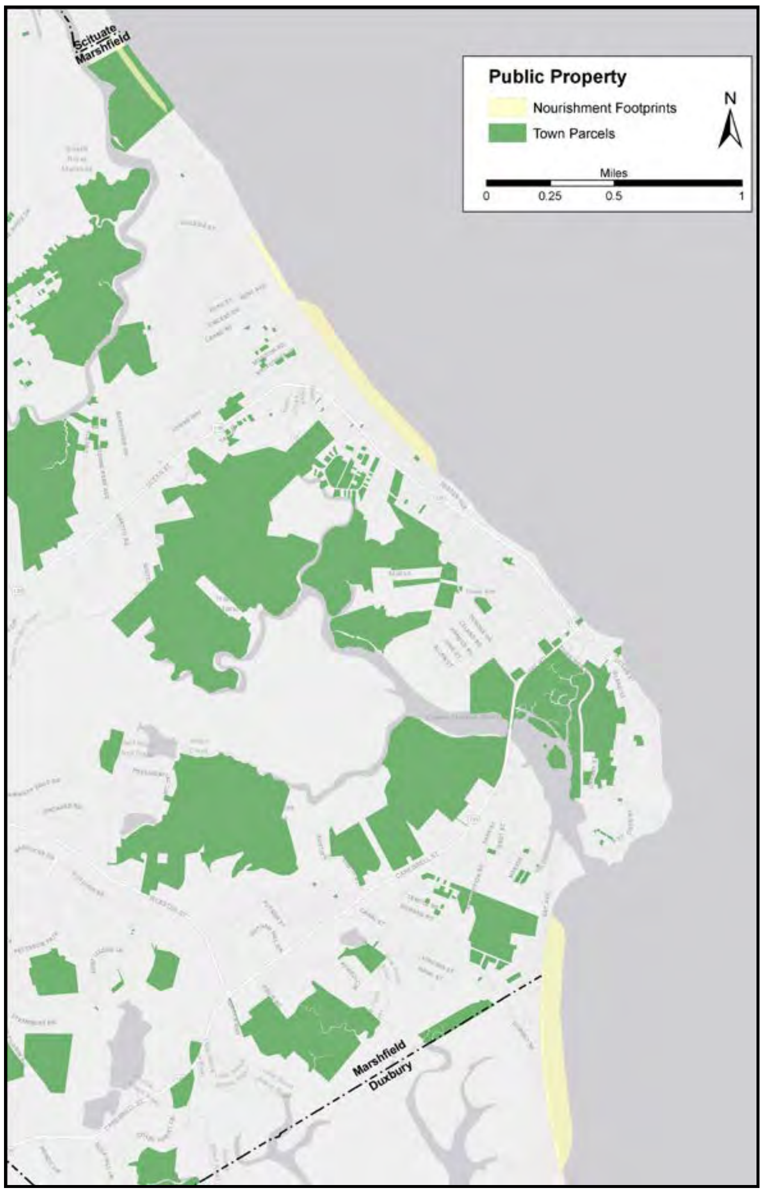


Figure C-37. Publicly owned lands in Marshfield and Duxbury.

1.11 Repetitive Loss Areas

FEMA flood claim data for the period 1978 through 2017 were reviewed to evaluate specific areas of Marshfield and Duxbury with high numbers of repetitive loss properties. The data are useful in prioritizing beaches with high probability of flood and/or storm damage for future resiliency projects. Sunrise Beach in Marshfield and Gurnet Rd. Beach in Duxbury had the highest number of repetitive loss properties, followed by the Brant Rock area and Bay Ave. Beaches in Marshfield (Figure C-38).

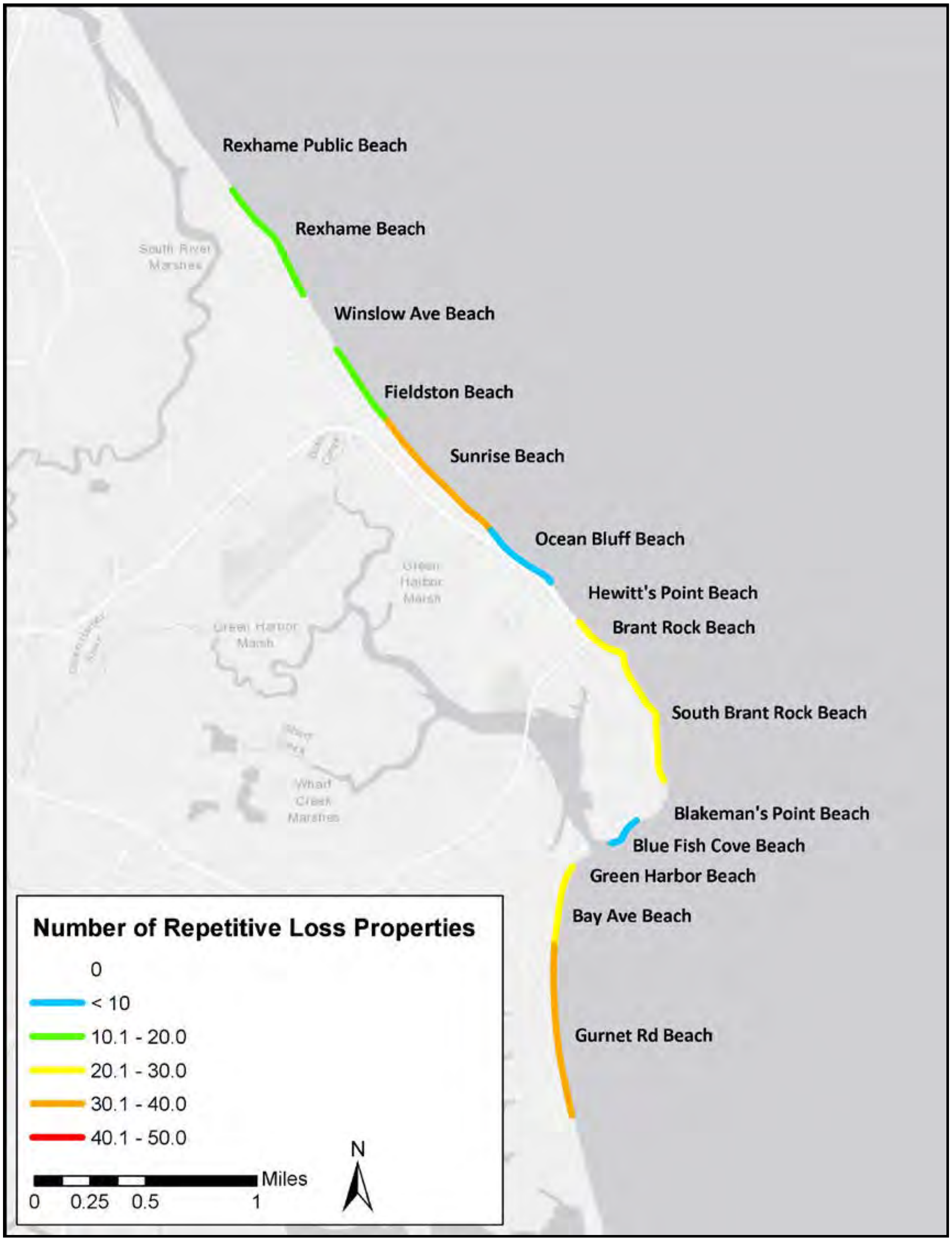


Figure C-38. Number of repetitive loss properties in each beach for the period 1978 to 2017.

Section D

Alternatives Considered

D. ALTERNATIVES ASSESSMENT

The Towns of Marshfield and Duxbury have evaluated alternatives for incorporating more resilient strategies for shore protection that will mitigate the effects of climate change, improve storm damage protection, reduce wave overtopping, provide protection for the existing shore protection structures, and can be adjusted to respond to changes in sea level. Rather than abandon the existing management approach, the Towns are seeking alternatives that will augment the current practices which include repair and maintenance of existing shore protection structures, elevating structures, buying out property owners, and regulating development in high hazard areas.

In preparation for the alternatives assessment, the study area was divided into fourteen (14) different beach areas based on the natural and anthropogenic features along the coastline. Primary factors used in the beach characterization were shoreline type, wetland resources, width of the high tide beach and intertidal zone, presence/absence of shore protection structures, and type of structure. The grouping of similar stretches of coastline was used to help guide the alternatives assessment, and eventually to select the most appropriate resiliency approach for each beach.

The goal of the alternatives analysis was to identify and evaluate reasonable, practicable, and feasible alternatives that will enhance the resiliency of the shoreline, while minimizing short and long-term impacts. To start, a variety of shore protection alternatives were identified and evaluated broadly in terms of their suitability for the Marshfield and Duxbury shoreline. The initial evaluation looked at three primary factors in determining suitability. These included (1) ability of the alternative to provide the necessary level of shore protection, (2) level of expected environmental impact, and (3) estimated costs associated with construction, and maintenance. Alternatives considered included hard (i.e., seawalls and revetments) and soft (i.e., beach and dune nourishment) engineering solutions, hybrid or innovative approaches, and continuing with the existing management approach, or *status quo*. Results from the initial broad evaluation of alternatives were then used as the basis for a more detailed assessment of alternatives for site-specific beaches along the Marshfield and Duxbury shoreline.

For beaches where soft, nature-based approaches using beach and dune nourishment were determined to be feasible, engineering designs were evaluated, and a preferred alternative was selected for permitting through this Expanded Environmental Notification Form (EENF). Other hard or hybrid options will require further study and engineering design, and therefore are not included as part of this permitting request to MEPA.

1.0 Beach Characterization

The shoreline in the study area was divided into fourteen (14) different beach areas as shown in Figure D-1. A summary of wetland resources, beach and nearshore characteristics, and types of shore protection structures for each beach area is provided in Table D-1. The initial alternatives assessment broadly considered the suitability of various hard, soft and hybrid alternatives for the Marshfield and Duxbury shoreline. The more detailed assessment that followed then evaluated the alternatives for each of the fourteen (14) beach areas.

Figure D-1. **Marshfield and Duxbury beach segments.**

Table D-1. Wetland Resources, Beach and Nearshore Characteristics, and Types of Shore Protection Structures for the Marshfield and Duxbury Beach Segments.

Beach	Wetland Resources	Beach & Nearshore Characteristics	Shore Protection Structure
Rexhame Public	coastal beach coastal dune barrier beach	public beach with sandy dune that extends across barrier beach; mixed grain size beach (sand, gravel and cobble) with relatively wide high tide beach and moderately wide intertidal zone	NA
Rexhame	coastal beach barrier beach (N end) rocky intertidal shore	private beach with mixed grain size (sand, gravel and cobble); bisected by partially submerged headland known as Beadle Rock; high tide beach narrows south of Beadle Rock while width of intertidal zone increases significantly	low-lying concrete seawalls and rock revetments bisected by unprotected beach access paths
Winslow Ave.	coastal beach coastal dune barrier beach (N end)	public beach with cobble dune and mixed grain size beach (sand, gravel); moderately wide high tide beach and wide gently sloping intertidal zone	NA
Fieldston	coastal beach	private beach with mixed grain size (sand, gravel); narrow high tide beach and wide gently sloping intertidal zone	concrete seawall
Sunrise	coastal beach barrier beach rocky intertidal shore	private beach with mixed grain size (sand, gravel); narrow high tide beach and wide gently sloping intertidal zone	concrete seawall with rip rap toe protection in places
Ocean Bluff	coastal beach rocky intertidal shore	private beach with mixture of grain sizes (sand, gravel and cobble); anchored at south by ~ 600 ft long low-profile groin; no high tide beach; narrow intertidal zone at north end that widens to gently sloping intertidal zone towards groin	concrete seawall with stone revetment at the toe; stone revetment at the southern end
Hewitt's Point	coastal beach rocky intertidal shore	private beach with mixture of gravel and cobble; steeply sloping and narrow high tide beach and intertidal zone	stone revetment at northern end and concrete seawall at central and southern end
Brant Rock	coastal beach barrier beach rocky intertidal shore	private beach with mixture of gravel and cobble; steeply sloping and narrow high tide beach and intertidal zone; anchored at south by ~750 groin to naturally occurring rocky outcrop known at Brant Rock	concrete seawall
South Brant Rock	coastal beach barrier beach rocky intertidal shore	private beach with mixed grain size (sand, gravel and cobble); narrow high tide beach and wide gently sloping intertidal zone	concrete seawall with rip rap toe protection; rubble mound revetment; concrete seawall with stone revetment at toe
Blackman's Point	coastal beach coastal bank rocky intertidal shore	private beach with eroding coastal bank and mixed grain size beach (sand, gravel and cobble); narrow high tide beach fronted by partially submerged rocky outcrop	NA
Blue Fish Cove	coastal beach barrier beach	private beach with mixed grain size (sand and gravel); moderately wide high tide beach and intertidal zone	low-lying rubble mound revetments
Green Harbor	coastal beach coastal dune barrier beach	public beach with sandy dune and beach; extensive high tide beach and dune area with wide and gently sloping intertidal zone	NA
Bay Ave.	coastal beach coastal dune (N end) barrier beach rocky intertidal shore	private beach with mixed grain size (sand and gravel); moderately wide high tide beach at the north that disappears to the south; wide and gently sloping intertidal zone	concrete seawall with rip rap toe protection in places
Gurnet Rd.	coastal beach coastal dune (middle) barrier beach	private beach with mixed grain size (sand and gravel); no high tide beach in the north that gradually widens to the south; wide and gently sloping intertidal zone	concrete seawall with rip rap toe protection in places

2.0 Alternatives Considered

2.1 Maintain Existing Management Approach – *Status Quo*

This alternative makes no changes to the existing management approach for the Marshfield and Duxbury shorelines. Both Towns would continue with repairs, rebuilds and maintenance of the existing shore protection structures, on an as needed basis. While the existing structures will continue to provide the last line of defense against landward retreat of the shoreline, storm damages to public and private properties caused by wave overtopping and flooding will not be addressed by this alternative. Wave interaction with the shore protection structures will continue to lower the beach elevations, expose structure foundations, and undermine the base of the shore protection structures. With future impacts of climate change and sea level rise, the *status quo* alternative will result in increased wave overtopping and flooding, thereby threatening public safety, health, and welfare. Implementation of this alternative as the only management approach will place the residential properties and public infrastructure at increasing risk, as the shore protection structures continue to degrade, and the beaches continue to erode.

The *status quo* alternative does nothing to restore sediment to critically eroded beaches, and instead continues to exacerbate the erosion problem. The ability of the affected beaches to provide wildlife habitat for shorebirds and to serve as a recreational resource will continue to be adversely impacted. As such, this alternative provides no environmental benefit to the system.

Historical data from Federal Emergency Management Agency (FEMA) flood insurance claims, as well as town records on costs associated with repairs and maintenance to the existing shore protection structures, emergency services during storms, and post storm clean up were used to estimate future costs of the *status quo* alternative. Costs for each town projected over the next 30 years are shown in Table D-2.

Table D-2. Projected Costs Over Next 30 Years to Maintain Existing Management Approach.

Town	FEMA Repetitive Loss Claims	Shore Protection Structure Repairs	Storm Related Public Services	Total
Marshfield	\$12.1 million	\$51.0 million	\$7.5 million	\$70.6 million
Duxbury	\$2.7 million	\$16.4 million	\$5.7 million	\$24.8 million

Projections shown for the FEMA repetitive loss claims were calculated using claims data from 1978 to 2017. The average annual payout over this time period was assumed to continue with an inflation rate of 3%. Future costs shown for repair of the existing shore protection structures were based on contractor bids for upcoming work and engineering department estimates and include annual inflation of 3% over the next 30 years. Projections for storm related public services were generated from town records for past events. The average cost per year was assumed to continue with an inflation rate of 3%.

The projections shown in Table D-2 should be considered conservative, as they do not factor in the influence of sea level rise, increased storm intensity or increased storm frequency on costs to the towns. The potential for lost tax revenue from a lowering of property values and a reduced income from tourism due to the loss of recreational resources are additional factors that the towns will face with the *status quo* alternative. This analysis of the *status quo* alternative provides a basis for comparison with other shoreline resiliency solutions identified for site-specific beaches in Section 3.0 below.

2.2 Enhance and/or Enlarge Existing Seawalls and Revetments

Seawalls and revetments are currently the main form of shore protection along the developed shorelines of Marshfield and Duxbury. In fact, 83% of the shoreline in Marshfield contains hard shore protection structures, and 91% of the developed shoreline in Duxbury has hard shore protection structures. The Towns have spent considerable resources over the years to repair and maintain the shore protection structures, and this work is expected to continue into the future. However, as described above for the *status quo* alternative, regular repair and maintenance of the structures, with no additional resiliency measures, will do nothing to fix the problems of wave overtopping, flooding, or damage to public and private infrastructure. As such, the possibility of enhancing and/or enlarging the existing shore protection structures was evaluated as an alternative.

Engineering analyses of overtopping at the Marshfield and Duxbury shore protection structures were conducted to determine whether increasing the crest elevation of the structures would have a measurable impact on overtopping rates. Engineering guidance from the U.S. Army Corps of Engineers (USACE, 2002) indicates that structural damage to buildings can be avoided when average overtopping rates are less than $3x10^{-4}$ $ft^3/sec/ft$ ($3x10^{-5}$ $m^3/sec/m$) (Figure D-2). Overtopping calculations using the Euro top method (van der Meer, 2016) were performed on the existing shore protection structures under 10-yr and 50-yr storm events. Results indicated overtopping rates above the U.S. Army Corps of Engineers threshold for structural damage at all existing shore protection structures along the Marshfield and Duxbury shoreline, with the exception of Rexhame Beach and Hewitt's Point Beach. The calculations were then updated to identify reductions in overtopping associated with increasing the crest elevation of the shore protection structures. Crest elevations necessary to avoid structural damage to buildings from overtopping were determined for each beach segment with coastal engineering structures. The analyses were performed for the 10-yr and 50-yr storm events and for a projected sea level rise scenario of 2 ft, corresponding to the 2040 to 2060 time frame.

Seawall and/or revetment modifications could also include the addition of a revetment along the seaward toe of the existing structures as a way of reducing wave overtopping. A similar shore protection design was implemented by the U.S. Army Corps of Engineers at Roughans Point in Revere in the late 1990s (D-3). Based on this design, conceptual revetment modifications that would protect against overtopping during a 50-yr storm with 2 ft of sea level rise were evaluated for the Marshfield and Duxbury shorelines. While providing significant overtopping protection, the revetment modifications would extend seaward of the existing walls by approximately 50 to75 ft, depending on local nearshore topography. Without the placement of nourishment in front of the modified revetments, this alternative would result in the loss of large areas of coastal beach.

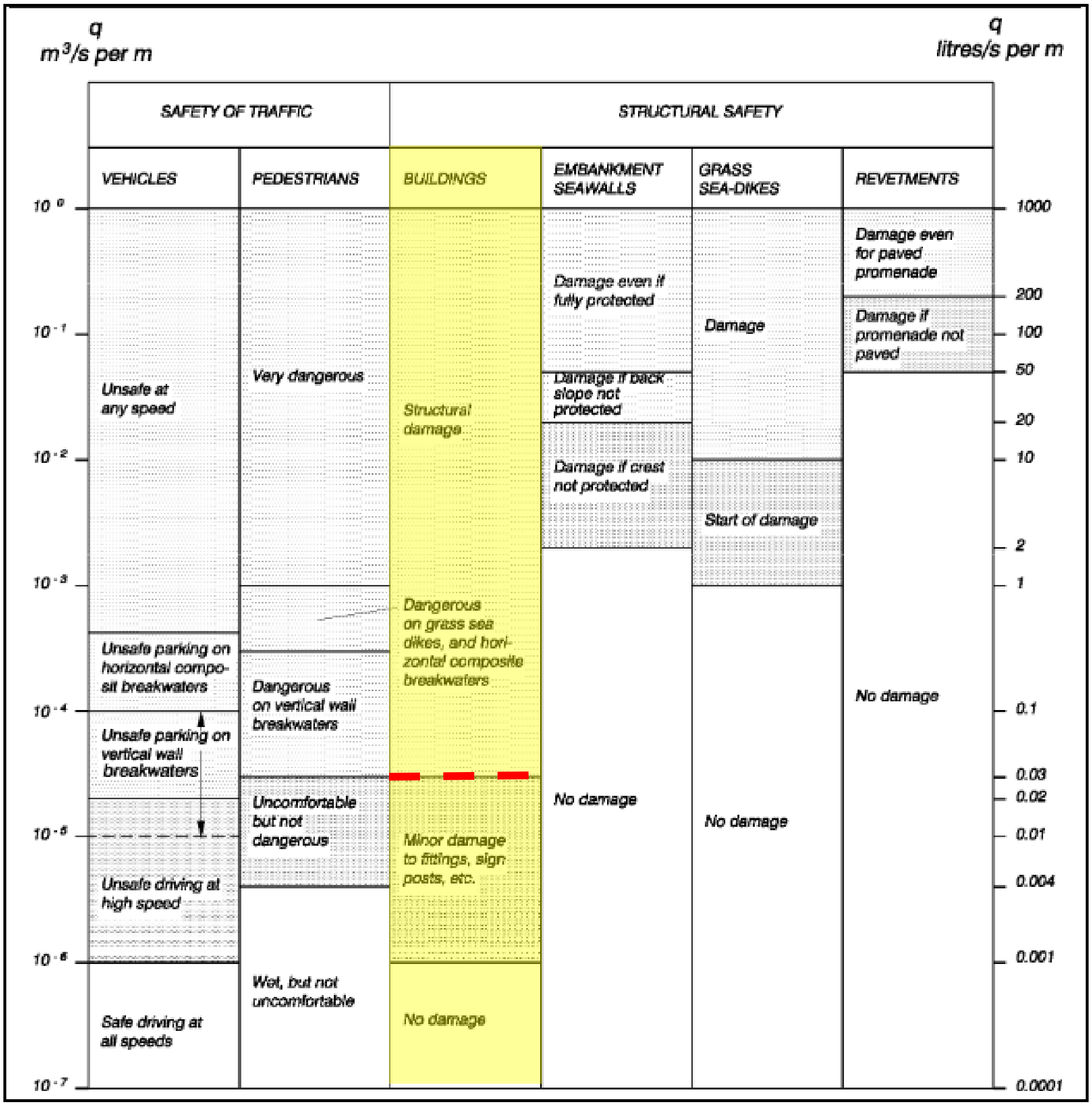


Figure D-2. Critical Values of Average Overtopping Discharges (USACE, 2011).

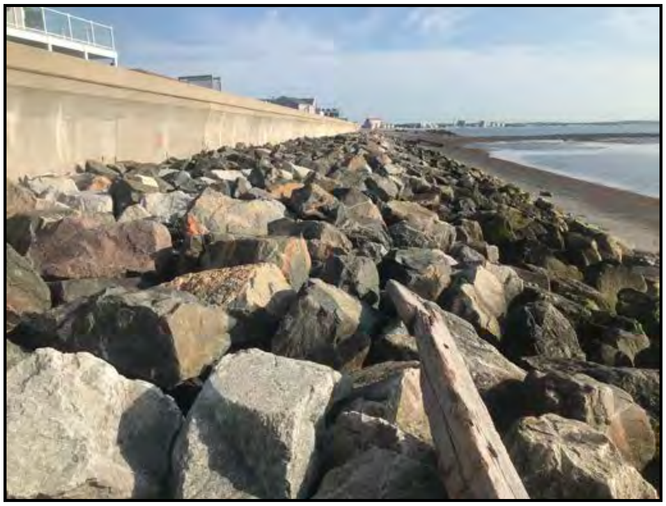


Figure D-3. Example of revetment extension in front of Rougan's Point seawall.

As with the *status quo* alternative, the enlargement of seawalls and revetments does nothing to restore sediment to critically eroded beaches, and instead continues to exacerbate erosion. The ability of the affected beaches to provide wildlife habitat for shorebirds and to serve as a recreational resource will continue to be adversely impacted. As such, this alternative provides no environmental benefit to the system.

Enhancing or enlarging the seawalls and/or revetments was only considered for locations where shore protection structures currently exist. Local, state and federal regulations generally prohibit new coastal engineering structures on barrier beaches and coastal dunes like those present along the Marshfield and Duxbury shorelines. Environmental permitting required to enhance or enlarge existing shore protection structures can be difficult and time consuming. In addition, compensatory mitigation in the form of beach nourishment is often required for projects proposing significant modifications to existing structures. In fact, recent permits issued to the Towns of Marshfield and Duxbury for enhancement of structures damaged by the March 2018 storms required the Towns to pursue permitting for compensatory beach nourishment.

The costs to raise the seawalls and revetments to elevations that would provide sufficient storm damage protection was evaluated based on construction estimates provided by the Towns of Marshfield and Duxbury for planned work on the Bay Ave. and Gurnet Rd. shore protection structures. The costs were estimated between $7,000 and $9,000 per linear ft. The higher costs would be for areas where existing buildings and roads are close enough to the structures, where steel sheeting would be required to ensure stability of the landward infrastructure. Costs to add a revetment along the seaward toe of the existing structures were estimated based on costs reported for the U.S. Army Corps of Engineers Rougans Point project (USACE, 1991). Assuming a 3% rate of inflation since 1991, current costs for extension of the revetment in 2020 would be $7,000 to $9,000 per linear ft.

2.3 Offshore Breakwaters

Offshore breakwaters are a shore protection alternative designed to reduce wave action in the lee of the structure to minimize and/or eliminate beach erosion. Beaches in the lee of the breakwater have calmer wave conditions that potentially allow for sediment deposition and beach accretion. Typically, this type of shore protection is provided from a single large offshore rubble mound (rock) structure, or a series of shorter segmented breakwaters oriented parallel to the shoreline. The structure is installed on the sea floor and extends into the water column to trigger wave breaking during storms.

A few criteria must be met for a breakwater to be effective at breaking storm waves and dissipating wave energy. The breakwater must be designed with enough profile (vertical height) off the bottom and large enough crest width relative to wavelength (width in offshore direction) to cause storm waves to trip and break. A low and/or narrow structure will not trigger wave breaking and therefore not be a viable shore protection alternative. The profile height of the structure becomes an issue with large tide ranges and/or substantial storm surges. The crest of the structure must be set at a height to cause wave breaking during storms when the water levels are elevated and can be further amplified by high tides.

Sediment trapped behind a breakwater is derived from the ambient littoral drift. However, in heavily armored or sediment starved areas like Marshfield and Duxbury, sediment accumulation is impacted significantly by the lack of material in the littoral system. In other words, even with a properly designed breakwater, there is no guarantee that sediment will accumulate along the adjacent beaches. Trapping the natural littoral drift can also be a concern for erosion of downdrift beaches. Artificially nourishing behind the breakwaters to an equilibrium beach profile may prevent downdrift erosion for some finite period of time (until more nourishment is required), and the longshore transport may continue, unaffected by the breakwater.

Conceptual designs for offshore breakwaters at Fieldston/Sunrise Beach and Bay Ave./Gurnet Rd. Beach were developed based on similar analyses conducted for North Scituate Beach and Surfside Road (Applied Coastal Research and Engineering, Inc., 2016). The designs were modeled after the existing stone breakwater at Winthrop Beach, MA which is located along the approximate -15 ft NAVD88 depth contour. The conceptual designs include a system of offshore breakwaters located approximately 900 ft from the shoreline and extending 3,340 ft in the longshore direction (Figures D-4 and D-5). The individual breakwater segments would be 330 ft long and separated by 100 ft gaps. A total of 8 segments would be needed to span the shoreline at each beach. The breakwater segments would have a crest elevation of 8.5 ft NAVD88, a crest width of 12 ft, and side slopes of 2V:3H. The large size of the breakwaters is required to effectively dissipate waves in the > 9.8 ft tidal range that exists along the Marshfield and Duxbury shorelines. The structure crests would extend above the water level at all stages of the tide but would be submerged by approximately 2 ft of water during a 100-yr storm event. The reduced water depth over the structure would cause waves to break offshore as the pass over the breakwater.

The footprint of the conceptual breakwaters at Fieldston/Sunrise and Bay Ave./Gurnet Rd. Beaches would be approximately 6.3 acres per site. As such, the structures would alter a significant area of benthic habitat and areas that are used for shellfishing. These impacts to the environment, along with the potential for adverse impacts to downdrift beaches would present significant challenges during the permitting process. Additionally, the conceptual design for the

Bay Ave./Gurnet Rd. Beaches is located in close proximity to the U.S. Army Corps of Engineers disposal area for sediment dredged from Green Harbor. While there is no data to suggest this material makes its way back to the beach, a breakwater in this location would eliminate any possibility of onshore transport of the material, thereby removing a possible source of sediment to the already starved beaches.

The volume of stone needed to build the breakwater at either beach would be approximately 134,400 cubic yards. Assuming a cost of $125/ton to source the stone and build the breakwater, the estimated cost for construction at one site would be approximately $22.5 million. Based on the likelihood for minimal sediment accumulation in the lee of the breakwaters, the expected area of impact, and the cost, this alternative was determined to be unsuitable for use along the Marshfield and Duxbury shorelines.

Figure D-4. Conceptual design for offshore breakwater offshore of Fieldston and Sunrise Beaches.

Figure D-5. Conceptual design for offshore breakwater offshore of Bay Ave and Gurnet Rd. Beaches.

2.4 Beach Nourishment

One of the primary causes of coastal erosion is a deficit of sediment within the coastal system. To offset this deficit, the placement of beach nourishment is a common alternative for improving the longevity of the shoreline where such a project is economically feasible. Beach nourishment would add sediment in front of the seawalls and revetments, or along the natural sections of beach, to create a wider beach that would dissipate wave energy and increase protection for public and private property that is currently threatened by wave overtopping.

Beach nourishment can be implemented as part of a large-scale engineered project that is designed to provide storm damage protection for a specific level of storm (i.e., 20 or 50-yr return period storm), or it can be implemented in conjunction with a dredging project that beneficially reuses dredged material to add sediment to the littoral system. Typically, the engineered projects call for a large volume of sediment to meet the design criteria while beneficial reuse projects involve smaller volumes that add material to a sediment starved system. The expectations and results associated with each type of nourishment project are different; beneficial reuse projects are designed to keep sediment in the littoral system, but not necessarily to provide any specific level of protection, while engineered projects are designed to provide a specific level of storm damage protection.

After a beach nourishment project is constructed, coastal processes act to reshape the nourishment to create a new equilibrium profile. This occurs during calm conditions as well as during storms. During these processes, sediment is transported in both the cross-shore and longshore directions. Material that moves offshore is typically not lost, as it serves to dissipate wave energy naturally during high energy wave conditions and can be transported back onshore during lower energy conditions (Figure D-6). Longshore transport of sediment from a beach nourishment project must be factored into the design, including the potential for impacts to sensitive resources and increased shoaling in nearby navigation channels and harbors. Over time, longshore transport carries sediment away from the project footprint and renourishment is required to maintain the desired level of storm damage protection. As such, a maintenance plan for periodic renourishment is necessary for this alternative to be an effective long-term management strategy. The service life of a beach nourishment project, and the expected renourishment interval, is estimated using wave and sediment transport modeling, where renourishment is typically considered when the project has lost 70% to 80% of material from the original footprint.

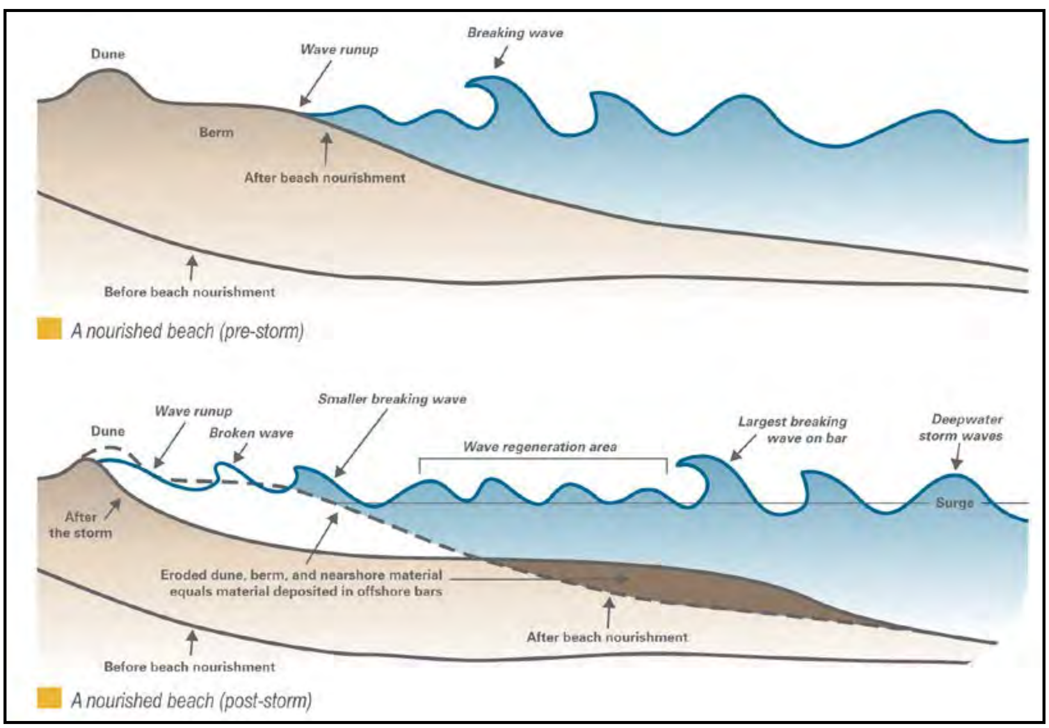


Figure D-6. Beach nourishment response to storm waves and increased water levels (USACE, 2020).

Sediment for beach nourishment can be sourced from upland or offshore borrow sites, or in the case of beneficial reuse, it can be obtained from nearby dredging projects. The use of upland sediment typically involves trucking. For large-scale projects this can require a significant number of round-trip truck deliveries that can result in traffic and noise impacts. Compatibility between upland and native beach sediment is also an issue that must be addressed, as the grain size distribution of the source material should be similar to, or slightly larger, than the native beach sediment. If an offshore borrow site is used, sediment is usually pumped directly to the beach nourishment location. Offshore borrow sites can provide large quantities of clean sand suitable for beach nourishment; however, the process of designating and permitting an offshore borrow site in Massachusetts can be lengthy and costly. This is primarily due to studies of environmental impacts that must be performed to permit an appropriate offshore borrow site. Beneficial reuse of sediment from nearby dredging projects can either be directly pumped to the beach or transported via truck. Here again, grain size compatibility between the dredged material and the receiving beach must be considered for beneficial reuse projects.

While beach nourishment is a widely accepted method of building coastal resiliency, there is the potential for adverse impacts if not carefully designed and constructed. Impacts to water quality caused by increased turbidity occur during placement and this can adversely impact finfish and shellfish; however, the turbidity is temporary during construction and impacts can be minimized by following time of year windows protective of sensitive species. Beach nourishment can also impact benthic communities and nearshore resource areas as sediment is placed directly on intertidal or subtidal habitats or is transported to these areas through cross shore and longshore transport. These impacts to benthic communities are generally considered to be short-lived as the species are resilient to high energy environments and able to recolonize relatively quickly. Impacts to nearby resources like rocky intertidal and navigation channels can be minimized and/or avoided by careful design that is based on an understanding of coastal processes and directions of sediment transport.

Beach nourishment at appropriate sites along the Marshfield and Duxbury shoreline would mitigate on-going erosion, improve storm damage prevention and flood control for public and private properties, enhance habitat for shorebirds, and improve the beaches as recreational resources. There would be a positive impact to property values in the area, as well as increased protection for the existing seawalls and revetments that provide the last line of defense. The improvement in shore habitat would require a management program to protect threatened and endangered species. Engineered beach nourishment designs would provide specific levels of protection with known requirements for renourishment. With permits in place for the larger scale engineered projects, the Towns would be able to accept material from nearby dredging projects for beneficial reuse, provided the sediment is compatible.

Costs for beach nourishment in Marshfield and Duxbury were determined assuming use of an upland sand source that would be trucked to the site. The costs include purchase of the nourishment material, trucking, and placement on the beach according to the engineering design. Based on projects at other sites in southeast Massachusetts, average costs of $30 per cubic yard were used.

2.5 Dune Nourishment

Construction of new dunes, or enhancement of existing dunes, can be an effective soft engineering method to improve shoreline resiliency. This alternative involves placement of sediment near the landward edge of the beach to increase the elevation and width of the dune. The larger dune provides storm damage protection by reducing flooding and overtopping. The new dune sediment can also serve as a source of material for nearby beaches, thereby contributing material to the littoral system.

Dune nourishment is appropriate in areas where there is a sufficient setback or distance from fluctuations of the daily tide. When dunes are constructed without a high tide beach in front of them, the sediment is easily washed away during periods of high tides and storms. Constructed dunes must also fit with the surrounding landscape, taking into consideration the elevation and location of the adjacent infrastructure and natural features. Crest elevation, crest width, and side slopes are design criteria that can be adjusted to maximize the protective nature of the dune while also fitting the dune into the surrounding landscape. Dune nourishment can be constructed as a stand along resiliency measure, or in conjunction with a beach nourishment project. Ongoing maintenance of constructed dunes must be considered, especially after storm events where dunes are badly eroded. Sediment type for dune construction should be compatible with the existing dune material, or with that of other nearby natural dunes. Dune nourishment can be performed using sandy sediments, or in certain high energy environments, it is more appropriate to use cobble sized material.

Dune nourishment at appropriate sites along the Marshfield and Duxbury shoreline would mitigate on-going erosion and improve storm damage prevention and flood control for public and private properties. In areas mapped as Priority and Estimated Habitat by the Natural Heritage and Endangered Species (NHESP) Program, the designs would need to maintain the habitat value of the existing resources by incorporating gentle slopes, using compatible sediment and limiting vegetation.

Costs for dune nourishment in Marshfield and Duxbury were determined assuming use of an upland sand source that would be trucked to the site. The costs include purchase of the nourishment material, trucking, and placement on the beach according to the engineering design. Based on projects at other sites in southeast Massachusetts, average costs of $30 per cubic yard were used. Where appropriate, costs for beach grass plantings were estimated at $1/sq ft of restored dune.

2.6 Intertidal Boulder Field

Portions of the Marshfield shoreline have naturally occurring rocky outcrops in the intertidal and subtidal zones. These areas are composed of a mixture of bedrock and/or coarse-grained cobbles and boulders. They serve as habitat for various species of macroalgae, crustaceans and finfish. These rocky outcroppings occur primarily in the areas between south Sunrise Beach, through Brant Rock to Blue Fish Cove. Rexhame Beach also contains an intertidal rocky outcrop known as Beadle Rock. In addition to providing complex habitat for marine organisms, these areas also help to attenuate wave energy during average and low energy events. The intertidal boulder field alternative would place additional rock in these areas to improve wave attenuation and storm damage protection during more severe storm events.

The intertidal boulder field alternative would be applicable only in areas that currently exhibit rocky outcroppings, as sandy substrata would not provide the structural base needed to support randomly placed large boulders. A mixture of stone sizes between 8 and 12 ton boulders would be placed in the intertidal zone in a random pattern. The boulders would serve to dissipate wave energy before it reaches the infrastructure along the shoreline and would also provide habitat benefits. It should be noted that the purpose of the nearshore boulder field would be to enhance storm damage protection through wave attenuation rather than accumulating sediment along the beach. Figure D-7 shows an example of a natural rocky intertidal area offshore of Rexhame Beach with a large boulder similar in size to boulders that would be used for this alternative. Conceptual layouts of intertidal boulder fields at Ocean Bluff, South Brant Rock and Blakeman's Beach are shown in Figures D-8 and D-9.

Figure D-7. Natural rocky intertidal shore at Rexhame Beach showing a large boulder similar in size to those considered for the intertidal boulder field.

Before proceeding with this alternative, additional engineering design would be required to identify the optimum stone placement and volume of material needed to achieve the desired level of storm damage protection. While the intertidal boulder field alternative would enhance the habitat value of the intertidal zone significantly, the path for environmental permitting and review of this resiliency method has not been tested in Massachusetts. Given the potential for improved storm damage protection using natural materials and methods, while also enhancing habitat value, there is optimism that the regulatory agencies will embrace the intertidal boulder field as an acceptable resiliency measure.

Costs associated with construction would include sourcing the boulders, transporting them to the site, and placing them in the intertidal zone. For the purposes of developing a unit cost it was assumed that the stones would be trucked to the site and placed using equipment accessed via the beach. A cost of $2,680 per linear foot of beach was estimated for an intertidal boulder field approximately 60 ft wide, based on data developed for a pilot project in Boston Harbor.

Figure D-8. Conceptual layout for intertidal boulder field and cobble berms at Ocean Bluff and Hewitt's Point.

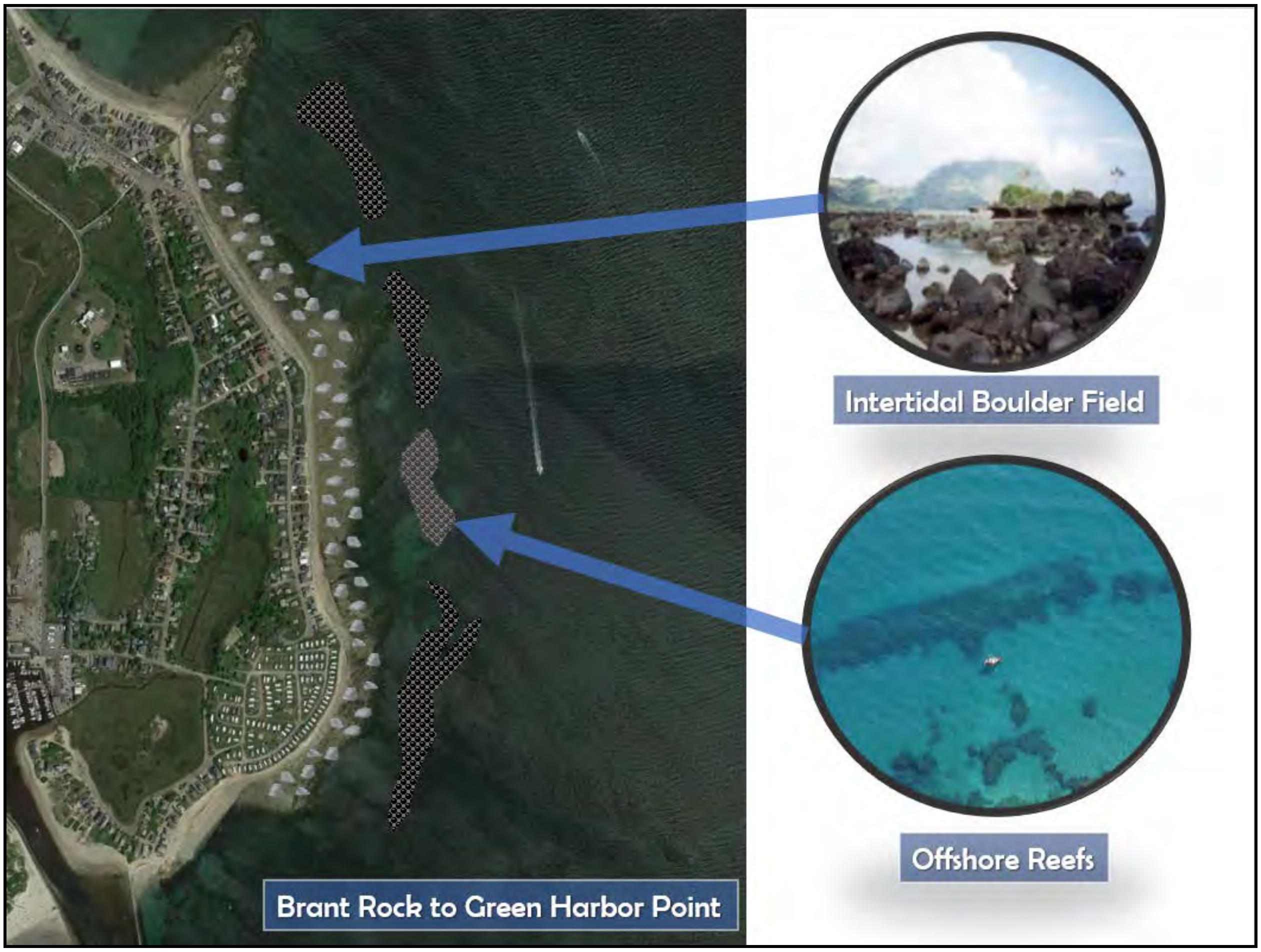


Figure D-9. Conceptual layout for nearshore boulder field at South Brant Rock and Blackman's Point.

2.7 Constructed Reefs

Constructed offshore reefs are a hybrid shore protection alternative that serve as the first line of defense focusing on breaking wave energy before it reaches the shoreline, while also creating hard bottom habitat. Artificial reefs have been constructed using a variety of concrete structures, natural rock, steel and other traditional hard materials (Figure D-10). The reefs essentially act as submerged breakwaters that provide little to no wave attenuation during periods of smaller wave activity, but force larger waves to break, thereby reducing wave energy reaching the shoreline.

Much like offshore breakwaters, there are key criteria that must be met for an artificial reef to be effective at breaking storm waves and dissipating wave energy. The reef must be designed with enough profile (vertical height) off the bottom and width at the top to cause storm waves to trip and break. They should also be placed in rocky seafloor areas with little sediment cover to prevent shifting, scour, and/or burial of the reef. The profile height of the reef presents an issue in areas of large tide range and/or substantial storm surge, since the structure must be submerged at all stages of the tide and yet still cause wave breaking during storms with increased water levels.

Figure D-10. Constructed reef elements; Reef Ball (left photo) and Layer Cake Reef Ball (right photo). (Harris, 2009).

For the Marshfield and Duxbury shoreline with an average tide range of 9.0 ft, constructed reefs submerged at low tide would provide little to no wave attenuation during storms with elevated water levels. Reefs constructed with crests high enough to trigger storm waves to break would be emergent during much of the daily tide, which would minimize the benefits for fisheries and shellfish habitat. Consequently, artificial reef structures were determined to provide little benefit to the Marshfield and Duxbury coastline in terms of storm damage protection and control of wave overtopping.

2.8 Managed Retreat

For the most vulnerable areas, managed retreat from the shoreline was also included as a potential alternative. This alternative was considered for sections of the shoreline that show a high probability of inundation given future protections of sea level rise. Results from the Massachusetts Coast Flood Risk Model (MC-FRM) were used to identify areas where managed retreat should be considered. MC-FRM simulates a full suite of processes that affect coastal water levels, including tides, waves, winds, storm surge, sea level rise, wave setup, and overtopping. The model was developed by Woods Hole Group for the Massachusetts Department of Transportation (MassDOT) as a tool to quantitatively incorporate climate change influences on sea level rise, tides, waves, storm track and storm intensity for the 2030, 2050, 2070, and 2100 time horizons. Model results provide discrete risk estimates for each time horizon to assist with both near- and long-term coastal resiliency planning. In particular, accurate and precise assessments of the exceedance probability of combined SLR and storm surge is provided to help identify areas of existing and near-term vulnerability requiring immediate action, as well as areas that will benefit from long-range planning for future preparedness and risk reduction.

Preliminary MC-FRM data for the Marshfield and Duxbury shoreline indicate high annual probabilities of flooding for certain sections of the coastline by the 2050 time horizon (Figures

D-11 through D-13). For example, by 2050 areas at Brant Rock, Blue Fish Cove, Bay Ave and Gurnet Rd beaches show 100% probability of flooding at least once during the year, with water coming from both the open ocean and Green Harbor or Duxbury Bay.

In these locations, a long-term option may be for the Towns to buy-out and remove the buildings and restore the land. This of course would require cooperation between the property owners and the Towns but would offer benefits by moving residents to safer locations and restoring the natural functions of the barrier beaches. For the purposes of this evaluation, costs associated with a buy-out program were based on the assessed value of the properties as reported in the Marshfield and Duxbury 2020 assessor's databases. Loss of tax revenue was also factored into the cost of this alternative. These resulting costs are likely the minimum that will be required as market value for oceanfront property is usually higher than the assessed value. Given that the managed retreat alternative is more of a long-term option, the costs were computed for 2050 and included a 3% increase in assessed value and tax revenue over the next 30 years.

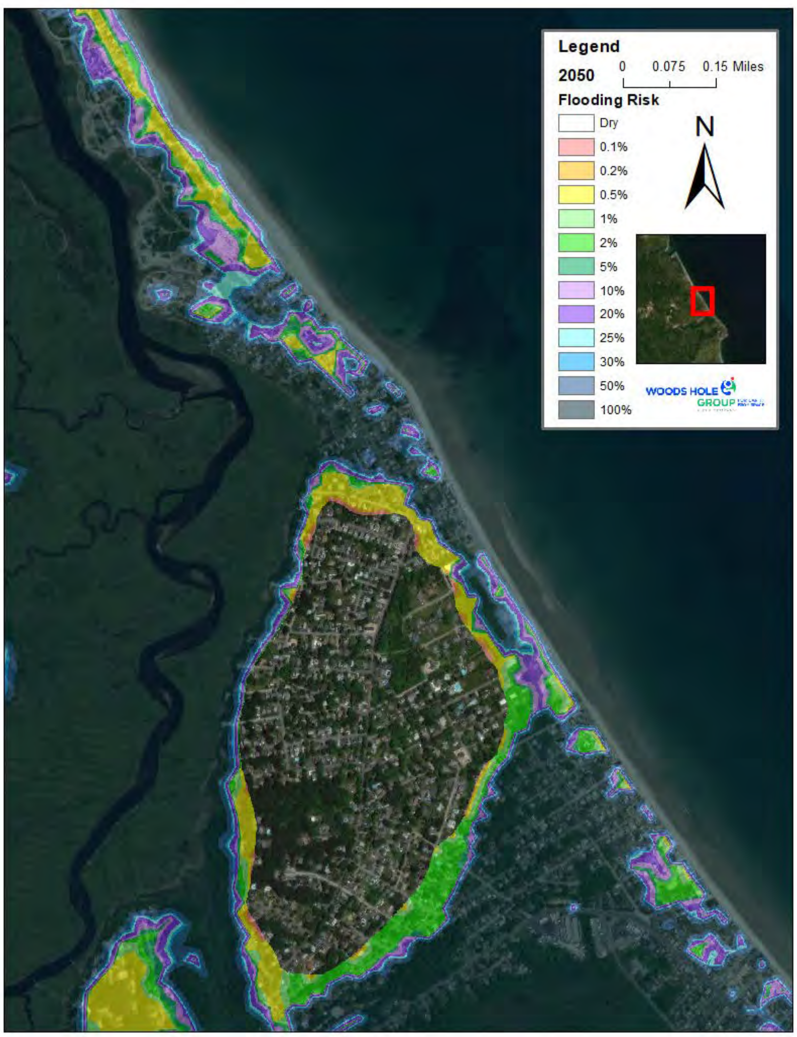


Figure D-11. Preliminary MC-FRM model results showing flood risk probabilities in 2050 for Rexhame Beach, Winslow Beach, and Fieldston Beach.

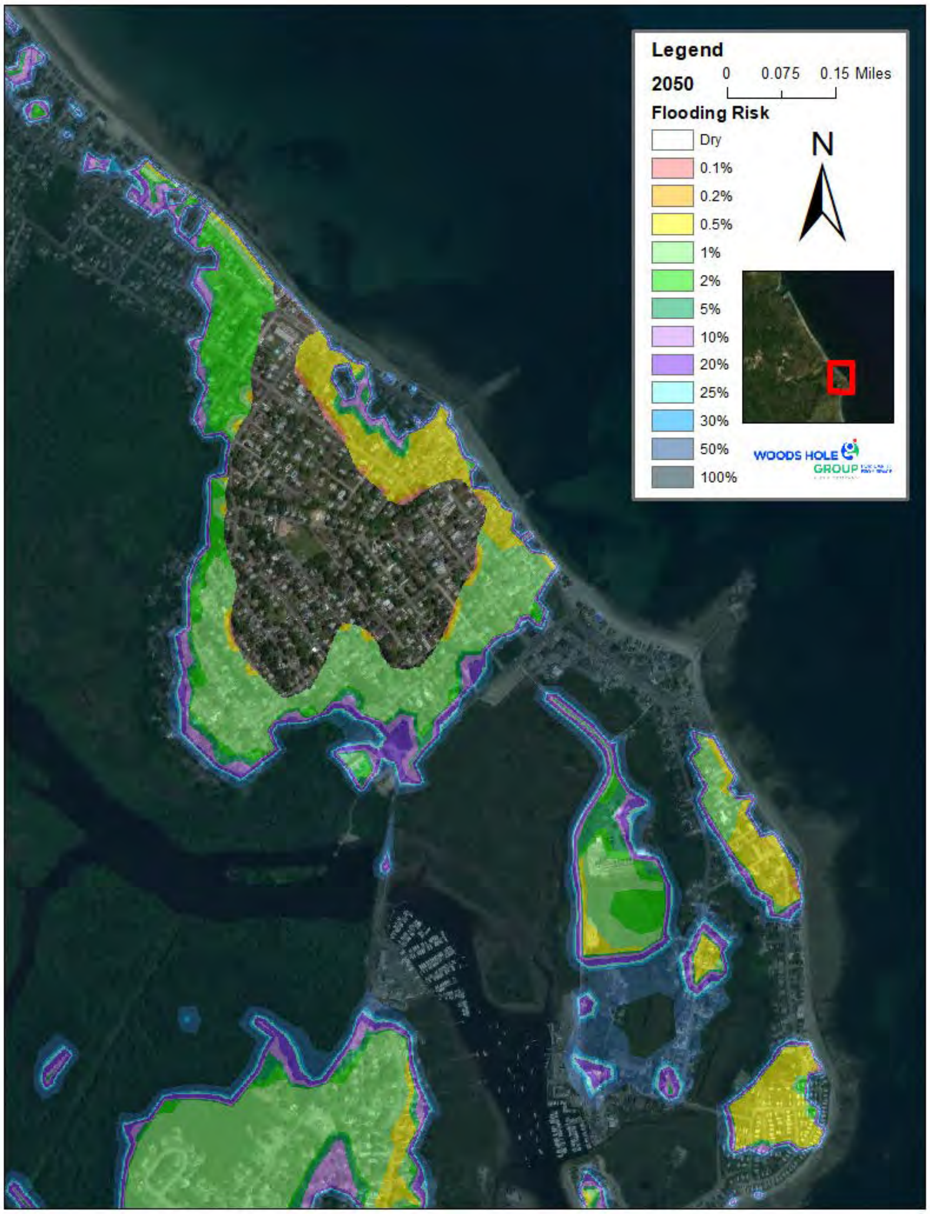


Figure D-12. Preliminary MC-FRM model results showing flood risk probabilities in 2050 for Sunrise Beach, Ocean Bluffs, Hewitt's Point, Brant Rock and Blue Fish Cove Beaches.

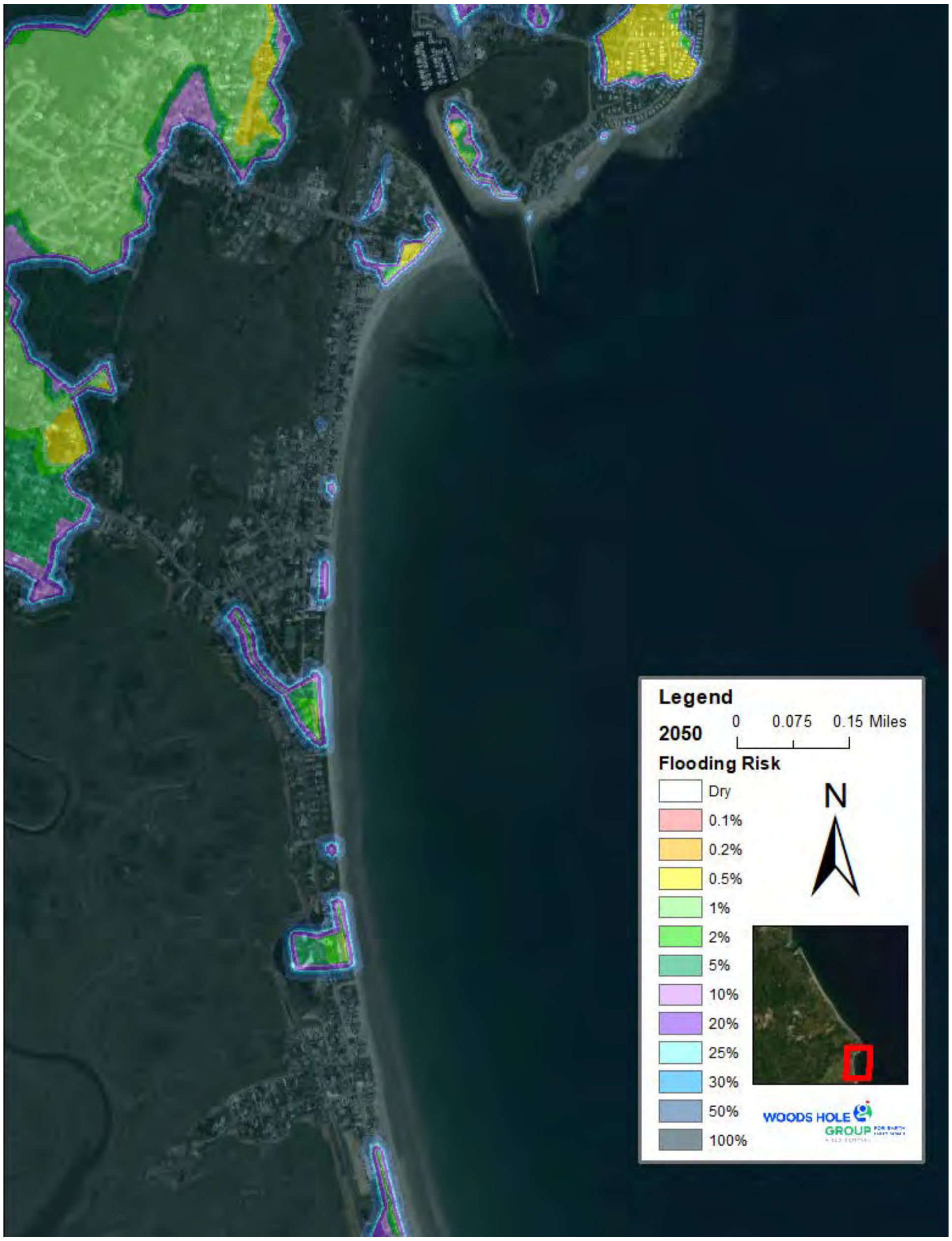


Figure D-13. Preliminary MC-FRM model results showing flood risk probabilities in 2050 for Bay Ave and Gurnet Rd. Beaches.

3.0 Assessment of Alternatives for Site-Specific Beaches

The following section discusses the shore protection and resiliency alternatives considered at each of the fourteen (14) site-specific beaches. Information gathered during the broad assessment of alternatives (Section 2.0) was used in combination with the site-specific beach characteristics to evaluate appropriate alternatives for each site. Engineering judgement was used to assess the applicability of different options, taking into consideration engineering feasibility, performance and long-term viability, potential environmental impacts, and cost. This information was then used to select the most appropriate alternative(s) for each beach. At some sites, both short- and long-term alternatives were identified. While emphasis was placed on identification of soft engineering approaches for increasing shoreline resiliency, depending on the beach, it was not always feasible to identify an appropriate soft engineering solution. For these beaches, further investigation and engineering design will be needed by the Towns before proceeding with a final plan for enhanced shore protection and improved resiliency.

3.1 Rexhame Public Beach

Rexhame Public Beach is an important recreational resource for the Town of Marshfield. It also provides wildlife habitat for state-listed shorebirds. The relatively wide high tide beach and coastal dune system provide storm damage protection for adjacent developed areas and the South River ecosystem. Shoreline change between 1978 and 2014 at Rexhame Public Beach has been both erosional and accretional with rates ranging from -0.95 to 0.59 ft/yr, including a wide uncertainty range (Figure C-16 in Section C). The beach has been nourished at least two (2) times in the past 20 years, which could have slowed the rates of shoreline change. Despite the relatively low rates of beach erosion, the seaward toe of the dune has retreated approximately 25 ft since 2010 (Figure D-14). Due to the relatively high rates of dune erosion and the desire by the Town to maintain Rexhame Beach as a recreational resource for the public, alternatives for beach and dune nourishment were evaluated. The *status quo* alternate was also considered as well as managed retreat for a longer-term alternative.

3.1.1 Maintain Existing Management Approach – *Status Quo*

The Town's currently maintains three controlled access paths between the parking lot and the beach. Sand fencing is used along the toe of the dune to help accumulate wind blown sediment and keep foot traffic off the dunes. The Town has accepted sediment for beneficial reuse from nearby dredging projects in the past; however, there is not a regular or frequent program for nourishment of the beach or dunes.

At its narrowest point, the dune in front of the parking lot is approximately 90 ft wide. Assuming no increase in the current rate of dune erosion, it would take just under 30 years before the dune is completely removed. However, this estimate does not factor in rising sea level or an increased frequency and intensity of storms associated with climate change. These factors will increase the rate of dune erosion and vulnerability of public infrastructure at Rexhame Public Beach. As an example, FEMA guidelines indicate that dunes must have a cross-sectional area above the 100-yr stillwater level greater than 540 sq ft in order to withstand a 100-yr storm event. The current dunes at Rexhame Beach do not meet this FEMA criteria, and as such significant erosion and loss of dune resource can be expected during a 100-yr storm. Continuing with the status quo at Rexhame Beach places the public resources at risk within the near future.

Figure D-14. Recent dune erosion at Rexhame Public Beach.

3.1.2 Beach and Dune Nourishment

Three (3) beach and/or dune nourishment alternatives were developed for Rexhame Public Beach. One alternative included dune restoration only (Rexhame Public – Alt 1), the second included dune restoration in combination with beach nourishment (Rexhame Public – Alt 2) and the third included beach nourishment only (Rexhame Public – Alt 3). The design elements, footprint areas and nourishment volumes for each alternative are provided in Table D-3. All alternatives for Rexhame Public Beach extended along the entire 1,980 ft stretch of undeveloped barrier beach (Figure D-15). Most of the beach area is owned by the Town of Marshfield and open to the public. The Sea Rivers Trust owns the northern most undeveloped parcel immediately north of Rexhame Public Beach (Figure D-15). Coordination between the Town and the Trust will be required to explore the possibility of extending the project onto the Sea Rivers Trust property.

The level of storm damage protection provided by the existing dunes at Rexahme Public Beach was quantified using the cross-shore sediment transport model XBeach. The same model was used to evaluate performance of the three nourishment alternatives when exposed to 10-yr and 50-yr return period storms. An evaluation of longshore transport was also performed to predict the design life of the nourishment alternatives. The longshore transport, or spreading analysis, used analytical methods to estimate the percentage of fill remaining within the project area through time. A median grain size of 0.35 mm was assumed for the dune modeling at Rexhame Public Beach based on grain size data gathered in support of this study.

Table D-3. Beach and Dune Nourishment Alternatives Evaluated for Rexhame Public Beach.

Alternative	Resiliency Type	Design Elements	Footprint Area (acres)	Volume (cu yds)
Rexhame Public – Alt 1	dune nourishment	dune crest elev. = 28 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:5	5.34	47,240
Rexhame Public – Alt 2	dune + beach nourishment	dune crest elev. = 28 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:5 berm elev. = 9.5 ft NAVD88 berm width = 75 ft nearshore slope = 1:12	14.92	82,570
Rexhame Public – Alt 3	beach nourishment	berm elev. = 11 ft NAVD88 berm width = 100 ft nearshore slope = 1:15	14.09	129,000

Figure D-15. Beach/dune nourishment alternatives considered for Rexhame Public Beach.

Results of the 10-yr and 50-yr storm simulations on the existing dune are shown in Figure D-16. The modeling shows erosion along the seaward face of the dune, with average retreat of 15 ft for the 10-yr storm and 28 ft for the 50-yr storm; however, the dune is not overtopped in either case. Sediment eroded from the face of the dune is transported offshore to the intertidal and subtidal zones below 0 ft NAVD88. The model results are consistent with performance of the dunes during past storms and with retreat of the dune toe illustrated in Figure D-14. Based on this information the existing dunes at Rexhame Beach can be considered to provide protection for a 50-yr return period storm. Application of the FEMA 540 rule indicates that the existing dunes also provide protection for storms up to the 100-yr event. FEMA's 540 rule uses the cross-sectional area of the dune above the 100-yr stillwater elevation and seaward of the dune peak to estimate the extent of dune erosion. Dunes with cross-sectional areas less than 540 square feet are considered to be completely removed during a 100-yr storm, while dunes with cross-sectional areas greater than 540 square feet are considered to retreat, leaving a portion of the dune intact for storm damage protection.

Figures D-17 and D-18 show performance of the beach and dune nourishment alternatives during 10-yr and 50-yr storms, respectively. The model results show similar dune erosion and nearshore deposition patterns for Rexhame Public - Alt 1 and Alt 2 under both the 10-yr and 50-yr storm simulations. Rexhame Public – Alt 3 shows greater dune erosion with more material transported to the nearshore zone. Even though significantly more sediment (129,000 cy) is needed to construct Rexhame Public – Alt 3, it does not provide a greater level of storm damage protection for the dunes. Rexhame Public – Alt 1 provides a similar level of protection to Rexhame Public – Alt 2 and requires 57% of the volume.

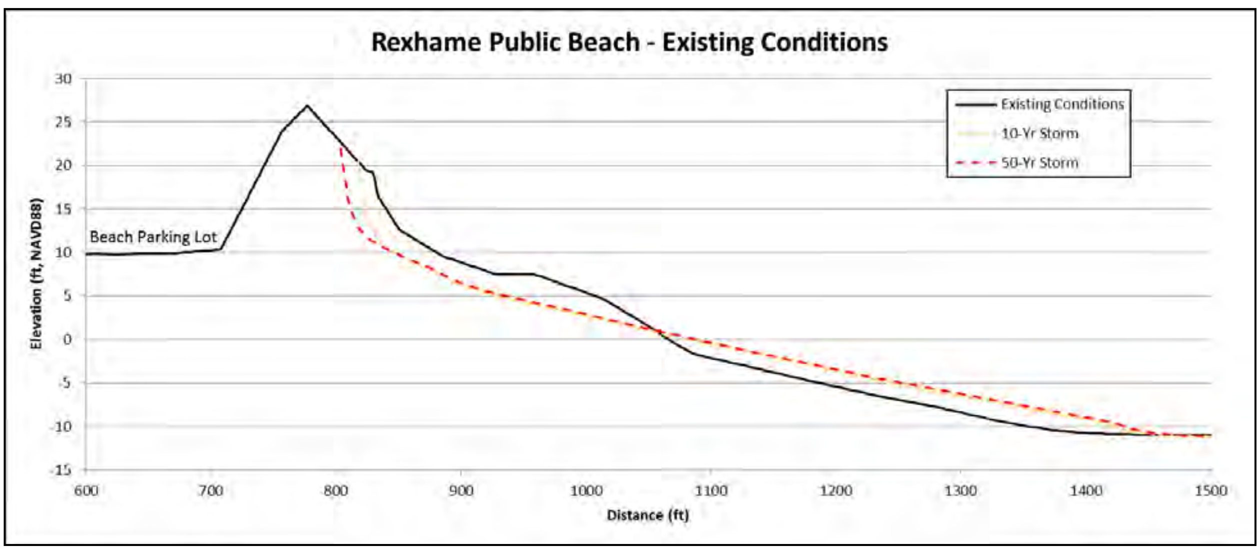


Figure D-16. XBeach model results for the existing dunes at Rexhame Public Beach for 10-yr and 50-yr storm events.

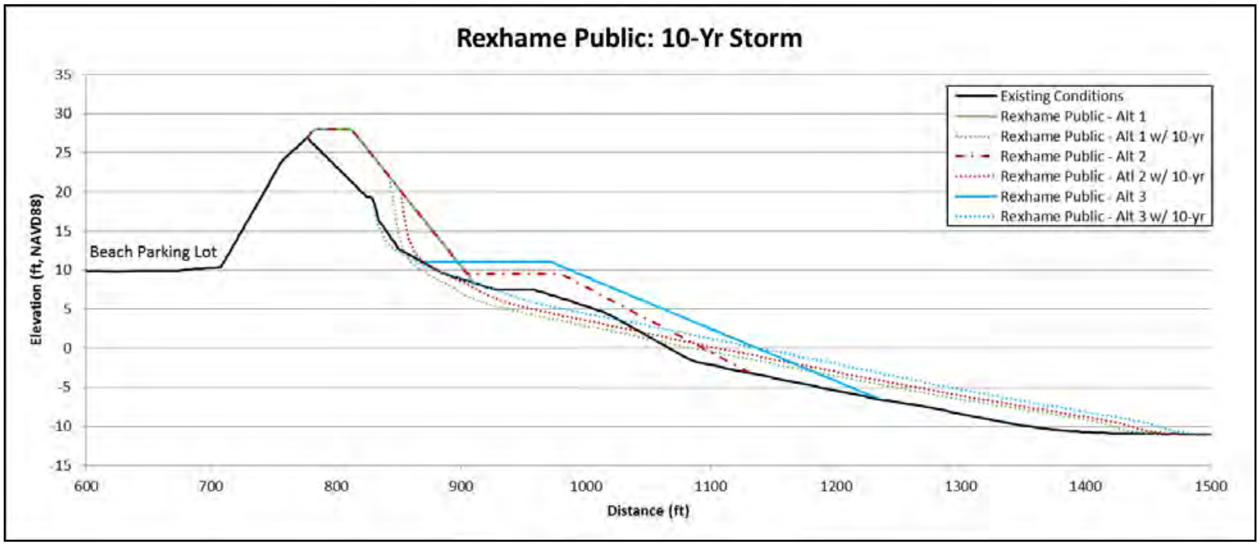


Figure D-17. XBeach model results for beach and dune nourishment alternatives at Rexhame Public Beach for a 10-yr storm event.

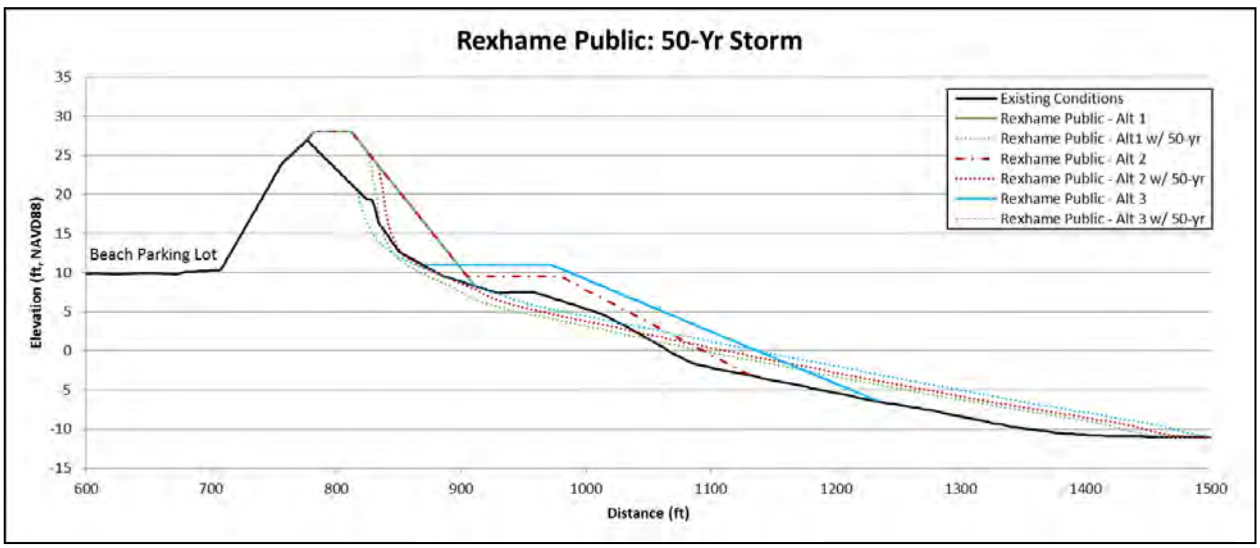


Figure D-18. XBeach model results for beach and dune nourishment alternatives at Rexhame Public Beach for a 50-yr storm event.

Design life computations were performed on the two nourishment alternatives for Rexhame Public Beach. Under average non-storm conditions, the dunes are just outside the zone of longshore transport, and therefore the design life computations were not applicable to the dune only alternative. The volume of nourishment remaining in the original project footprints as a function of time is shown in Figure D-19. The ranges shown for each project reflect variations in design life with and without background erosion rates for Rexhame Public Beach. The fill material is shown to initially spread relatively quickly, as indicated by the decrease in percentage of fill remaining, as the shoreline adjusts to a new equilibrium. This behavior is typical of beach nourishment response, since a large perturbation has been added to the coastline. After a few years, however, this trend begins to decelerate and the material remaining stabilizes.

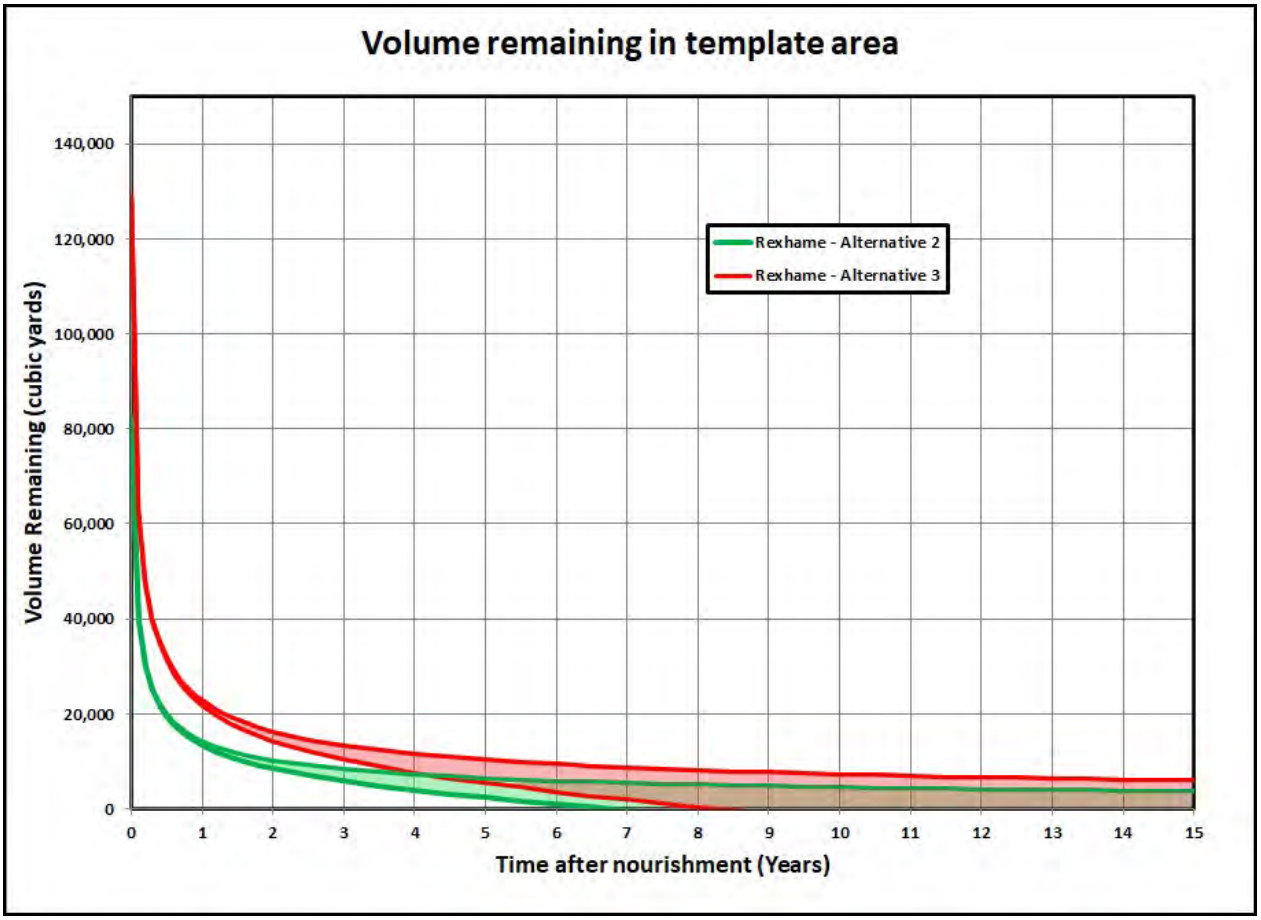


Figure D-19. Service life estimates for beach nourishment alternatives at Rexhame Public Beach.

Costs associated with the Rexhame Public Beach alternatives are summarized in Table D-4. The costs include the sand purchase, trucking, spreading and planting of beach grass for the two alternatives that include dunes. Projected costs over the next 30 years are also provided assuming renourishment every 6 years for Rexhame Public – Alt 2 and every 8 years for Rexahme Public – Alt 3, when the design life calculations indicate that all material has eroded from the original project footprint. The rule of thumb for renourishment when 70% to 80% of the volume is lost from the footprint was not used at this site, since the goal of the nourishment is to provide sediment to the littoral system and protect public beach resources. A renourishment interval of 10 years was utilized for Rexhame Public – Alt 1, in order to maintain a minimum dune width of 60 ft, given the background erosion rate of 2.8 ft/yr.

Table D-4. Costs Associated with Beach and Dune Nourishment Alternatives at Rexhame Public Beach.

Resiliency Alternative	Initial Construction Cost	Costs Over Next 30 Years
Rexhame Public – Alt 1	$1.67 million	$4.99 million
Rexhame Public – Alt 2	$2.72 million	$13.62 million
Rexhame Public – Alt 3	$3.87 million	$14.51 million

3.1.3 Managed Retreat

Managed retreat of the public beach facilities at Rexhame is an option in the long-term when erosion and/or flooding threatens the parking lot. One option would be to eliminate a portion, or all, of the parking lot and restore the dune in a more landward location. This alternative would impact public access during the summer when the parking lot fills to capacity. Without changes to the fee structure for resident beach stickers and daily parking fees, a reduction in parking at Rexhame Public Beach would result in decreased revenue. Long-range plans for off-site parking and providing a shuttle service for beach users were included as recommendations in the Town's 2018 Beach Management Plan (Woods Hole Group, 2018). Costs associated with acquisition of property for off site parking and running the shuttle service would also be incurred with the managed retreat alternative.

3.2 Rexhame Beach (Parker to Porter Streets)

The developed portion of Rexhame Beach between Parker and Porter Streets contains approximately 270 single family homes on lots averaging 0.14 acres in size. Most of the ocean facing properties have some form of hard shore protection, either seawalls or revetments. Recent shoreline change data between 1978 and 2014 show net accretion with average rates on the order of +1.0 ft/yr, although the data show a high degree of uncertainty (Figure C-16 in Section C). Nearshore areas along the center of Rexhame Beach contain naturally occurring rocky intertidal resources. This feature acts to attenuate incoming waves and provides a natural form of shore protection for developed areas of Rexhame Beach during low energy storm events. However, the developed infrastructure continues to be vulnerable to larger storms. The beach areas are privately owned. To protect the existing rocky intertidal resources while enhancing the resiliency of the shoreline, both hard engineering and hybrid alternatives were considered. The *status quo* alternate was also considered as well as managed retreat for a longer-term alternative.

3.2.1 Maintain Existing Management Approach – *Status Quo*

Existing management in the Rexhame Beach area of Marshfield is primarily undertaken by the property owners on a site by site basis. FEMA data from 1978 to 2018 for this area indicate between 10 and 20 repetitive loss properties with total claims between $0.85 and $1.7 million (Figure C-38 in Section C), but additional non-repetitive loss claims are likely. Town records specific to Rexhame Beach for providing emergency services during storms or post-storm clean up are not available; however, costs to continue providing these services under the *status quo* alternative are expected to increase in the future given the impacts of climate change. FEMA flood insurance claims are also expected to increase with this alternative.

3.2.2 Enhance and/or Enlarge Shore Protection Structures

The average crest elevation of the shore protection structures along Rexhame Beach is 16.8 ft NAVD88 and the average elevation of the beach at the toe of the structures 7.3 ft NAVD88. These conditions, in combination with the shallower water depths over the rocky intertidal resource, result in relatively low overtopping rates during current day 10-yr and 50-yr storms. However, when considering a 2 ft increase in sea level by 2040 to 2060, the structures will need to be increased in height by approximately 1.5 ft to reduce overtopping rates to levels that would prevent structural damage to the adjacent homes. Costs associated with raising the structures 1.5 ft for the entire 3,025 ft long stretch of Rexhame Beach would be approximately $21.18 million. Given that the structures are privately owned, it is assumed these costs would be borne by the property owners.

3.2.3 Intertidal Boulder Field

The existing rocky intertidal resource in the nearshore area of Rexhame Beach provides an optimum location for additional wave attenuation through construction of an intertidal boulder field. The primary goal of the boulder field would be to reduce wave overtopping during high energy storms and future conditions with sea level rise. Additional engineering would be needed to design the boulder field to ensure reductions in wave overtopping for specific storm events; however, assuming a conceptual design with a 60 ft wide boulder field along the entire 3,025 ft stretch of Rexhame Beach, estimated costs for construction would be $8.11 million. The footprint of the boulder field would be approximately 181,500 sq ft.

3.2.4 Managed Retreat

Managed retreat from the shoreline at Rexhame Beach was considered as an option for the long-term as a way to reduce coastal vulnerability. Preliminary results from the MC-FRM model show that portions of Rexhame Beach will have a 100% probability of flooding by 2050 (Figure D-11). As such, the managed retreat alternative would be appropriate to phase in over the next 30 years. The 2020 assessor's database shows total property values for the first row of homes most affected by coastal flooding and wave overtopping to be $26.50 million. To fully implement this alternative, the Town would need to seek state and federal funding to buy the property owners out. Consideration would also need to be given to the loss of annual tax revenue from these property owners, estimated to be approximately $353,220. Close coordination between the town and affected property owners will be required to implement this alternative.

3.3 Winslow Ave. Beach (Porter St. to Rexhame Rd.)

The Winslow Ave. Beach area between Porter St. and Rexhame Rd. has lower density development that other areas of Marshfield and the structures are set back 250 to 400 ft from the beach. The area east of South Circuit Ave. contains 42 single family homes on lots averaging 0.41 acres in size. The properties are not protected by coastal engineering structures. Instead a broad and low-lying cobble dune separates the residences from the coastal beach. Shoreline change data between 1978 and 2014 show accretion and erosion ranging from +1.0 to -1.2 ft/yr, with a high degree of uncertainty (Figure C-16 in Section C). The beach is owned by the Town of Marshfield and open to the public for recreational purposes, although parking is not provided, and access is limited to two locations. Alternatives considered for Winslow Ave. Beach included *status quo*, dune nourishment/enhancement, and managed retreat.

3.3.1 Maintain Existing Management Approach – *Status Quo*

The Town does not have an active program for management of Winslow Ave. Beach and FEMA data from 1978 to 2018 show no repetitive loss properties (Figure C-39 in Section C). Even though there are no repetitive loss claims in this area, it is possible some of the properties have sustained flood damages or filed claims with FEMA. With the existing data it is not possible to estimate the current costs associated with the *status quo* alternative. However, given the high probability for increased flooding and storm damages resulting from the impacts of climate change, future management activities will likely be required to reduce vulnerability of the natural and built environment.

3.3.2 Dune Nourishment

Two (2) dune nourishment alternatives were developed for Winslow Ave. Beach. Winslow – Alt 1 included a dune with crest elevation of 15.5 ft NAVD88 and Winslow – Alt 2 included a dune with crest elevation of 17 ft NAVD88. Both dune alternatives were designed to blend with existing landforms at the north and south ends of the project. The design elements, footprint areas and nourishment volumes for each alternative are provided in Table D-5. Both alternatives extended along the entire 1,540 ft length of the existing dune (Figure D-20) which is owned by the Town of Marshfield.

Table D-5. Dune Nourishment Alternatives Evaluated for Winslow Ave. Beach.

Alternative	Resiliency Type	Design Elements	Footprint Area (acres)	Volume (cu yds)
Winslow – Alt 1	dune nourishment	dune crest elev. = 15.5 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:7	3.7	11,200
Winslow – Alt 2	dune nourishment	dune crest elev. = 17 ft NAVD88 dune crest width = 40 ft dune seaward slope = 1:7	4.5	17,850

Figure D-20. Dune nourishment alternatives considered for Winslow Ave. Beach.

The level of storm damage protection provided by the existing dunes at Winslow Ave. Beach was quantified using the cross-shore sediment transport model XBeach-G. The same model was used to evaluate performance of the dune nourishment alternatives when exposed to 10-yr and 50-yr return period storms. A median grain size of 19.0 mm was assumed for the dune modeling based on grain size data gathered in support of this study. Results of the 10-yr and 50-yr storm simulations on the existing dune are shown in Figure D-21. The modeling shows overtopping and landward migration of the dune crest during both storm simulations. A portion of sediment eroded from the dune is transported landward as overwash, and some sediment is transported offshore to the intertidal and subtidal areas.

Figure D-21. XBeach-G model results for the existing dunes at Winslow Ave. Beach for 10-yr and 50-yr storm events.

Figures D-22 and D-23 show performance of the dune nourishment alternatives during 10-yr and 50-yr storms, respectively. For the 10-yr storm, the model predicts that most of the Winslow – Alt 1 dune will be eroded, leaving the profile similar to current day conditions. The Winslow – Alt 2 design withstands the 10-yr storm and leaves enough dune in place to provide flood protection for future storms (Figure D-22). The 50-yr storm simulations show overwash and landward retreat of both alternatives, with crest elevations approximately 0.5 to 1 ft lower than the existing dunes. Both alternatives would reduce flooding and wave impacts on the adjacent developed properties during a 50-yr storm but would require renourishment to restore the dune to the design elevations and widths.

Costs associated with construction of the Winslow Ave. dune alternatives are summarized in Table D-6. The costs include purchase of the cobble, trucking to the site, and spreading. Projected costs over the next 30 years are also provided assuming renourishment every 10 years.

Figure D-22. XBeach-G model results for dune nourishment alternatives at Winslow Ave. Beach for a 10-yr storm event.

Figure D-23. XBeach-G model results for dune nourishment alternatives at Winslow Ave. Beach for a 50-yr storm event.

Table D-6. Costs Associated with Dune Nourishment Alternatives at Winslow Ave. Beach.

Resiliency Alternative	Initial Construction Cost	Costs Over Next 30 Years
Winslow – Alt 1	$336,000	$1.01 million
Winslow – Alt 2	$535,500	$1.61 million

3.3.3 Elevate Homes

Elevating the first row of homes in the Winslow Ave. area was considered as an option for the long-term as a way to reduce coastal vulnerability. Preliminary results from the MC-FRM model show that the first row of homes is vulnerable to flooding by 2050. Assuming a cost of $125,000 per home, it would cost approximately $1.13 million to elevate the 9 homes vulnerable to flooding by 2050. Close coordination between the town and affected property owners would be required, and federal and/or state monies would be needed to help the property owners with elevating the buildings. For example, the Town would be able to apply for Hazard Mitigation Grants on behalf of the homeowners to help with the cost of elevating the buildings.

3.4 Fieldston and Sunrise Beaches (Rexhame Rd. to Sekonnet Ave)

The Fieldston and Sunrise Beach areas of Marshfield are densely developed with single family homes. Approximately 151 homes are located in the Fieldston area and 395 homes in the Sunrise area; lot sizes average 0.12 acres (Figures D-30 & D-31). Vertical seawalls extend along the entire 5,675 ft stretch of beach. While the Town of Marshfield completed projects between 2012 and 2018 to rebuild and increase the elevation of the seawalls at Fieldston and Sunrise Beaches, the beaches on the seaward side of the seawalls are privately owned. Recent shoreline change data between 1978 and 2014 show a trend of increasing erosion from north to south. Rates of erosion are as high as -2.0 ft/yr at the southern end of Sunrise Beach (Figure C-16 in Section C), although in many areas the seawall prevents further retreat of the shoreline and storm waves interacting with the seawalls have resulted in a lowering of the beach elevation. Wave overtopping during storms can cause significant damage in this area. Resiliency measures considered for Fieldston and Sunrise Beaches included the *status quo* alternative and enhancing the existing shore protection structures. Beach/dune nourishment was also considered as a way to restore sediment to the system while also protecting the seawalls from further damage, reducing the potential for wave overtopping, and minimizing the need for additional toe protection to prevent collapse of the seawall. Finally, managed retreat was considered as a long-term alternative.

3.4.1 Maintain Existing Management Approach – *Status Quo*

Future management by the Town of Marshfield for Fieldston and Sunrise Beaches includes regular maintenance of the recently rebuilt seawalls. FEMA data from 1978 to 2018 indicate between 10 and 20 repetitive loss properties for Fieldston Beach and between 30 and 40 repetitive loss properties for Sunrise Beach (Figure C-38 in Section C), but additional non-repetitive loss claims are likely. Total claims for this period were $0.89 million for Fieldston Beach and $1.80 million for Sunrise Beach. Table D-7 provides a summary of costs to maintain the *status quo* for these beaches over the next 30 years (with 5% inflation), including estimated costs for providing storm related public services. Continuing with the current management approach will be costly and will do nothing to increase the resiliency of the coastline.

Table D-7. Projected Costs Over Next 30 Years to Maintain Existing Management Approach for Fieldston and Sunrise Beaches.

Beach	FEMA Repetitive Loss Claims	Maintenance of Shore Protection Structure	Storm Related Public Services	Total
Fieldston	$0.72	$0.22 million	$0.54 million	$1.48 million
Sunrise	$1.46 million	$0.39 million	$0.94 million	$2.79 million

(Note: Status quo costs do not include FEMA non-repetitive loss claims)

3.4.2 Enhance and/or Enlarge Shore Protection Structures

The crest elevation of the seawalls in Fieldston and Sunrise is 18.6 ft NAVD88. The elevation of the beach at the toe of the seawalls decreases from 4.4 ft to -0.5 ft NAVD88 from north to south. Under existing conditions, wave overtopping capable of causing structural damage to adjacent homes occurs during a 50-yr storm event at Fieldston Beach and during 10-yr and greater storms at Sunrise Beach. Table D-8 provides a summary of seawall crest increases that would be needed to prevent structural damage during 10-yr and 50-yr storm events, with current sea levels and with 2 ft of sea level rise (SLR) expected between the 2040 and 2060 time horizon. Based on existing elevations of the infrastructure landward of the seawalls, and the design of the seawalls themselves, it is likely that crest increases greater than 4 ft would not be practical without significant modifications to the sites (i.e., roadway modifications, building redesign/relocation to landward edge of property). Costs associated with raising the structures 0.5 – 4.0 ft along the entire 5,675 ft of Fieldston and Sunrise Beach would be between $39.73 and $51.08 million. Given that the enlarged structures would not provide the necessary protection during future sea level rise scenarios, this alternative would require further modifications to the seawalls such as adding a revetment along the seaward toe.

Table D-8. Storms Capable of Causing Structural Damage to Buildings from Wave Overtopping at Fieldston & Sunrise Beaches and Seawall Elevation Increases Needed to Avoid Damaging Wave Overtopping.

Beach Scenario	10-Yr Storm	50-Yr Storm	10-Yr Storm + 2 ft SLR	50-Yr Storm + 2 ft SLR
Fieldston Beach				
Existing Seawall Overtopped	No	Yes	Yes	Yes
Seawall Increase	0	0.5 ft	5.0 ft	7.5 ft
Sunrise Beach North				
Existing Seawall Overtopped	Yes	Yes	Yes	Yes
Seawall Increase	0.5 ft	3.5 ft	7.5 ft	> 8.0 ft
Sunrise Beach South				
Existing Seawall Overtopped	Yes	Yes	Yes	Yes
Seawall Increase	> 8.0 ft	> 8.0 ft	> 8.0 ft	> 8.0 ft

3.4.3 Beach and Dune Nourishment

Three (3) beach and dune nourishment alternatives were developed for the Fieldston and Sunrise Beach areas. The design elements, footprint areas and nourishment volumes for each alternative are provided in Table D-9. All alternatives extended along the entire 5,675 ft stretch of privately-owned beach (Figure D-24). Coordination between the Town and private property owners is currently underway to secure rights of entry for construction and public access easements.

Cross shore modeling of existing conditions and the three (3) nourishment alternatives was performed for 1-yr, 2-yr and 10-yr storm events. The modeling considered the mixed grain size beach and assumed 50% sand at 0.35 mm and 50% gravel at 10.2 mm. Spreading analysis were also performed to estimate the percentage of fill remaining within the project area through time. Results of the spreading analysis were used to develop a schedule for renourishment.

Table D-9. Nourishment Alternatives Evaluated for Fieldston and Sunrise Beaches.

Alternative	Resiliency Type	Design Elements	Footprint Area (acres)	Volume (cu yds)
Fieldston/Sunrise – Alt 1	dune + beach nourishment	dune crest elev. = 13 ft NAVD88 dune crest width = 20 ft dune seaward slope = 1:5 berm elev. = 8.0 ft NAVD88 berm width = 55 ft nearshore slope = 1:20	37.0	339,350
Fieldston/Sunrise – Alt 2	dune + beach nourishment	dune crest elev. = 13 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:5 berm elev. = 9.5 ft NAVD88 berm width = 90 ft nearshore slope = 1:12	30.5	389,770
Fieldston/Sunrise – Alt 3	beach nourishment	berm elev. = 11 ft NAVD88 berm width = 100 ft nearshore slope = 1:15	34.0	409,100

Figure D-24. Nourishment alternatives considered for Fieldston and Sunrise Beaches.

Results of the 1-yr, 2-yr and 10-yr storm simulations on the existing beaches at Fieldston and Sunrise show scour along the toe of the seawalls and a general lowering of the beach (Figure D-25). Sediment eroded from the beach is transported seaward of the MLW line, extending as far as 500 ft from the seawalls. These model results are consistent with performance of the beaches during past storms and with a long-term lowering of the beach elevation observed in the historical LiDAR data (Figure C-17 in Section C).

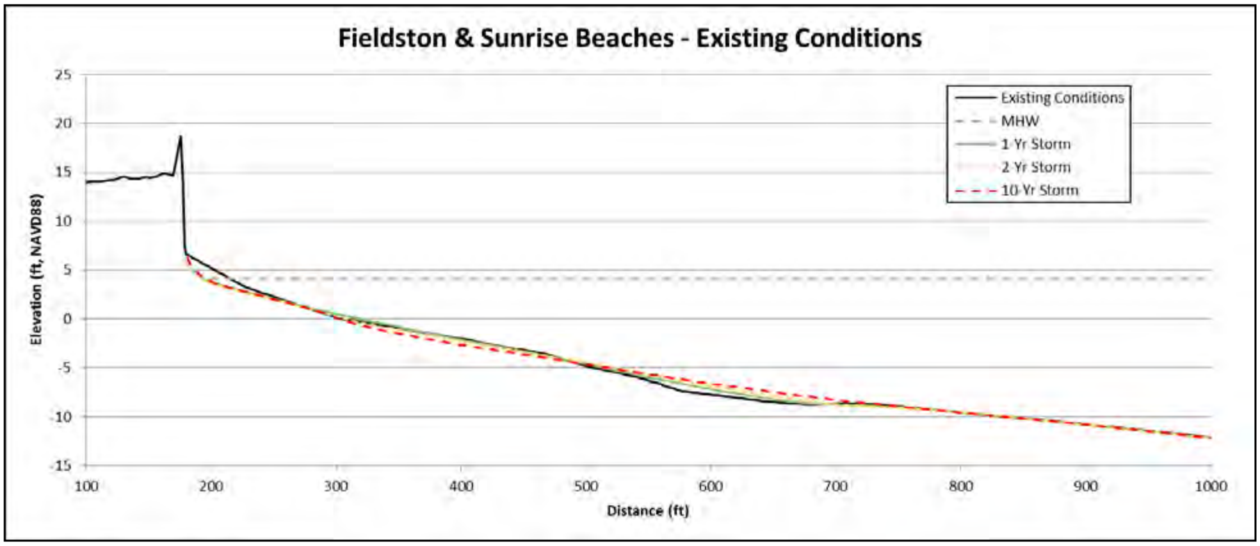


Figure D-25. XBeach and XBeach-G model results for existing conditions at Fieldston & Sunrise Beaches for 1-yr, 2-yr and 10-yr storm events.

Figures D-26 through D-28 show performance of the nourishment alternatives during 1-yr, 2-yr and 10-yr storms, respectively. The model results for the 1-yr storm show erosion of the berm (dry beach) with all three alternatives; Alt 3 with the highest elevation berm shows the greatest scarping (Figure D-26). The dunes in Fieldston/Sunrise – Alt 1 and 2 remain intact with the 1-yr storm. Retreat of the MHW line is greatest with Alt 2 at 46 ft and lowest with Alt 1 at 36 ft. Sediment eroded from the upper portion of the beach is transported seaward to the intertidal and subtidal portions of the beach with all alternatives.

For the 2-yr storm, all three nourishment alternatives show erosion of the berm (Figure D-27). Fieldston/Sunrise – Alt 1 and Alt 2 lose most of the berm and some material from the toe of the dune. Fieldston/Sunrise – Alt 3 loses approximately one-half the width of the nourished berm. Retreat of MHW is greatest with Alt 2 ad 56 ft and lowest with Alt 1 and Alt 3 at 49 ft. All of the alternatives show that sediment eroded from the upper portion of the beach is transported seaward to the intertidal and subtidal zones.

With a 10-yr storm, the cross shore modeling for Fieldston/Sunrise - Alt 1 shows erosion of the entire berm and removal of most of the dune (Figure D-28). Significant berm and minor dune toe erosion also occur with Fieldston/Sunrise - Alt 2, while Alt 3 shows removal of approximately one-half of the berm. Retreat of the MHW line ranges from 62 ft with Alt 1 and Alt 3, to 69 ft with Alt 2. Sediment eroded from the upper portion of the beach is transported seaward to the intertidal and subtidal portions of the beach with all alternatives.

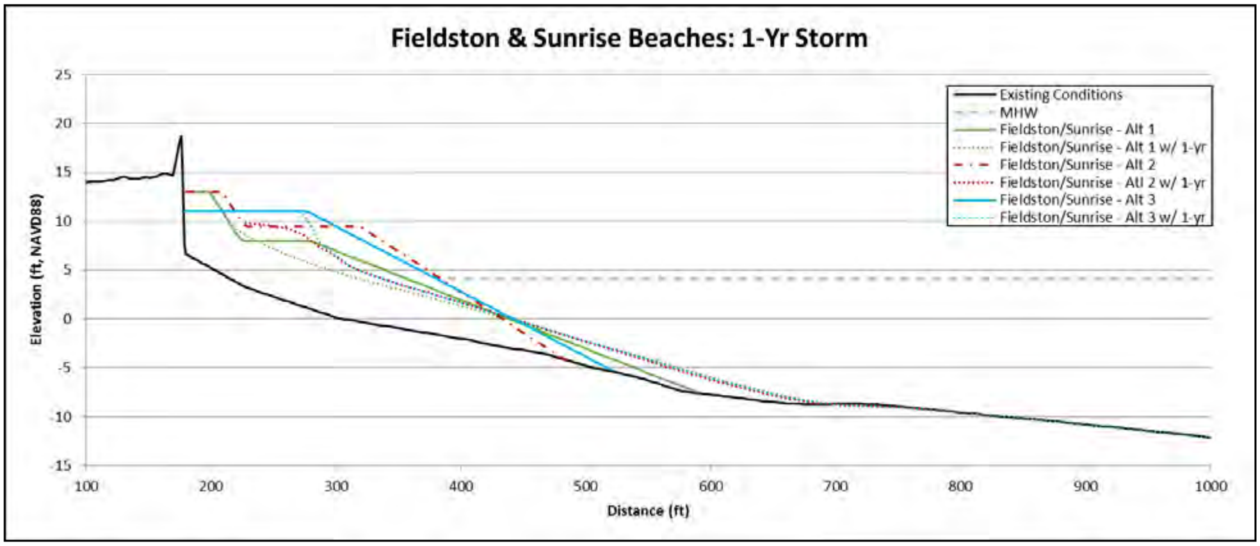


Figure D-26. **XBeach and XBeach-G model results for nourishment alternatives at Fieldston and Sunrise Beaches for a 1-yr storm event.**

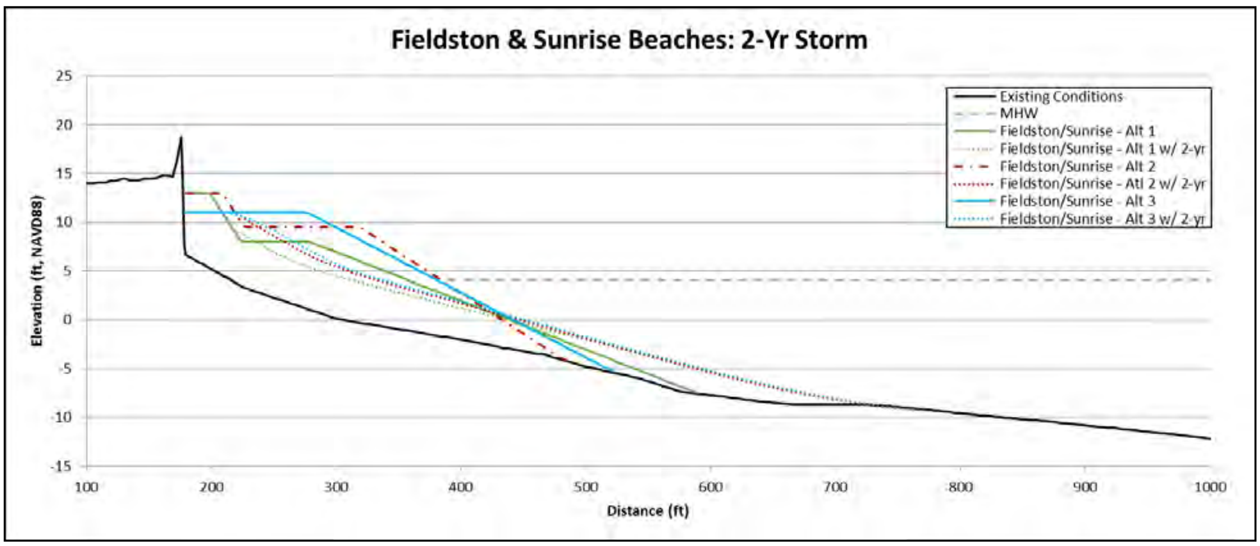


Figure D-27. **XBeach and XBeach-G model results for nourishment alternatives at Fieldston and Sunrise Beaches for a 2-yr storm event.**

Results of the design life computations showing volume of nourishment remaining in the original footprints as a function of time for the Fieldston and Sunrise Beach alternatives are shown in Figure D-29. The fill material is shown to initially spread relatively quickly, as indicated by the decrease in percentage of fill remaining, as the shoreline adjusts to a new equilibrium. Based on the criteria that renourishment should be performed when 70% to 80% of the volume is lost from the original footprint, the modeling suggests that renourishment will be needed 1.5 to 4.0 years after initial construction to maintain the designed level of storm damage protection. Fieldston/Sunrise – Alt 3 has the longest service life and Fieldston/Sunrise – Alt 1 has the shortest service life.

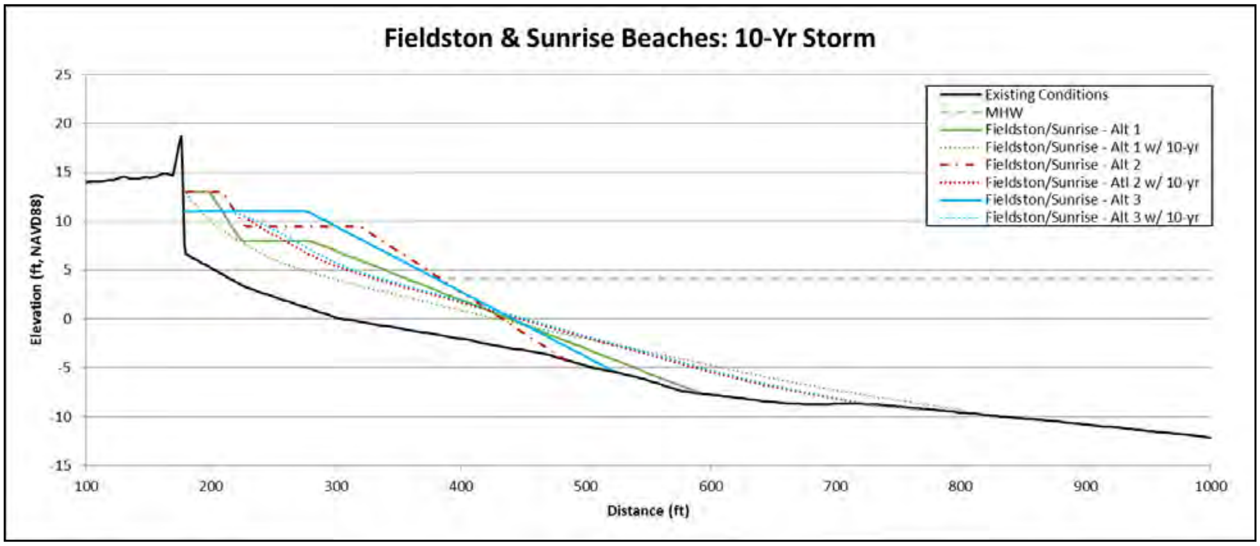


Figure D-28. **XBeach and XBeach-G model results for nourishment alternatives at Fieldston and Sunrise Beaches for a 10-yr storm event.**

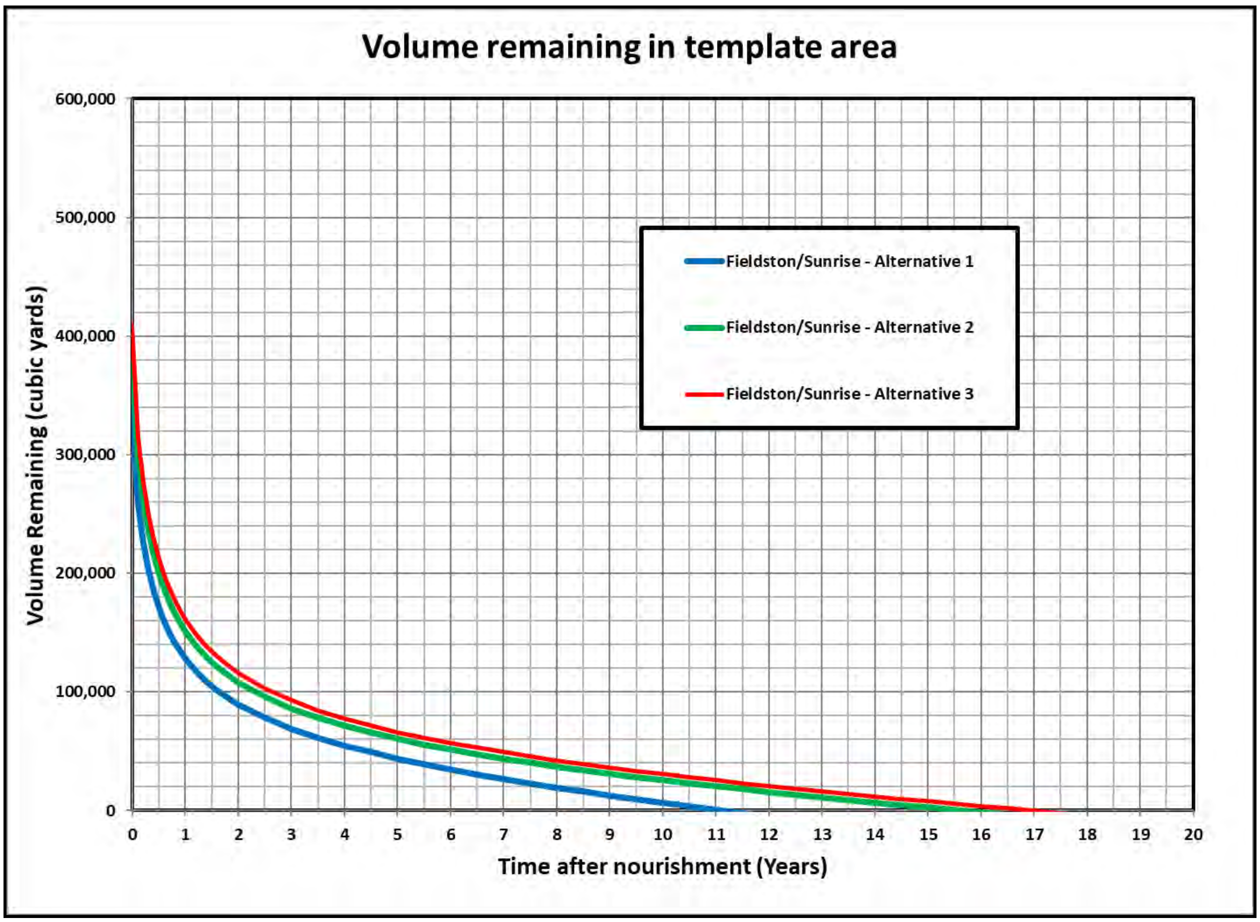


Figure D-29. **Service life estimates for beach nourishment alternatives at Fieldston and Sunrise Beaches.**

Figure D-30 shows the width of the beach berm (dry beach) over time for the three Fieldston and Sunrise nourishment alternatives. As with the service life estimates, the berm width decreases rapidly during the first year following construction. By year 2 the berm widths for Alt 2 and Alt 3 are estimated to be 25 to 30 ft and only 15 ft for Alt 1.

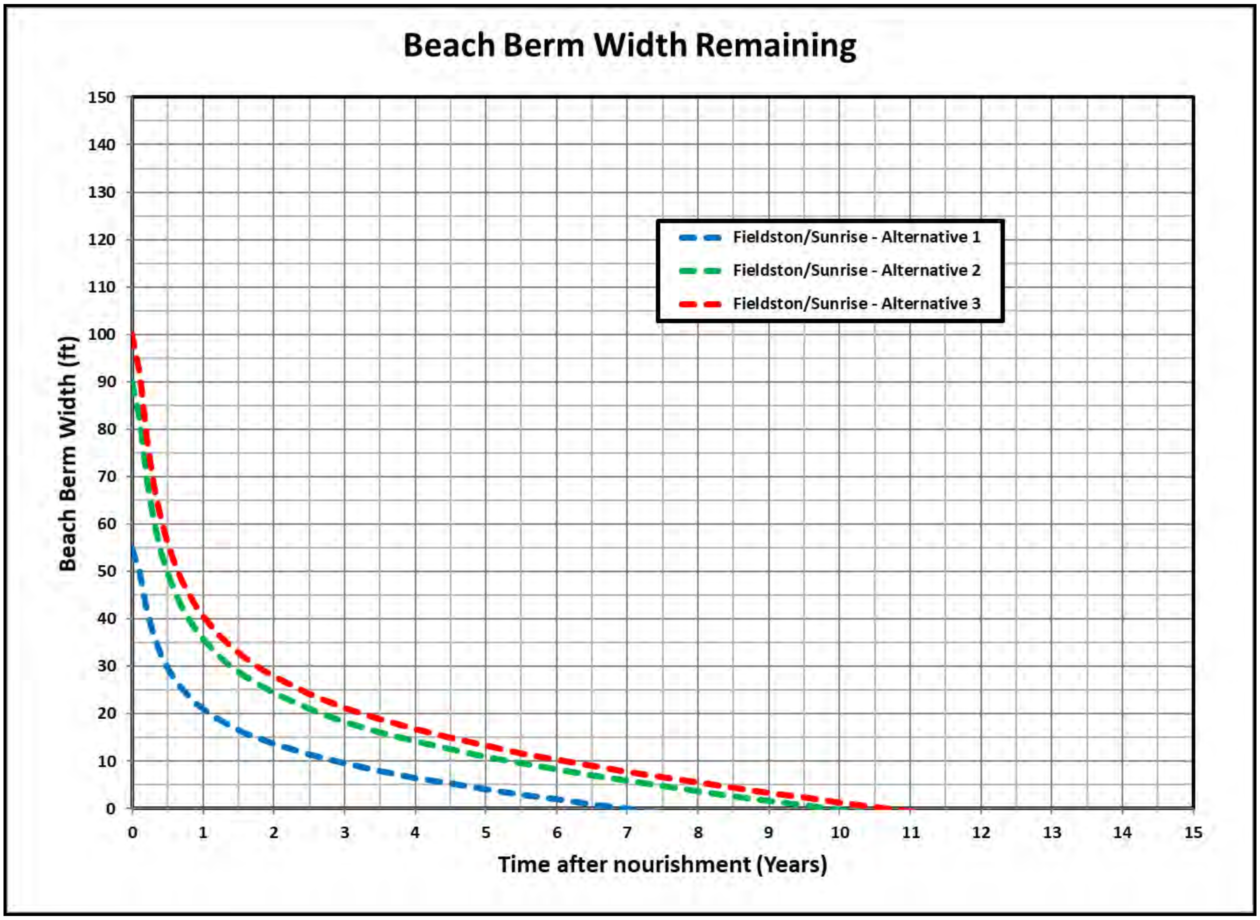


Figure D-30. Berm width over time for beach nourishment alternatives at Fieldston and Sunrise Beaches.

Impacts of the three (3) Fieldston/Sunrise nourishment alternatives on rates of wave overtopping were also evaluated. Calculations summarized in Table D-8 above indicate that existing rates of wave overtopping increase from north to south along Fieldston and Sunrise Beaches, with damaging overtopping occurring at Sunrise Beach during a 10-yr storm event and greater. Beach profile data for the 10-yr storm scenarios from XBeach and XBeach-G were used to evalute changes in overtopping rates for each alternative. The calculations showed a 100% reduction in wave overtopping for all three (3) alternatives indicating no damage to buildings from overtopping during a 10-yr storm event.

Over time as additional storms and longshore spreading act to reshape the nourishment, the elevation of the beach in front of the seawalls will lower and the risk of overtopping will increase. To quantify the critical beach elevation at which damaging wave overtopping starts to occur, additional calculations were performed for Fieldston and Sunrise Beaches. For the 10-yr and 50-yr storms, damaging overtopping will begin to occur when the beach drops to an elevation of 3.5 ft and 4.5 ft NAVD88, respectively. For Fieldston/Sunrise – Alt 1 the berm (dry beach) would have to lower 3.5 to 4.5 ft to reach the critical elevation. Because the starting berm elevations for Fieldston/Sunrise – Alt 2 and Alt 3 are higher, the beach would have to lower between 5 and 7.5 ft to reach the critical elevation for damaging wave overtopping.

Costs associated with the Fieldston and Sunrise Beach alternatives are summarized in Table D-10. The costs include the purchase of sand purchase, trucking, and spreading following the design template. Projected costs over the next 30 years are also provided assuming renourishment every 6 years when 80% of the volume is lost from the original footprint.

Table D-10. Costs Associated with Nourishment Alternatives at Fieldston and Sunrise Beaches.

Resiliency Alternative	Initial Construction Cost	Costs Over Next 30 Years
Fieldston/Sunrise – Alt 1	$10.18 million	$91.62 million
Fieldston/Sunrise – Alt 2	$11.69 million	$76.00 million
Fieldston/Sunrise – Alt 3	$12.27 million	$92.92 million

3.4.4 Managed Retreat

Managed retreat from the shoreline at Fieldston and Sunrise Beaches was considered as an option for the long-term as a way to reduce coastal vulnerability. Preliminary results from the MC-FRM model show that portions of Fieldston and Sunrise Beach will have a 100% probability of flooding by 2050 (Figures D-11 and D-12 above). While the model data indicate flood pathways from both the ocean and the Green Harbor River system, the most vulnerable properties will be those closest to the ocean that will experience damaging wave overtopping in combination with flooding (Figures D-31 and D-32). The 2020 assessor's database shows total property values for the first row of homes most affected by coastal flooding and wave overtopping to be $18.62 million in Fieldston and $32.17 million in Sunrise. To fully implement this alternative, the Town would need to seek state and federal funding to buy the property owners out. Consideration would also need to be given to the loss of annual tax revenue from the property owners, estimated to be approximately $677,020. To pursue this alternative over the next 30 years, close coordination between the town and affected property owners would be required, and federal and/or state monies would be needed to help the Town with property acquisitions.

Figure D-31. Fieldston Beach showing properties vulnerable to overtopping with potential costs for managed retreat along the first row of homes.

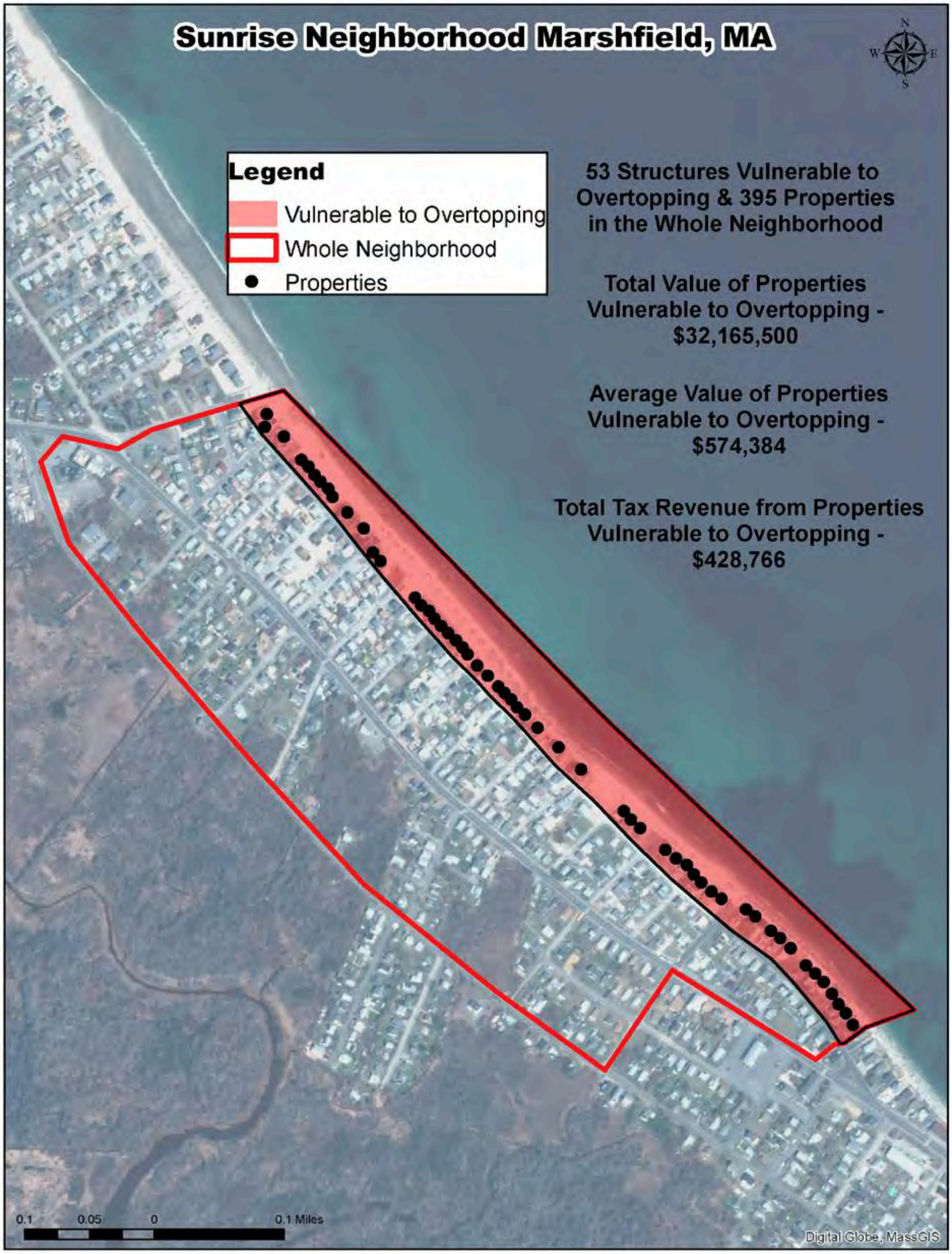


Figure D-32. Sunrise Beach showing properties vulnerable to overtopping with potential costs for managed retreat along the first row of homes.

3.5 Ocean Bluff, Hewitt's Point, Brant Rock and South Brant Rock Beaches (Sekonnet Ave to South end Ocean St.)

The area of Marshfield between Ocean Bluff and South Brant Rock is developed with single family homes and a small pocket of commercial development in the Brant Rock area. Approximately 152 homes and businesses on lots averaging 0.17 acres in size are located in the area seaward of Ocean St., Dyke Rd., and the north end of Island St (Figures D-33 & D-34). A combination of seawalls and/or revetments extends along the entire 7,645 ft stretch of beach. The Town has performed maintenance on these structures over the past 20 to 30 years. Portions of the revetment at Ocean Bluff are currently failing and in need of repair and the Town has commissioned a study to evaluate alternatives for repairing the revetment.

For the most part, beaches on the seaward side of the shore protection structures are privately owned. Recent shoreline change data between 1978 and 2014 show erosion rates as high as -2.0 ft/yr at Ocean Bluff, decreasing to a nearly stable shoreline at the South Brant Rock area (Figure C-16 in Section C). In many areas the seawalls/revetments have prevented further retreat of the shoreline and storm waves interacting with the seawalls have resulted in a lowering of the beach elevation. Nearshore areas of the Ocean Bluff to South Brant Rock shoreline contain naturally occurring rocky intertidal resources. To protect the existing rocky intertidal resources while enhancing the resiliency of the shoreline, both hard engineering and hybrid alternatives were considered. The *status quo* alternate was also considered as well as managed retreat for a longer-term alternative.

3.5.1 Maintain Existing Management Approach – *Status Quo*

Future management by the Town of Marshfield for the Hewitt's Point to South Brant Rock area includes regular maintenance of the existing seawalls and revetments. For the Ocean Bluff area future management estimates include reconstruction of the existing revetment. FEMA data from 1978 to 2018 indicate a total of 45 repetitive loss properties along this section of beach (Figure C-38 in Section C), but additional non-repetitive loss claims are likely. Total claims for this period were $30,830 for Ocean Bluff, $4.04 million for Brant Rock and $2.13 million for South Brant Rock. Table D-11 provides a summary of costs to maintain the *status quo* over the next 30 years (with 5% inflation), including estimated costs for providing storm related public services. This approach will be costly and will do nothing to increase the resiliency of the coastline.

Table D-11. Projected Costs Over Next 30 Years to Maintain Existing Management Approach for Beaches Between Ocean Bluff and South Brant Rock.

Beach	FEMA Repetitive Loss Claims	Maintenance of Shore Protection Structure	Storm Related Public Services	Total
Ocean Bluff	$24,900	$14.00 million	$0.49 million	$14.51 million
Hewitt's Point	$0	$9.27 million	$0.31 million	$9.58million
Brant Rock	$3.26 million	$3.27 million	$0.35 million	$6.89million
South Brant Rock	$1.72 million	$10.22 million	$0.85 million	$12.79 million

(Note: Status quo costs do not include FEMA non-repetitive loss claims)

3.5.2 Enhance and/or Enlarge Shore Protection Structures

The crest elevation of the seawalls and revetments between Ocean Bluff and South Brant Rock range between 18.4 ft and 20.7 ft NAVD88. The elevation of the beach at the toe of the shore protection structures ranges from -0.85 ft to 4.65 ft NAVD88. Under existing conditions, wave overtopping capable of causing structural damage to adjacent homes occurs during a 10-yr storm event and greater at Ocean Bluff, Brant Rock and South Brant Rock Beaches. Hewitt's Point Beach experiences lower rates of overtopping primarily because the elevation of the cobble beach in front of the shore protection structure is higher than the surrounding beaches. Table D-12 provides a summary of seawall crest increases that would be needed to prevent building damage during 10-yr and 50-yr storm events, with current sea levels and with 2 ft of sea level rise (SLR) expected between the 2040 and 2060 time horizon. Based on existing elevations of the infrastructure (i.e., homes, roads), and the design of the shore protection structures themselves, it is likely that crest increases greater than 4 ft would not be practical without significant modifications to the sites (i.e., roadway modifications, building redesign/relocation to landward edge of property) . Costs associated with raising the structures 0.5 – 4.0 ft at each beach would be between $10.58 and $29.23 million. Given that the enlarged structures would not provide the necessary protection during future sea level rise scenarios, this alternative would require further modifications to the seawalls such as adding a revetment along the seaward toe, at additional cost and impact to the beach resources.

Table D-12. Storms Capable of Causing Structural Damage to Buildings from Wave Overtopping between Ocean Bluff and South Brant Rock Beaches and Structure Elevation Increases Needed to Avoid Damaging Wave Overtopping.

Beach Scenario	10-Yr Storm	50-Yr Storm	10-Yr Storm + 2 ft SLR	50-Yr Storm + 2 ft SLR
Ocean Bluff Beach				
Existing Seawall Overtopped	Yes	Yes	Yes	Yes
Seawall Increase	> 8.0 ft	> 8.0 ft	> 8.0 ft	> 8.0 ft
Hewitt's Point Beach				
Existing Seawall Overtopped	No	No	Yes	Yes
Seawall Increase	0 ft	0 ft	4.0 ft	6.5 ft
Brant Rock Beach				
Existing Seawall Overtopped	Yes	Yes	Yes	Yes
Seawall Increase	0.5 ft	3.5 ft	8.0 ft	> 8.0 ft
South Brant Rock Beach				
Existing Seawall Overtopped	Yes	Yes	Yes	Yes
Seawall Increase	3.5 ft	8.0 ft	> 8.0 ft	> 8.0 ft

3.5.3 Nearshore Boulder Field

The existing rocky intertidal resources in the nearshore areas of Ocean Bluff, Hewitt's Point, Brant Rock and South Brant Rock provide an optimum location for additional wave attenuation through construction of an intertidal boulder field. The primary goal of the boulder field would be to reduce wave overtopping during high energy storms and future conditions with sea level rise. Additional engineering would be needed to design the boulder field to ensure reductions in wave overtopping for specific storm events; however, assuming a conceptual design with a 60 ft wide boulder field along the entire 7,645 ft stretch of beach, estimated costs for construction would be $20.49 million. The footprint of the boulder field would be approximately 458,700 sq ft.

3.5.4 Managed Retreat

A plan for managed retreat from the shoreline between Ocean Bluff and South Brant Rock was considered as an option for the long-term as a way to reduce coastal vulnerability. Preliminary results from the MC-FRM model show the highest probabilities of flooding by 2050 to be located along the south end of Ocean Bluff, Brant Rock and the southern end of South Brant Rock (Figure D-12). While the model data indicate flood pathways from both the ocean and the Green Harbor River system, the most vulnerable properties will be those closest to the ocean that will experience damaging wave overtopping in combination with flooding. The 2020 assessor's database shows total property values for homes and businesses most affected by coastal flooding and wave overtopping to be $57.10 million. To fully implement this alternative, the Town would need to seek state and federal funding to buy the property owners out. Consideration would also need to be given to the loss of annual tax revenue from the property owners, estimated to be approximately $761,084. Figures D-33 and D-34 show the affected properties for the Brant Rock and South Brant Rock areas. To pursue this alternative over the next 30 years, close coordination between the town and affected property owners would be required, and federal and/or state monies would be needed to help the town with property acquisitions.

Figure D-33. Brant Rock showing properties vulnerable to overtopping with potential costs for managed retreat for the most vulnerable properties.

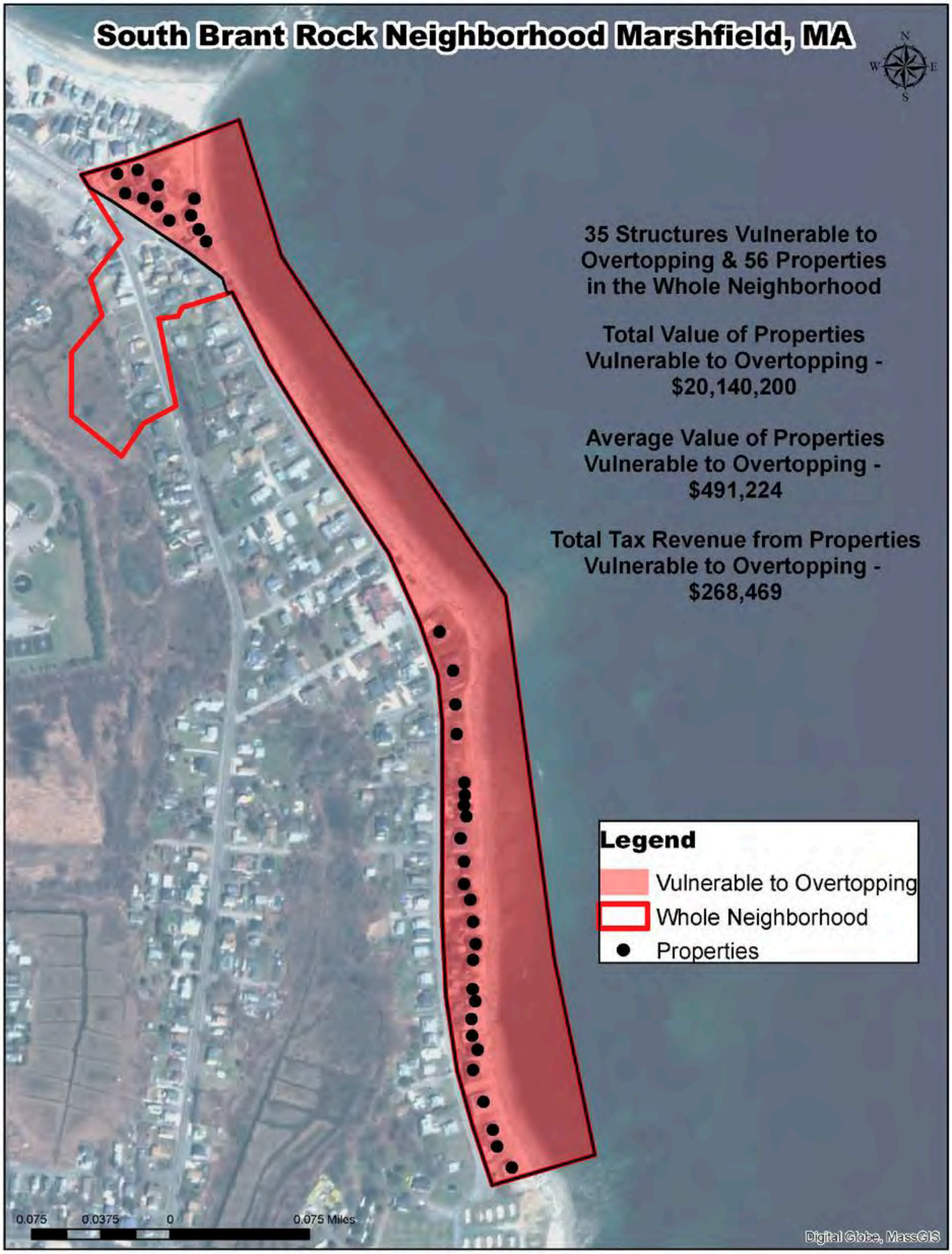


Figure D-34. South Brant Rock showing properties vulnerable to overtopping with potential costs for managed retreat for the most vulnerable properties.

3.6 Blackman's Point Beach

Blackman's Point contains a seasonal campground with manufactured homes and recreational vehicles that is open from May 1 to September 30. The campground is located at the top of a coastal bank and the bank is covered with loose boulders. Nearshore areas of Blackman's Point contain extensive rocky intertidal resources composed of bedrock and cobbles. The campground and adjacent beach are privately-owned, and maintenance of the shoreline is not performed by the Town of Marshfield. Recent shoreline change data between 1978 and 2014 show a relatively stable shoreline (Figure C-16 in Section C). Given the seasonal use of the area and the low erosion rates, only two alternatives were considered; *status quo* and managed retreat.

3.6.1 Maintain Existing Management Approach – *Status Quo*

Maintaining the existing management approach for Blackman's Point would require no action from the Town of Marshfield. Owners of the manufactured homes and recreational vehicles in the first row along the top of the coastal bank are required to remove the structures in the off season to avoid storm damage. As long as this practice continues, vulnerability to coastal storms will be minimized.

3.6.2 Managed Retreat

Managed retreat from Blackman's Point campground was considered as an option for the long-term to reduce risks caused by climate change. Preliminary results from the MC-FRM model show 100% probability of flooding in 2050 across the southern end of the campground (Figures D-12 and D-13 above). As such, the managed retreat alternative includes abandoning the most vulnerable section of the campground over the next 30-year period. Costs associated with this alternative were not available at the time this document was prepared.

3.7 Blue Fish Cove Beach (Cove/A St. junction to Water St.)

The Blue Fish Cove area of Marshfield is developed with single family homes on a narrow and low-lying barrier beach that separates Green Harbor River from the Atlantic Ocean. The area seaward of A St. and north of the Green Harbor jetty includes approximately 26 homes on lots averaging 0.20 acres in size (Figure D-34). The ocean facing homes at the northern end of Blue Fish Cove Beach are protected by stone revetments. The homes at the southern end of Blue Fish Cove have loose stones placed directly on the beach. A large outcropping of bedrock is located on the beach east of the Green Harbor jetty. Recent shoreline change data between 1978 and 2014 show a relatively stable shoreline (Figure C-16 in Section C). The beaches and shore protection structures in the area are privately owned. As such, the only resiliency measures considered by the Town of Marshfield for Blue Fish Cove were *status quo* and managed retreat.

3.7.1 Maintain Existing Management Approach – *Status Quo*

Maintaining the existing management approach for Blue Fish Cove Beach would require no action from the Town of Marshfield. Since the existing structures are owned and maintained by the property owners, it is assumed that all costs associated with maintenance would be covered by the owners. With future increases in sea level, it is assumed that the *status quo* alternative will not provide the necessary level of protection needed to protect the homes from damages caused by flooding and wave overtopping.

3.7.2 Managed Retreat

Managed retreat from the shoreline in the Blue Fish Cove area was considered as an option for the long-term to reduce coastal vulnerability. Preliminary results from the MC-FRM model show 100% probability of flooding across the entire barrier beach by 2050 (Figure D-13 above). Given the vulnerability of this area to flooding from both the ocean and Green Harbor, costs associated with retreat of all homes from the Blue Fish Cove area were considered. The 2020 assessor's database shows property values for all 24 homes affected by coastal flooding and wave overtopping in 2050 to be $12.86 million (Figure D-35). To fully implement this alternative, the Town would need to seek state and federal funding to buy the property owners out. Consideration would also need to be given to the loss of annual tax revenue from the property owners, estimated to be approximately $171,446. To pursue this alternative over the next 30 years, close coordination between the town and affected property owners would be required, and federal and/or state monies would be needed to help the town with property acquisitions.

3.8 Green Harbor Beach

Green Harbor Beach is located immediately west of the entrance to Green Harbor and is protected by the jetty that runs along the western side of the harbor. The Town owns and operates a popular public beach at Green Harbor. The beach width averages 140 ft to 230 ft and is backed by an extensive system of coastal dunes. There are 19 developed properties at Green Harbor Beach located landward of the coastal dunes along Bay Ave. Most of the properties are developed with single family homes on lots averaging 0.13 acres in size. The beach is approximately 585 ft long and does not contain any shore protection structures. Although recent shoreline change data between 1978 and 2014 show a trend of erosion (Figure C-16 in Section C), aerial photographs dating back to 2001 in Google Earth indicate little change in the location of MHW or the toe of the dune. Given the wide sand beach and dune system in combination with the stable shoreline, only two alternatives were considered; *status quo* and managed retreat.

Figure D-35. Blue Fish Cove area showing properties vulnerable to flooding and overtopping with potential costs for managed retreat.

3.8.1 Maintain Existing Management Approach – Status Quo

The Town's currently maintains one controlled access path between the parking lot and Green Harbor Beach. A second access path from the end of Bay Ave runs along the Green Harbor jetty. Sand fencing is commonly installed along the toe of the dune to help accumulate wind-blown sediment and keep foot traffic off the dunes. Many years ago, the Town accepted sediment for beneficial reuse from dredging in Green Harbor; however, for the past twenty-five (25) years sediment dredged from the Harbor has been placed in a nearshore disposal site near the Marshfield/Duxbury town line. As such, there is not a regular or frequent program for nourishment of the beach at Green Harbor. The *status quo* alternative would continue the current practices to manage the public beach. Although the primary dune does not meet FEMA's criteria for providing protection during a 100-yr event, the 100 ft to 300 ft wide feature provides a natural and resilient buffer to coastal storms.

3.8.2 Managed Retreat

Managed retreat from the shoreline at Green Harbor Beach was considered as an option for the long-term to reduce coastal vulnerability. Preliminary results from the MC-FRM model show a high probability of flooding across the entire barrier beach by 2050 (Figure D-13 above). Given the vulnerability of this area to flooding from both the ocean and Green Harbor, costs associated with retreat of all homes from the Green Harbor Beach area was considered. The 2020 assessor's database shows property values for all homes affected by coastal flooding in 2050 to be $20.18 million. To pursue this alternative over the next 30 years, close coordination between the town and affected property owners would be required, and federal and/or state monies would be needed to help the town with property acquisitions.

3.9 Bay Ave. and Gurnet Rd. Beaches

The Bay Ave. and Gurnet Rd. Beaches are located along the barrier beach north and south of the Marshfield and Duxbury town line. Bay Ave. barrier beach in Marshfield is developed with 125 single family homes on average lot sizes of 0.37 acres. In Duxbury, the barrier beach (excluding Marginal and Pine Point Rds.) is developed with 165 single family homes on average lot sizes of 0.21 acres. Vertical seawalls extend along the entire 6,010 ft stretch of beach. The only exception occurs along a 350 ft stretch of the shoreline in Duxbury where no coastal engineering structures are present. The seawalls in this area are in poor condition, having sustained damage most recently during the winter 2018 storm season. Both towns are either in the process of repairing the seawalls or planning to repair them in the next few years. Permits issued for the seawall repairs include a condition for beach nourishment to restore sediment to the system and to provide protection for the seawalls. Most of the beaches in this area are privately owned.

Recent shoreline change data between 1978 and 2014 show a trend of decreasing erosion from north to south (Figure C-16 in Section C). Rates of erosion are as high as -2.0 ft/yr along Bay Ave. in Marshfield and decrease to approximately -0.5 ft/yr along Gurnet Rd. in Duxbury. In many places the seawalls have prevented further retreat of the shoreline and storm waves interacting with the seawalls have resulted in a lowering of the beach elevation. This change in beach elevation is not captured in the shoreline change data. Wave overtopping during storms can cause significant damage in this area. Resiliency measures considered for Bay Ave. and

Gurnet Rd. Beaches included the *status quo* alternative and enhancing the existing shore protection structures. Beach/dune nourishment was also considered to restore sediment to the system while also protecting the seawalls from further damage, reducing the potential for wave overtopping and minimizing the need for additional toe protection to prevent collapse of the seawall. Finally, managed retreat was considered as a long-term alternative.

3.9.1 Maintain Existing Management Approach – Status Quo

Future management by the Towns of Marshfield and Duxbury for the Bay Ave. and Gurnet Rd. Beaches includes regular maintenance of the seawalls that are currently or planned to be rebuilt. FEMA data from 1978 to 2018 indicate between 20 and 30 repetitive loss properties for Bay Ave. and between 30 and 40 repetitive loss properties for Gurnet Rd. Beach (Figure C-38 in Section C). Total claims for this period were $2.13 million for the Bay Ave. properties and $3.04 million for the Gurnet Rd. properties, although additional non-repetitive loss claims likely occurred during this time period as well. Table D-13 provides a summary of costs to maintain the *status quo* for these beaches over the next 30 years, including estimated costs for providing storm related public services. Continuing with the current management approach will be costly and will do nothing to increase the resiliency of the coastline.

Table D-13. Projected Costs Over Next 30 Years to Maintain Existing Management Approach for Bay Ave. and Gurnet Rd. Beaches.

Beach	FEMA Repetitive Loss Claims	Maintenance of Shore Protection Structure	Storm Related Public Services	Total
Bay Ave.	$1.72 million	$4.85 million	$0.51 million	$7.08 million
Gurnet Rd.	$2.46 million	$10.17 million	$1.07 million	$13.69 million

(Note: Status quo costs do not include FEMA non-repetitive loss claims)

3.9.2 Enhance and/or Enlarge Shore Protection Structures

The crest elevation of the seawalls along Bay Ave and Gurnet Rd Beaches is approximately 15.4 ft NAVD88. The elevation of the beach at the toe of the seawalls increases from 1.6 ft to 6.2 ft NAVD88 from north to south. Under existing conditions, wave overtopping capable of causing structural damage to adjacent homes occurs during a 10-yr storm event and greater at Bay Ave and Gurnet Rd Beaches. Table D-14 provides a summary of seawall crest increases that would be needed to prevent structural damage during 10-yr and 50-yr storm events, with current sea levels and with 2 ft of sea level rise (SLR) expected between the 2040 and 2060 time horizon. Based on existing elevations of the infrastructure landward of the seawalls, and the design of the seawalls themselves, it is likely that crest increases greater than 4 ft would not be practical without significant modifications to the sites (i.e., roadway modifications, building redesign/relocation to landward edge of property, raise grade behind the seawalls). Costs associated with raising the structures 3.5 – 8.0 ft along the entire 5,675 ft of Fieldston and Sunrise Beach would be between $39.73 and $51.08 million. Given that the enlarged structures would not provide the necessary protection during future sea level rise scenarios, this alternative would require further modifications to the seawalls such as adding a revetment along the seaward toe.

Table D-14. Storms Capable of Causing Structural Damage to Buildings from Wave Overtopping at Bay Ave. and Gurnet Rd. Beaches and Seawall Elevation Increases Needed to Avoid Damaging Wave Overtopping.

Beach Scenario	10-Yr Storm	50-Yr Storm	10-Yr Storm + 2 ft SLR	50-Yr Storm + 2 ft SLR
Bay Ave. Beach				
Existing Seawall Overtopped	Yes	Yes	Yes	Yes
Seawall Increase	7.0 ft	> 8.0 ft	> 8.0 ft	> 8.0 ft
Gurnet Rd. Beach				
Existing Seawall Overtopped	No	Yes	Yes	Yes
Seawall Increase	0	3.5 ft	3.5 ft	6.0 ft

3.9.3 Beach and Dune Nourishment

Three (3) beach and dune nourishment alternatives were developed for the Bay Ave. and Gurnet Rd. Beach areas. The design elements, footprint areas and nourishment volumes for each alternative are provided in Table D-15. All alternatives extended along the entire 6,010 ft stretch of privately-owned beach (Figure D-36). Coordination between the Town and private property owners is currently underway to secure rights of entry for construction and public access easements.

Table D-15. Nourishment Alternatives Evaluated for Bay Ave. and Gurnet Rd. Beaches

Alternative	Resiliency Type	Design Elements	Footprint Area (acres)	Volume (cu yds)
Bay Ave/Gurnet Rd – Alt 1	dune + beach nourishment	dune crest elev. = 11 ft NAVD88 dune crest width = 20 ft dune seaward slope = 1:5 berm elev. = 8.0 ft NAVD88 berm width = 85 ft nearshore slope = 1:20	50.3	313,160
Bay Ave/Gurnet Rd – Alt 2	dune + beach nourishment	dune crest elev. = 13 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:5 berm elev. = 9.5 ft NAVD88 berm width = 90 ft nearshore slope = 1:12	36.4	511,030
Bay Ave/Gurnet Rd – Alt 3	beach nourishment	berm elev. = 11 ft NAVD88 berm width = 100 ft nearshore slope = 1:15	41.5	527,740

Cross shore modeling of existing conditions and the three (3) nourishment alternatives was performed for 1-yr, 2-yr and 10-yr storm events. The modeling considered the mixed grain size beach and assumed 50% sand at 0.38 mm and 50% gravel at 11.5 mm. Spreading analysis were also performed to estimate the percentage of fill remaining within the project area through time. Results of the spreading analysis were used to develop a schedule for renourishment.

Figure D-36. Nourishment alternatives considered for Bay Ave. and Gurnet Rd. Beaches.

Results of the 1-yr, 2-yr and 10-yr storm simulations on the existing beaches at Bay Ave. and Gurnet Rd. show scour along the toe of the seawalls and a general lowering of the beach (Figure D-37). Sediment eroded from the beach is primarily transported to the intertidal zone approximately 80 ft from the seawalls. These model results are consistent with performance of the beaches during past storms and with a long-term lowering of the beach elevation observed in the historical LiDAR data (Figures C-18 and C-19 in Section C).

Figure D-37. XBeach and XBeach-G model results for existing conditions at Bay Ave. and Gurnet Rd. Beaches for 1-yr, 2-yr and 10-yr storm events.

Figures D-38 through D-40 show performance of the nourishment alternatives during 1-yr, 2-yr and 10-yr storms, respectively. The model results for the 1-yr storm show erosion of the berm (dry beach) with Bay Ave/Gurnet Rd – Alt 1 and Alt 2 (Figure D-38). The berm remains intact with Alt 3, but there is scarping of the beach immediately below the berm. The dunes in Bay Ave/Gurnet Rd – Alt 1 and Alt 2 remain intact with the 1-yr storm. Retreat of the MHW line is greatest with Alt 2 at 43 ft and lowest with Alt 1 and 26 ft. Sediment eroded from the upper portion of the beach is transported seaward to the intertidal and subtidal portions of the beach with all alternatives.

For the 2-yr storm, all three nourishment alternatives show erosion of the berm (Figure D-39). Bay Ave/Gurnet Rd – Alt 1 and Alt 2 lose most of the berm and some material from the dune. Bay Ave/Gurnet Rd – Alt 3 loses approximately one-third the width of the nourished berm. Retreat of MHW is between 39 and 42 ft with all three alternatives. Sediment eroded from the upper portion of the beach is transported seaward to the intertidal and subtidal portions of the beach with all scenarios.

With a 10-yr storm, the cross-shore modeling shows very similar results for all three alternatives (Figure D-40). The dunes and berm are eroded and the level of the beach immediately in front of the seawalls drops to 7.6 ft NAVD88 for Bay Ave/Gurnet Rd - Alt 1, 8.5 ft NAVD88 for Alt 2 and 9.0 ft NAVD88 for Alt 3. Retreat of the MHW line is greatest with Alt 1 at

121 ft and smallest with Alt 3 at 104 ft. Sediment eroded from the upper portion of the beach is transported seaward to the intertidal and subtidal portions of the beach with all alternatives.

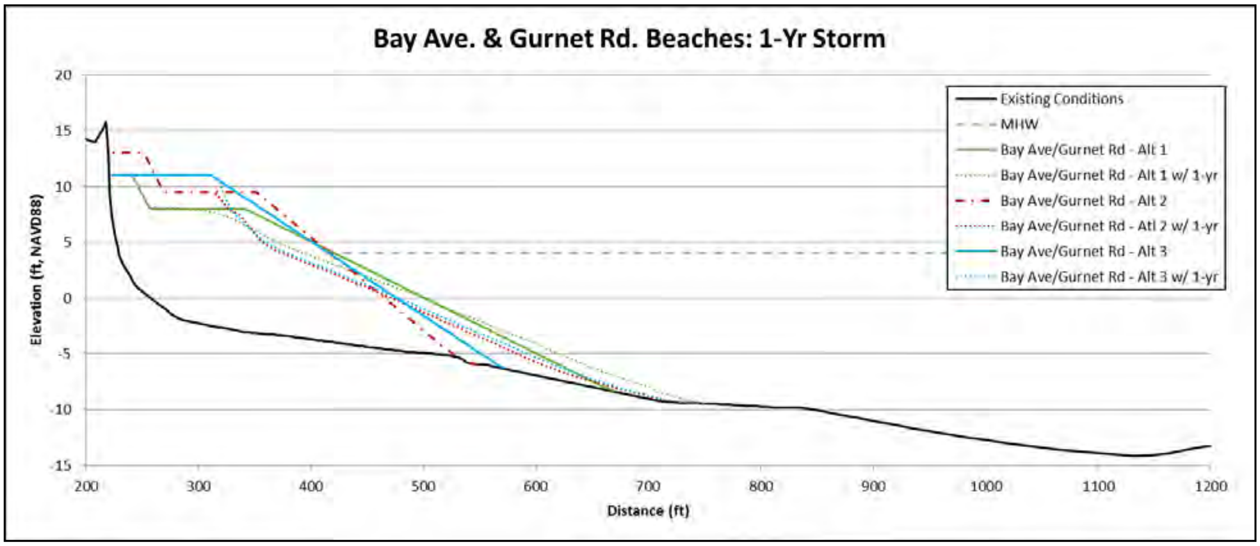


Figure D-38. XBeach and XBeach-G model results for nourishment alternatives at Bay Ave. and Gurnet Rd. Beaches for a 1-yr storm event.

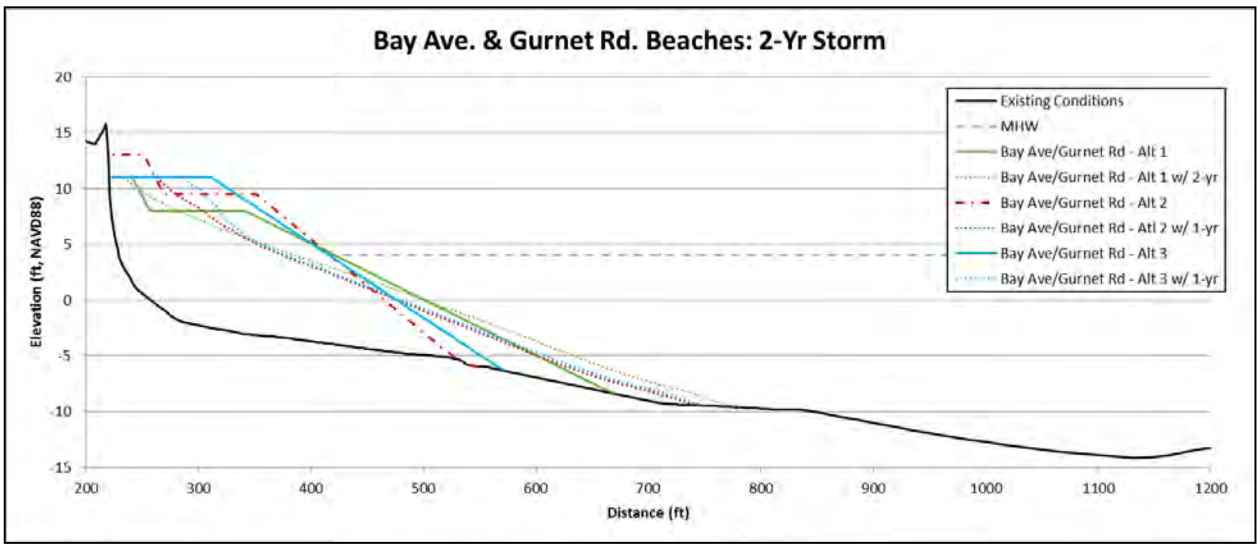


Figure D-39. XBeach and XBeach-G model results for nourishment alternatives at Bay Ave. and Gurnet Rd. Beaches for a 2-yr storm event.

Results of the design life computations for the Bay Ave. and Gurnet Rd. Beach alternatives are shown in Figure D-41. The fill material is shown to initially spread relatively quickly, as indicated by the decrease in percentage of fill remaining, as the shoreline adjusts to a new equilibrium. Based on the criteria that renourishment should be performed when 70% to 80% of the volume is lost from the original footprint, the modeling suggests that renourishment will be needed between 3 and 5.5 years after initial construction. Bay Ave/Gurnet Rd – Alt 1 has the shortest service life and Bay Ave/Gurnet Rd – Alt 3 has the longest service life. The service life of a nourishment project at Bay Ave. and Gurnet Rd. Beaches could be extended through beneficial reuse of sediment dredged annually from Green Harbor. With annual renourishment of 30,000 cy from the harbor dredging, the service life of Alt 1 would be increased by 5 to 6 years (Figure 42).

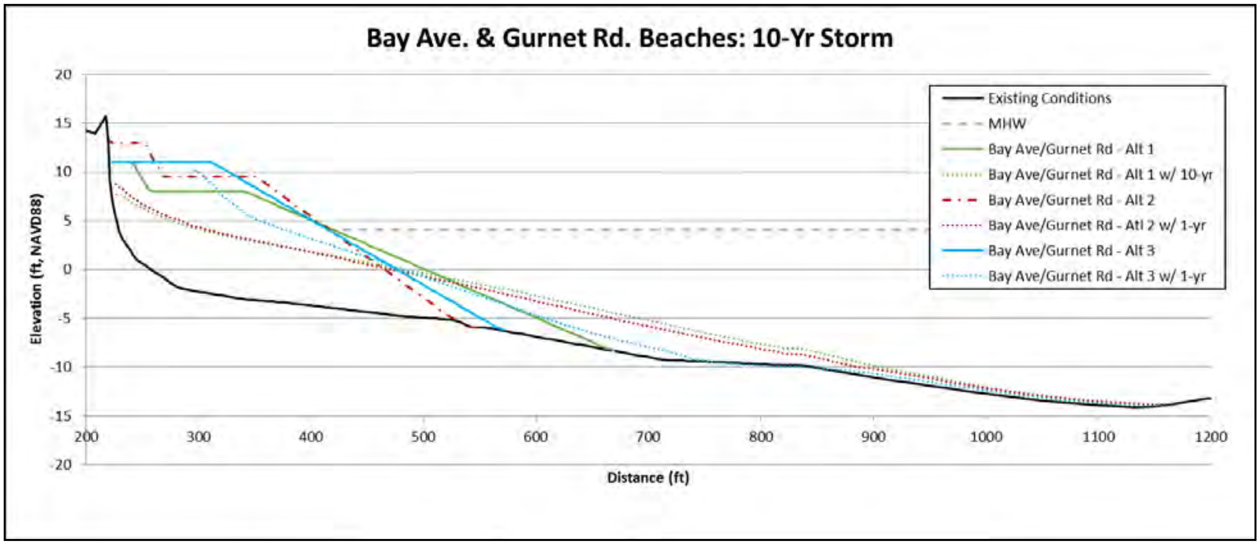


Figure D-40. XBeach and XBeach-G model results for nourishment alternatives at Bay Ave. and Gurnet Rd. Beaches for a 10-yr storm event.

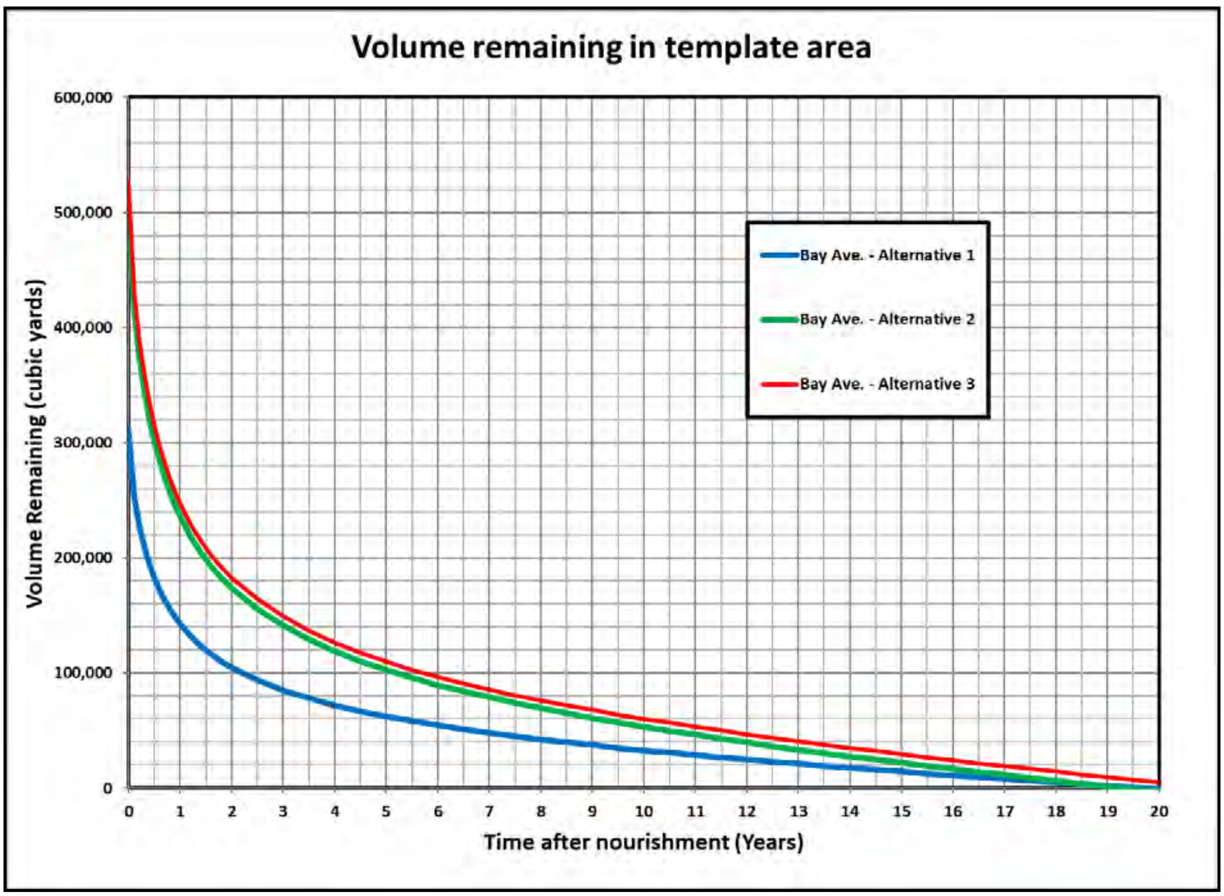


Figure D-41. Service life estimates for beach nourishment alternatives at Bay Ave. and Gurnet Rd. Beaches.

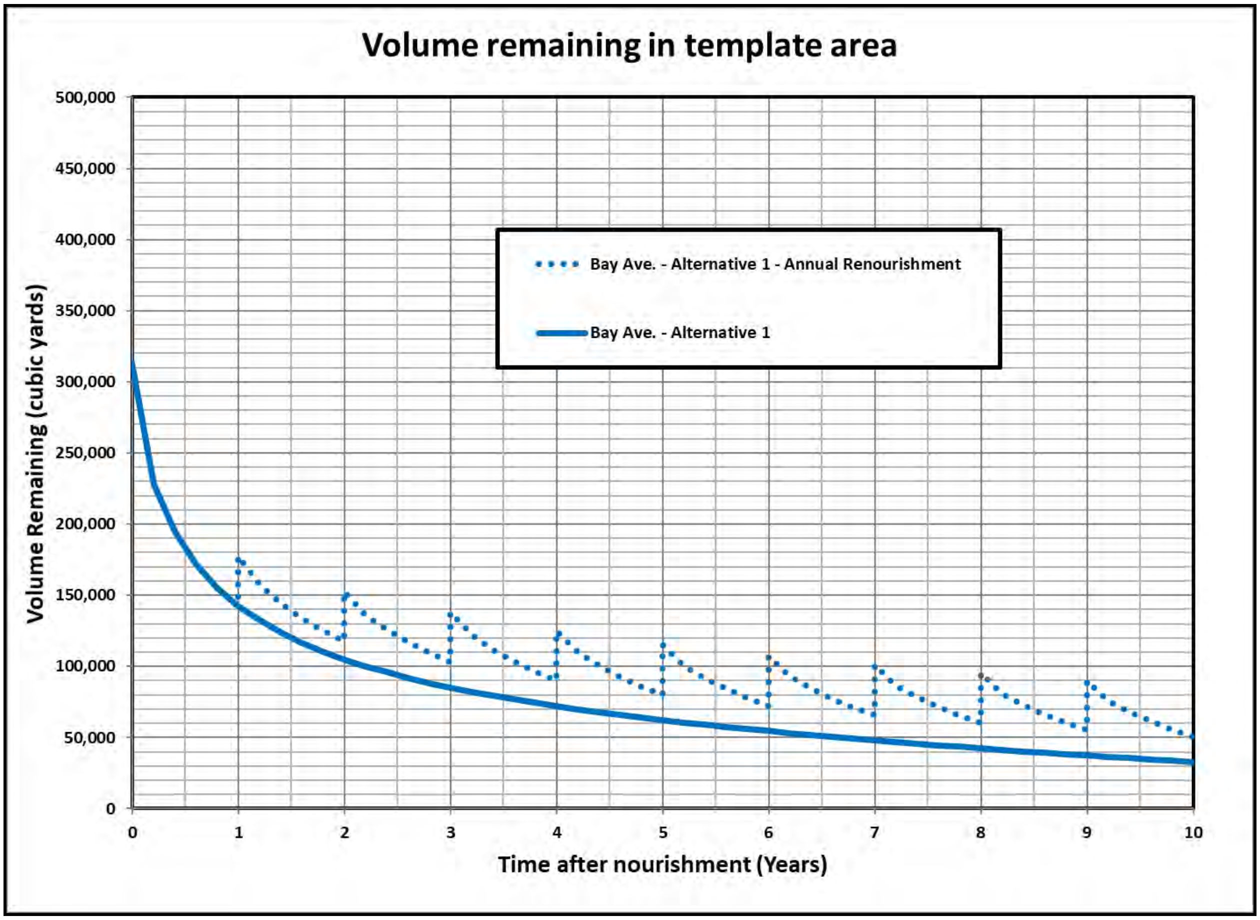


Figure D-42. Service life estimate for Bay Ave/Gurnet Rd – Alt 1 assuming annual renourishment of 30,000 cubic yards dredged from Green Harbor.

Figure D-43 shows the width of the beach berm (dry beach) over time for the three Bay Ave. and Gurnet Rd. nourishment alternatives. As with the service life estimates, the berm width decreases rapidly during the first year following construction. By year 2 the berm widths for all alternatives are estimated to be 30 ft.

Impacts of the three (3) Bay Ave/Gurnet Rd nourishment alternatives on rates of wave overtopping were also evaluated. Calculations summarized in Table D-14 above indicate that existing rates of wave overtopping decrease from north to south along the Bay Ave. and Gurnet Rd. Beaches, with damaging overtopping occurring during a 10-yr storm event and greater. Beach profile data for the 10-yr storm scenarios from XBeach and XBeach-G were used to evaluate changes in overtopping rates for each alternative. The calculations showed a 100% reduction in wave overtopping for all three (3) alternatives indicating no damage to buildings from overtopping during a 10-yr storm event.

Over time as additional storms and longshore spreading act to reshape the nourishment, the elevation of the beach in front of the seawalls will lower and the risk of overtopping will increase. To quantify the critical beach elevation at which damaging wave overtopping starts to occur, additional calculations were performed for the Bay Ave. and Gurnet Rd. Beaches. For the 10-yr and 50-yr storms, damaging overtopping will begin to occur when the beach drops to an elevation of 3.5 ft and 4.5 ft NAVD88, respectively. For Bay Ave/Gurnet Rd – Alt 1 the berm would have to lower 3.5 to 4.5 ft to reach the critical elevation. Because the starting berm elevations for Bay Ave/Gurnet Rd – Alt 2 and Alt 3 are higher, the beach would have to lower between 5 and 7.5 ft to reach the critical elevation for damaging wave overtopping.

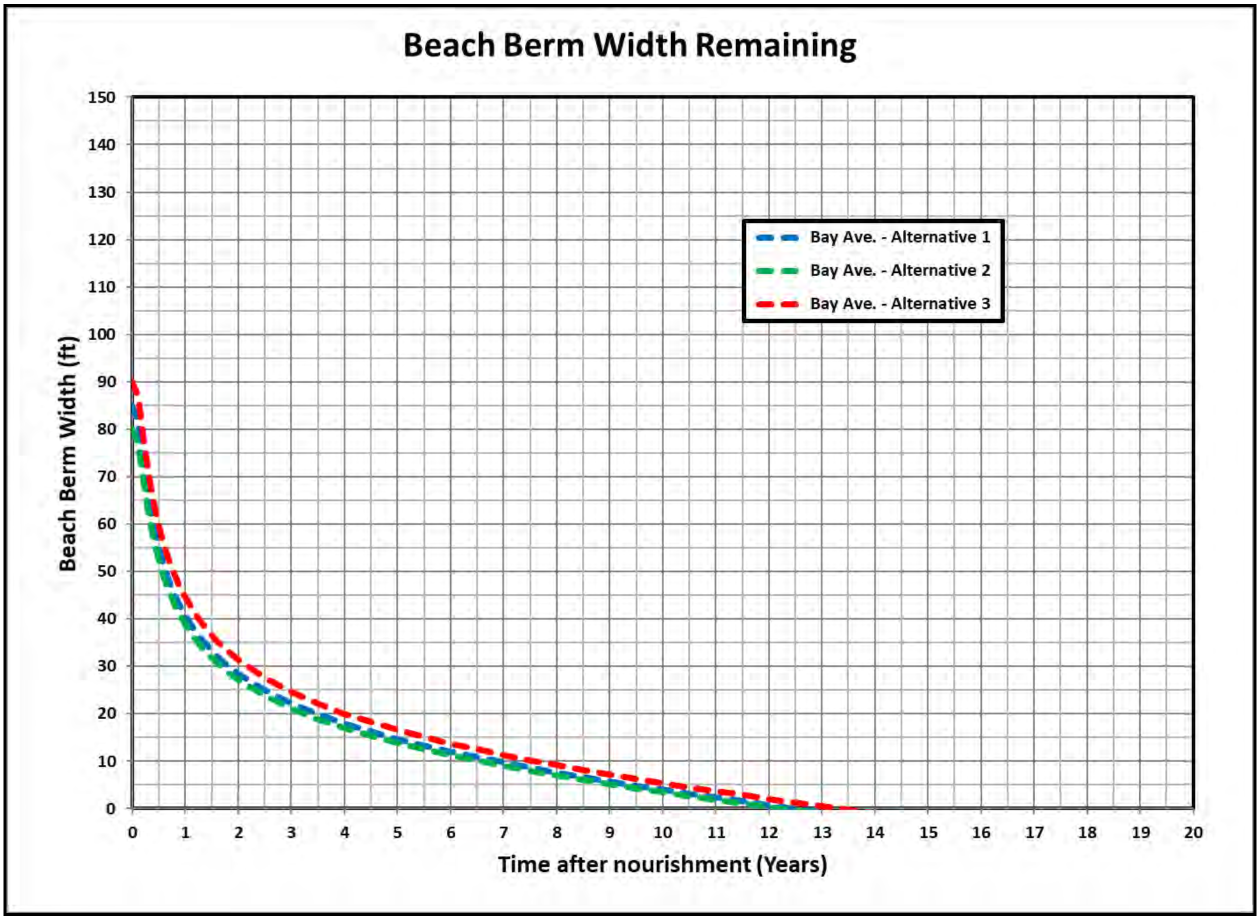


Figure D-43. Berm width over time for beach nourishment alternatives at Bay Ave. and Gurnet Rd. Beaches.

Costs associated with the Bay Ave. and Gurnet Rd. Beach alternatives are summarized in Table D-16. The costs include the purchase of sand purchase, trucking, and spreading following the design template. Projected costs over the next 30 years are also provided assuming renourishment every 5 years for Alt 1, every 3.75 years for Alt 2 and every 3.3 years for Alt 3 when 80% of the volume is lost from the original footprint.

Table D-16. Costs Associated with Nourishment Alternatives at Bay Ave. and Gurnet Rd. Beaches.

Resiliency Alternative	Initial Construction Cost	Costs Over Next 30 Years
Bay Ave/Gurnet Rd – Alt 1	$9.40 million	$53.24 million
Bay Ave/Gurnet Rd – Alt 2	$15.33 million	$76.65 million
Bay Ave/Gurnet Rd – Alt 3	$15.83 million	$70.53 million

3.9.4 Managed Retreat

Managed retreat from the shoreline at Bay Ave. and Gurnet Rd. Beaches was considered as an option for the long-term to reduce coastal vulnerability. Preliminary results from the MC-FRM model show that all of Bay Ave. and portions of Gurnet Rd. Beach will have a 100% probability of flooding by 2050 (Figures D-13 above). While the model data indicate flood pathways from the ocean as well as Green Harbor and Duxbury Bay, the most vulnerable properties will be those closest to the ocean that will experience damaging wave overtopping in combination with flooding (Figures D-44 and D-45). The 2020 assessor's database shows property values for the first row of homes most affected by coastal flooding and wave overtopping to be \$36.08 million along Bay Ave. and \$47.30 million at Gurnet Rd. The annual tax revenue for the Town of Marshfield from these property owners is \$975,089; for the Town of Duxbury the annual tax revenue is \$705,984. To pursue this alternative over the next 30 years, close coordination between the towns and affected property owners would be required, and federal and/or state monies would be needed to help the town with property acquisitions.

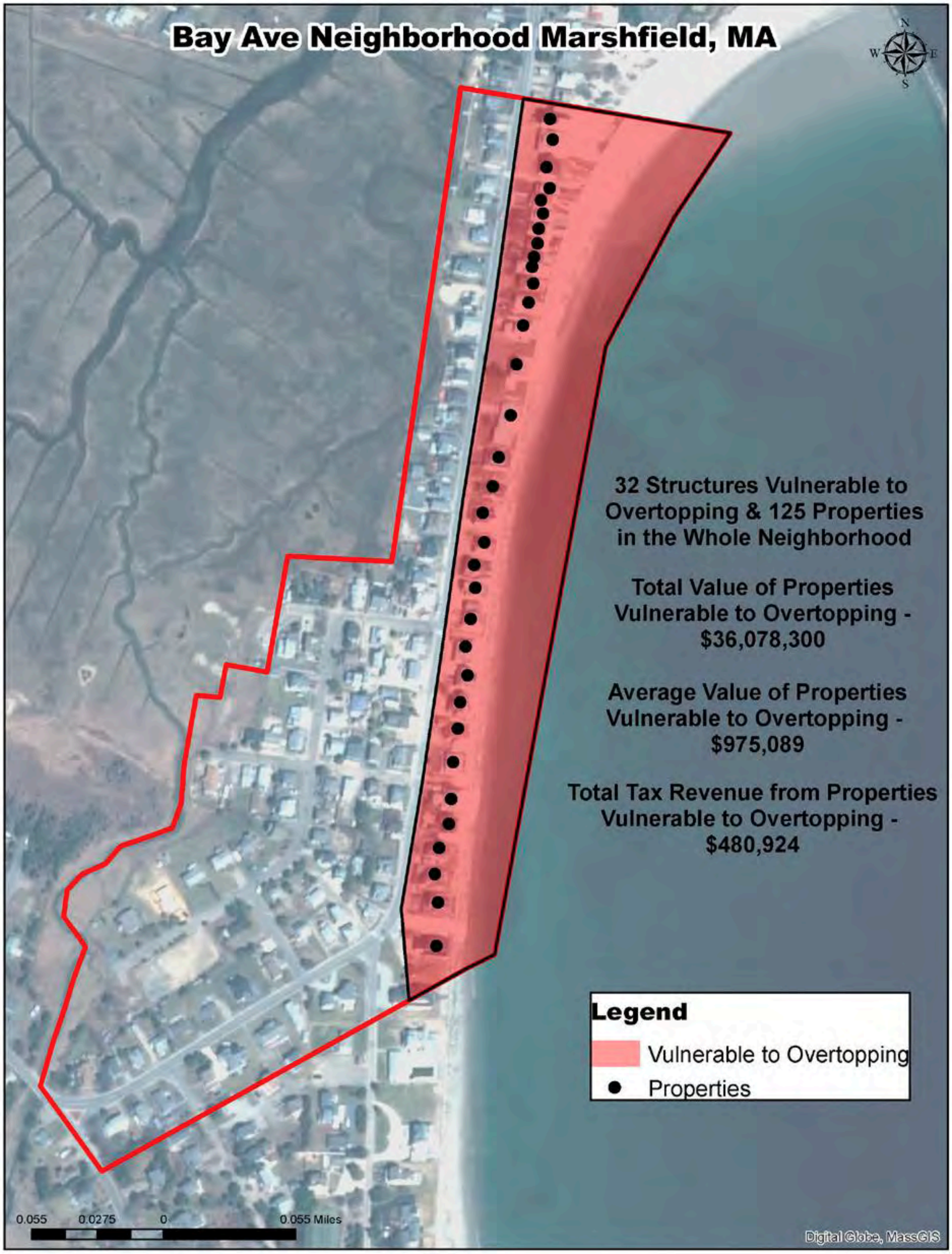


Figure D-44. Bay Ave. area showing properties vulnerable to flooding and overtopping with potential costs for managed retreat.

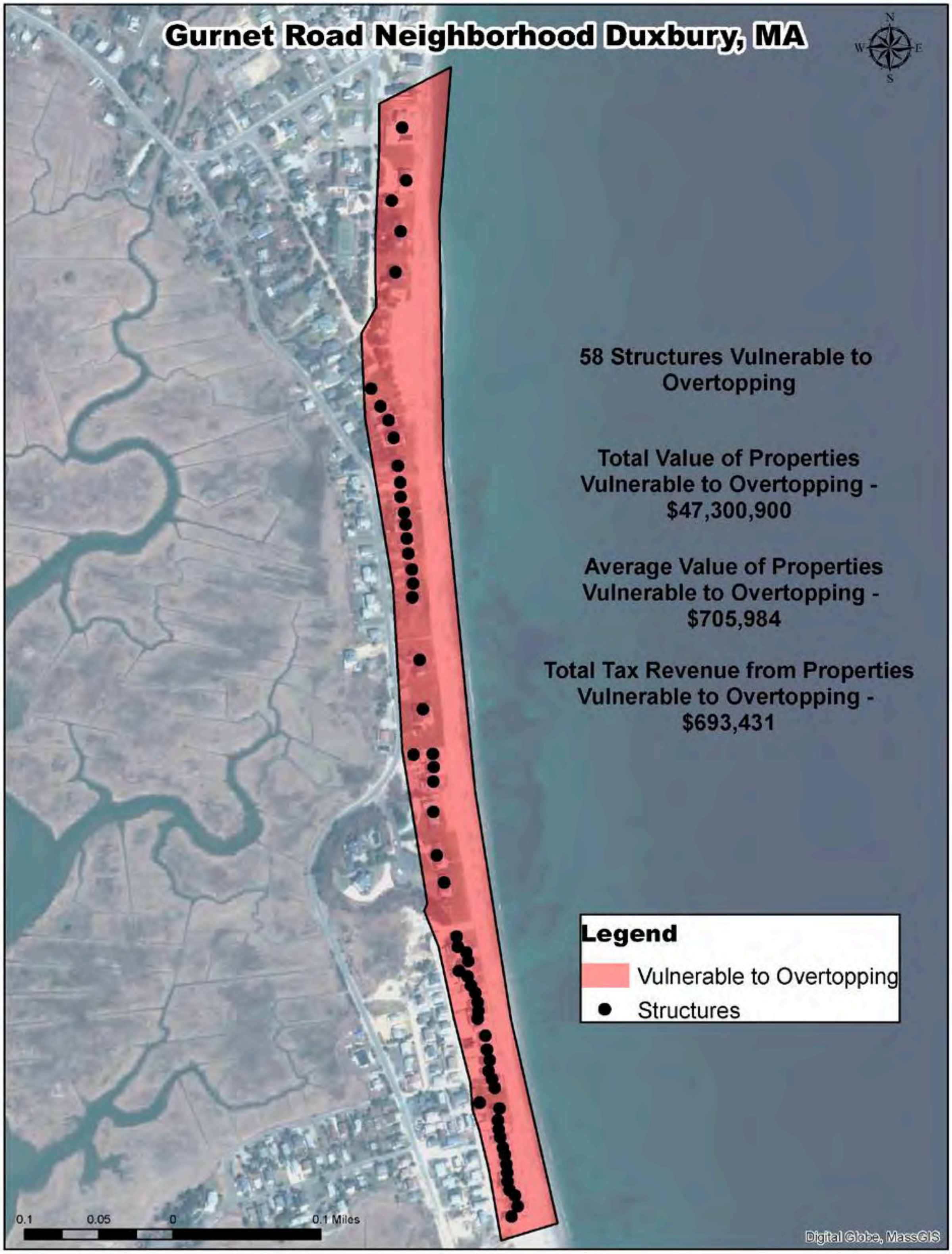


Figure D-45. Gurnet Rd. area showing properties vulnerable to flooding and overtopping with potential costs for managed retreat.

3.10 Site Specific Selection of Resiliency Alternatives

The preceding assessment was utilized to select the most appropriate alternatives for building shoreline resiliency at key locations along the Marshfield and Duxbury shoreline. While emphasis was placed on identification of soft engineering approaches for increasing shoreline resiliency, depending on the beach, it was not always feasible to identify appropriate soft engineering solutions. For these beaches, further investigation and engineering design will be needed by the Towns before proceeding with final plans and permitting for enhanced shore protection and improved resiliency. The remaining locations where soft engineering solutions were identified as viable alternatives were carried through to the next phase of the analysis to evaluate environmental impacts so that a preferred alternative could be selected. Table D-17 provides a summary of alternatives considered for each beach and identifies the sites carried forward to the assessment of impacts.

Table D-17. Summary of Resiliency Alternatives Considered for Beaches in Marshfield and Duxbury Showing Locations Where Beach and/or Dune Nourishment was Carried Through to the Assessment of Impacts.

Beach	*Status Quo*	Enhance/ Enlarge Existing Structures	Beach Nourishment	Dune Nourishment	Nearshore Boulder Field	Managed Retreat	Further Design Needed	Carried Through to Assessment of Impacts
Rexhame Public	√	NA	√	√	X	√	X	√
Rexhame	√	√	X	X	√	√	√	X
Winslow Ave.	√	NA	X	√	X	√	X	√
Fieldston	√	√	√	√	X	√	X	√
Sunrise	√	√	√	√	X	√	X	√
Ocean Bluff	√	√	X	X	√	√	√	X
Hewitt's Point	√	√	X	X	√	√	√	X
Brant Rock	√	√	X	X	√	√	√	X
South Brant Rock	√	√	X	X	√	√	√	X
Blackman's Point	√	NA	X	X	√	√	X	X
Blue Fish Cove	√	√	X	X	√	√	√	X
Green Harbor	√	NA	X	X	X	√	X	X
Bay Ave.	√	√	√	√	X	√	X	√
Gurnet Rd.	√	√	√	√	X	√	X	√

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Section E

Assessment of Impacts

E. ASSESSMENT OF IMPACTS

Environmental impacts associated with the beach and dune nourishment alternatives considered for Rexhame Public Beach, Winslow Ave. Beach, Fieldston and Sunrise Beaches and Bay Ave. and Gurnet Rd. Beaches are discussed in this section. Both the potential adverse impacts and benefits to the environment from the various alternatives are addressed. Although environmental impacts are unavoidable, the project design focused on minimizing potential adverse impacts, while achieving project objectives. The overall benefits of restoring sediment to critically eroded beaches via any of the alternatives considered include the following:

- enhanced storm damage protection and flood control
- reduced wave overtopping
- protection for existing coastal engineering structures that serve as the last line of defense against erosion
- enhanced wildlife habitat for federal and state-listed species
- enlarged area for recreational use

The assessment of impacts associated with all eleven (11) beach and/or dune nourishment alternatives are discussed in this section, in terms of physical and ecological impacts.

1.0 Impacts Associated with Alternatives for Rexhame Public Beach

Table E-1 provides a summary of the three (3) beach and/or dune nourishment alternatives developed for Rexhame Public Beach. The nourishment designs extend along the entire 1,980 ft of undeveloped barrier beach (Figure E-1). Most of the beach is owned by the Town of Marshfield and open to the public. The Sea Rivers Trust owns the northern most undeveloped parcel immediately north of Rexhame Public Beach (See Project Plans in Section O). The Town will be coordinating with Sea Rivers Trust regarding extension of the project onto their property.

All three (3) nourishment alternatives provide protection from dune overwash for storms up the 50-yr event (Figures D-17 and D-18 in Section D), and the FEMA 540 ft rule indicates protection up to the 100-yr storm event. Service life estimates for the two (2) beach nourishment alternatives indicate that 70% to 80% of the nourishment is lost within the first year after construction (Figure D-19 in Section D).

1.1 Physical Impacts – Rexhame Public Beach

Shoreline Change – The beach nourishment alternatives, Alt 2 and Alt 3, will move MHW seaward by 50 and 75 ft, respectively. The location of MHW will not be altered by Alt 1 since it involves only dune nourishment. Although the background rate of erosion for this area of Marshfield will not change as a result of the nourishment alternatives, by placing additional sediment on the dunes and beaches, a portion of the material that would have naturally been transported to the region will be supplied. The sand placement will stem, at least temporarily, the current shoreline erosion through the replacement of material to the sand-starved beaches. A net benefit to the shoreline erosion will be achieved through these alternatives.

Table E-1. Beach and Dune Nourishment Alternatives Evaluated for Rexhame Public Beach.

Alternative	Resiliency Type	Design Elements	Footprint Area (acres)	Volume (cu yds)
Rexhame Public – Alt 1	dune nourishment	dune crest elev. = 28 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:5	5.34	47,240
Rexhame Public – Alt 2	dune + beach nourishment	dune crest elev. = 28 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:5 berm elev. = 9.5 ft NAVD88 berm width = 75 ft nearshore slope = 1:12	14.92	82,570
Rexhame Public – Alt 3	beach nourishment	berm elev. = 11 ft NAVD88 berm width = 100 ft nearshore slope = 1:15	14.09	129,000

Figure E-1. Beach/dune nourishment alternatives considered for Rexhame Public Beach.

Sediments – Sediment used for construction of the dunes in Alt 1 and Alt 2 would be clean sand with an average grain size between 0.32 and 0.35 mm. Sediments for the beach nourishment portions of Alt 2 and 3 would be coarser with an average grain size of approximately 7.8 mm, allowing for mixtures of cobble, gravel and sand to match the existing beach sediments as summarized in Table E-2. Prior to selection and approval of any sediment source for use at Rexhame Public Beach the sediment characteristics will be evaluated and used to match the grain size envelopes shown in Table E-2. As such, the Rexhame Public Beach alternatives are not expected to alter the characteristics of the beach present prior to construction.

Table E-2. Grain Size Envelope for Rexhame Public Beach Alternatives.

	Coastal Dune (Alt 1 and 2)			
	Cobble %	**Gravel %**	**Sand %**	**Silt/Clay %**
Min	0	0	99.4	0.2
Max	0	0	99.8	0.3
	Coastal Beach (Alt 2 and 3)			
	Cobble %	**Gravel %**	**Sand %**	**Silt/Clay %**
Min	0	1.0	3.0	0.0
Max	4	93.0	98.9	0.1

Sediment Transport – Beach and dune nourishment alternatives considered for Rexhame Public Beach will not affect the existing sediment transport potential described in Section C.1.7. Sediment transport analyses indicate a potential transport of 2,250 cy/yr to the south along this stretch of shoreline (Figure C-28 in Section C). This potential assumes sand is available for transport and will remain the same regardless of local changes made from Rexhame Public - Alt 1, - Alt 2, or - Alt 3. The two (2) beach nourishment alternatives would place sediment within the active zone of littoral transport, which would result in more sediment movement to the south. In contrast, the dune nourishment alternative would keep sediment higher on the beach and would provide a source of material for adjacent beaches only during storms. From a coastal management perspective, the addition of sand to the sediment-starved shoreline will have a significant benefit, as more material will be available to the system, and the benefits can be felt at other eroding downdrift beaches to the south. Even though the potential annual rate of transport is relatively low, it is important to minimize the volume of sediment moving to the south due to the presence of rocky intertidal resources approximately 1,500 ft downdrift of Rexhame Public Beach (Figure E-2). Alt 1 has the lowest potential for increasing actual rates of sediment transport towards this sensitive resource.

1.2 Ecological Impacts – Rexhame Public Beach

Wetland Resource Areas – Direct impacts to wetland resource areas from the three (3) alternatives for Rexhame Public Beach are summarized in Table E-3. Alt 1 impacts only coastal dune, coastal beach, barrier beach and estimated habitats of rare wildlife, while Alt 2 and Alt 3 impact additional resources including land under the ocean and land containing shellfish. Rexhame Public – Alt 2 has the greatest direct impact at 14.92 acres; Alt 1 has the smallest direct impact at 5.34 acres.

Table E-3. Resource Area Impacts with Rexhame Public Beach Alternatives.

Alternative	Area of Direct Impact (acres)							
	Land Under the Ocean	Coastal Beach	Coastal Dune	Barrier Beach	Land Containing Shellfish	Rocky Intertidal Shore	Land Subject to Coastal Storm Flowage	Estimated Habitats of Rare Wildlife
Rexhame Public – Alt 1	--	2.41	2.93	5.34	--	--	5.34	5.34
Rexhame Public – Alt 2	0.64	11.35	2.93	14.92	6.24	--	14.92	14.92
Rexhame Public – Alt 3	2.48	11.61	0	14.09	8.93	--	14.09	14.09

Benthic Habitat – Impacts to benthic habitat will occur with Rexhame Public – Alt 2 and Alt 3 due to placement of sand below the MHW line. Alt 2 will impact 0.64 acres and Alt 3 will impact 2.48 acres of benthic habitat. Due to the absence of eelgrass and rocky intertidal resources in the project area, there will be no impacts to these resources with Alt 2 or Alt 3. Impacts to the benthic habitat will be temporary, as disturbed organisms are expected to recolonize within one year of the nourishment, as is typical of nearshore sandy habitat recruitment (Burlas, M., Ray, G. L., & Clarke, D., 2001).

Fisheries Resources – Alt 1 will result in no impacts to fisheries resources. Because of the limited nearshore area affected by Rexhame Public – Alt 2 and Alt 3, and the timing of construction, there are no anticipated adverse impacts to fisheries in the area. Appropriate time of year (TOY) windows will be coordinated with Division of Marine Fisheries and National Marine Fisheries Service through the permitting process to minimize/eliminate potential impacts to fish feeding, migration, and spawning activities.

Habitat of Rare Wildlife – Rexhame Public Beach contains priority and estimated habitat for the Piping Plover and Seabeach Needlegrass (See Section C.1.8.7). Engineering design elements for all three alternatives were developed to avoid adverse impacts to Piping Plover habitat. The coastal dune slopes for Alt 1 and Alt 2 are 1V:5H and nearshore slopes for Alt 2 and 3 range from 1V:12H to 1V:15H. Additionally, beach grass planting is proposed landward of the dune crest only, thereby avoiding grass on the seaward side of the dunes where the chicks nest and forage. The Rexhame Public Beach alternatives also avoid impacts to Seabeach Needlegrass which is found on the landward side of the dune crest and within the secondary dunes. All alternatives avoid work in these areas.

1.3 Selection of Preferred Alternative for Rexhame Public Beach

Rexhame Public – Alt 1 was selected as the preferred alternative since it minimizes impacts to existing resource areas, provides a similar level of protection as the beach nourishment alternatives, costs less and does not require frequent renourishment.

2.0 Impacts Associated with Alternatives for Winslow Ave. Beach

Table E-4 provides a summary of both dune nourishment alternatives developed for Winslow Ave Beach. The nourishment designs extend along the entire 1,540 ft of the existing dune (Figure E-2). All areas inside the project footprints are owned by the Town of Marshfield and open to the public (See Project Plans in Section O).

Dune nourishment Alt 1 provides protection from dune overwash for storms below the 10-yr event, while Alt 2 withstands the 10-yr storm and leaves enough dune in place to provide flood protection for low level future storms (Figures D-22 and D-23 in Section D). Both alternatives reduce flooding and wave impacts on the adjacent developed properties during a 50-yr storm but would require subsequent renourishment to restore the dune to the design elevations and widths.

Table E-4. Dune Nourishment Alternatives Evaluated for Winslow Ave. Beach.

Alternative	Resiliency Type	Design Elements	Footprint Area (acres)	Volume (cu yds)
Winslow – Alt 1	dune nourishment	dune crest elev. = 15.5 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:7	3.70	11,200
Winslow – Alt 2	dune nourishment	dune crest elev. = 17 ft NAVD88 dune crest width = 40 ft dune seaward slope = 1:5	4.50	17,850

2.1 Physical Impacts – Winslow Ave. Beach

Shoreline Change – The dune nourishment alternatives, Alt 1 and Alt 2, will have no impact on the location of MHW, as all material will be above the high tide beach. Although the background rate of erosion for this area of Marshfield will not change as a result of the nourishment alternatives, by placing additional sediment on the dunes, a portion of the material that would have naturally been transported to the region will be supplied. The nourishment will stem, at least temporarily, the current shoreline erosion through the replacement of material to the sediment-starved beaches. A net benefit to the shoreline erosion will be achieved through these alternatives.

Sediments – Sediment used for construction of the dunes in Winslow - Alt 1 and Alt 2 would be a mixture of cobble, gravel and sand following the grain size envelope summarized in Table E-5. The average grain size would range between 6.9 and 19.0 mm to be compatible with the existing dune sediment. Prior to selection and approval of any sediment source for use at Winslow Ave Beach the sediment characteristics of the source material will be evaluated and used to match the grain size envelopes shown in Table E-5. As such, the Winslow Ave. Beach alternatives are not expected to alter the characteristics of the dune present prior to construction.

Figure E-2. **Beach/dune nourishment alternatives considered for Winslow Ave Beach.**

Table E-5. **Grain Size Envelope for Winslow Ave Dune Alternatives.**

	Coastal Dune (all alternatives)			
	Cobble %	**Gravel %**	**Sand %**	**Silt/Clay %**
Min	0	77.0	6.0	0
Max	4	90.0	22.9	0.1

Sediment Transport – Dune nourishment alternatives considered for Winslow Ave. Beach will not affect the existing sediment transport potential described in Section C.1.7. Sediment transport analyses indicate a potential net transport of 3,900 cy/yr to the south along this stretch of beach (Figure C-28 in Section C). This potential assumes that sediment is available for transport and will remain the same regardless of local changes made from Winslow Ave. - Alt 1 or Alt 2. The dune nourishment alternatives would keep sediment higher on the beach which would only be available for transport during storms. Cross-shore modeling of the alternatives (Section D.3.3.2) indicates that sediment will be driven further in the dunes and pulled into the nearshore during storms. From a coastal management perspective, the addition of sand to the sediment-starved shoreline will have a significant benefit, as more material will be available to the system, and the benefits can be felt at other eroding downdrift beaches to the south.

2.2 Ecological Impacts – Winslow Ave. Beach

Wetland Resource Areas – Direct impacts to wetland resource areas from the Winslow Ave. Beach alternatives are summarized in Table E-6. Both alternatives impact coastal dune, coastal beach, barrier beach and land subject to coastal storm flowage. Winslow – Alt 2 has the greatest direct overall impact at 4.92 acres; Alt 1 has the smallest direct impact at 3.54 acres.

Table E-6. Resource Area Impacts with Winslow Ave. Alternatives.

Alternative	Area of Direct Impact (acres)							
	Land Under the Ocean	Coastal Beach	Coastal Dune	Barrier Beach	Land Containing Shellfish	Rocky Intertidal Shore	Land Subject to Coastal Storm Flowage	Estimated Habitats of Rare Wildlife
Winslow Ave – Alt 1	--	1.49	2.05	2.30	--	--	3.54	--
Winslow Ave – Alt 2	--	1.49	3.16	2.90	--	--	4.65	--

Benthic Habitat – No impacts to benthic habitat are expected with the Winslow Ave. Beach alternatives as no nourishment will be placed in intertidal or subtidal areas.

Fisheries Resources – No impacts to fisheries resources are expected with the Winslow Ave. Beach alternatives as no nourishment will be placed in intertidal or subtidal areas.

Habitat of Rare Wildlife – Habitat for rare wildlife habitat does not exist in the Winslow Ave. Beach area and therefore no impacts to this resource will occur.

2.3 Selection of Preferred Alternative for Rexhame Public Beach

Winslow – Alt 2 was selected as the preferred alternative since it provides increased storm damage protection without a significant increase in resource area impact, sediment volume or cost.

3.0 Impacts Associated with Alternatives for Fieldston and Sunrise Beaches

Table E-7 provides a summary of beach and dune nourishment alternatives developed for Fieldston and Sunrise Beaches. The nourishment designs extend along the entire 5,675 ft of the existing beach (Figure E-3). The nourishment footprints impact 66 private properties and 1 Town of Marshfield property (See Project Plans in Section O). The Town is coordinating with the private property owners to secure the necessary easements for placing the nourishment material.

Modeling of the alternatives indicates readjustment of the nourishment material to a more gradual profile with 1-yr, 5-yr and 10-yr storms, with a retreat of the MHW line and transport of sediment into the nearshore zone (Figures D-26 through D-28 in Section D). Based on the criteria that renourishment should be performed when 70% to 80% of the volume is lost from the original footprint, the modeling indicates that renourishment will be needed 1.5 to 4.0 years after initial construction to maintain the designed level of storm damage protection (Figure D-29 in Section D). Fieldston/Sunrise – Alt 3 has the longest service life and Fieldston/Sunrise – Alt 1 has the shortest service life.

Table E-7. Nourishment Alternatives Evaluated for Fieldston and Sunrise Beaches.

Alternative	Resiliency Type	Design Elements	Footprint Area (acres)	Volume (cu yds)
Fieldston/Sunrise – Alt 1	dune + beach nourishment	dune crest elev. = 13 ft NAVD88 dune crest width = 20 ft dune seaward slope = 1:5 berm elev. = 8.0 ft NAVD88 berm width = 55 ft nearshore slope = 1:20	37.0	339,350
Fieldston/Sunrise – Alt 2	dune + beach nourishment	dune crest elev. = 13 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:5 berm elev. = 9.5 ft NAVD88 berm width = 90 ft nearshore slope = 1:12	30.5	389,770
Fieldston/Sunrise – Alt 3	beach nourishment	berm elev. = 11 ft NAVD88 berm width = 100 ft nearshore slope = 1:15	34.0	409,100

Figure E-3. Nourishment alternatives considered for Fieldston and Sunrise Beaches.

3.1 Physical Impacts – Fieldston and Sunrise Beaches

Shoreline Change – The beach nourishment Alt 1 will move MHW seaward by approximately 155 ft, while Alt 2 and Alt 3 will move MHW seaward by as much as 185 ft. Although the background rate of erosion for this area of Marshfield will not change as a result of the nourishment alternatives, by placing additional sediment on the dunes and beaches, a portion of the material that would have naturally been transported to the region will be supplied. The sand placement will stem, at least temporarily, the current shoreline erosion through the replacement of material to the sand-starved beaches. A net benefit to the shoreline erosion will be achieved through these alternatives.

Sediments – Sediment used for construction of the nourishment for all three alternatives would be clean beach compatible material with a grain size distribution that falls within the envelope summarized in Table E-8. The average grain size would be 7.2 mm, allowing for a mixture of cobble, gravel and sand to match the existing beach sediments. Prior to selection and approval of any sediment source for use at Fieldston/Sunrise Beaches the sediment characteristics will be evaluated and used to match the grain size envelopes shown in Table E-8. As such, the Fieldston/Sunrise Beach alternatives are not expected to alter the characteristics of the beach present prior to construction.

Table E-8. Grain Size Envelope for Rexhame Public Beach Alternatives.

	Coastal Beach (all Alternatives)			
	Cobble %	**Gravel %**	**Sand %**	**Silt/Clay %**
Min	0	2.0	7.0	0
Max	34.0	82.0	97.3	0.7

Sediment Transport – Beach and dune nourishment alternatives considered for Fieldston and Sunrise Beaches will not affect the existing sediment transport potential described in Section C.1.7. Sediment transport analyses indicate a convergence zone near the boundary between the two beaches, with a net transport of 3,900 cy/yr moving to the south and a net transport of 6,100 cy/yr moving to the north (Figure C-28 in Section C). This potential assumes sand is available for transport and will remain the same regardless of local changes made from the Fieldston/Sunrise - Alt 1, - Alt 2, or - Alt 3. Sediment placed in the active zone of littoral transport will be available for transport along the entire beach and may result in an accumulation of material along the center of the beach. From a coastal management perspective, the addition of sand to the sediment-starved shoreline will have a significant benefit, as more material will be available to the system, and the benefits can be felt at other eroding beaches to the north and south.

3.2 Ecological Impacts – Fieldston and Sunrise Beaches

Wetland Resource Areas – Direct impacts to wetland resource areas from the three (3) alternatives for Fieldston and Sunrise Beaches are summarized in Table E-9. All three alternatives have direct impacts to the same wetland resources, including Land Under the Ocean, Coastal Beach, Barrier Beach, Land Containing Shellfish, Rocky Intertidal Shore and Land Subject to Coastal Storm Flowage. Fieldston/Sunrise – Alt 1 has the greatest direct impact at 37.0 acres; Alt 2 has the smallest direct impact at 30.5 acres.

The 1.09 acres of impact to Rocky Intertidal Shore occurs in an area immediately adjacent to the seawall at the southern end of Sunrise Beach (Figure C-31 in Section C). The resource does not have attached biota, and therefore is not complex hard bottom, but still provides limited value as rocky intertidal habitat. To avoid loss of this resource, 1.09 acres of similar rocky intertidal habitat will be replicated elsewhere in the project footprint.

Table E-9. Resource Area Impacts with Fieldston/Sunrise Beach Alternatives.

Alternative	Area of Direct Impact (acres)							
	Land Under the Ocean	Coastal Beach	Coastal Dune	Barrier Beach	Land Containing Shellfish	Rocky Intertidal Shore	Land Subject to Coastal Storm Flowage	Estimated Habitats of Rare Wildlife
Fieldston/ Sunrise – Alt 1	6.90	30.10	--	22.23	35.90	1.09	37.00	--
Fieldston/ Sunrise – Alt 2	2.40	28.10	--	18.14	29.40	1.09	30.50	--
Fieldston/ Sunrise – Alt 3	4.00	30.00	--	20.31	32.90	1.09	34.00	--

Benthic Habitat – Impacts to benthic habitat will occur with Fieldston/Sunrise – Alt 1, - Alt 2 and – Alt 3 due to placement of material below the MHW line. The largest direct impact to benthic habitat will occur with Alt 1 and the smallest impact will occur with Alt 2. However, impacts to the benthic habitat will be temporary, as disturbed organisms are expected to recolonize within one year of the nourishment, as is typical of nearshore sandy habitat recruitment (Burlas, M., Ray, G. L., & Clarke, D., 2001).

Fisheries Resources – Impacts to fisheries resources will occur with Fieldston/Sunrise – Alt 1, - Alt 2 and – Alt 3 due to placement of material below the MHW line. Alt 1 would have the greatest impact to fisheries habitat, while Alt 2 would have the smallest impact. However, impacts will be minimized by adhering to appropriate time of year (TOY) windows in coordination with Division of Marine Fisheries and National Marine Fisheries Service during the permitting process.

Habitat of Rare Wildlife – Habitat for rare wildlife habitat does not exist in the Fieldston/Sunrise Beach area and therefore no impacts to this resource will occur.

3.3 Selection of Preferred Alternative for Rexhame Public Beach

Fieldston/Sunrise – Alt 2 was selected as the preferred alternative since it performs better than, or similar to the other alternatives, minimizes impacts to existing resource areas, and costs less.

4.0 Impacts Associated with Alternatives for Bay Ave. and Gurnet Rd. Beaches

Table E-10 provides a summary of beach and dune nourishment alternatives developed for Bay Ave and Gurnet Rd Beaches. The nourishment designs extend along the entire 6,010 ft of the existing beach (1,941 ft in Marshfield and 4,069 ft in Duxbury; Figure E-4). The nourishment footprints impact 22 private properties in Marshfield and 65 private properties in Duxbury (See Project Plans in Section O). The Towns are coordinating with the private property owners to secure the necessary easements for placing the nourishment material.

Modeling of the alternatives indicates readjustment of the nourishment material to a more gradual profile with 1-yr, 5-yr and 10-yr storms, with a retreat of the MHW line and transport of sediment into the nearshore zone (Figures D-38 through D-40 in Section D). Based on the criteria that renourishment should be performed when 70% to 80% of the volume is lost from the original footprint, the modeling indicates that renourishment will be needed 3.0 to 5.5 years after initial construction to maintain the designed level of storm damage protection (Figure D-41 in Section D). Bay Ave/Gurnet Rd – Alt 3 has the longest service life and Bay Ave/Gurnet Rd – Alt 1 has the shortest service life.

Table E-10. Nourishment Alternatives Evaluated for Bay Ave. and Gurnet Rd. Beaches

Alternative	Resiliency Type	Design Elements	Footprint Area (acres)	Volume (cu yds)
Bay Ave/Gurnet Rd – Alt 1	dune + beach nourishment	dune crest elev. = 11 ft NAVD88 dune crest width = 20 ft dune seaward slope = 1:5 berm elev. = 8.0 ft NAVD88 berm width = 85 ft nearshore slope = 1:20	50.3	313,160
Bay Ave/Gurnet Rd – Alt 2	dune + beach nourishment	dune crest elev. = 13 ft NAVD88 dune crest width = 30 ft dune seaward slope = 1:5 berm elev. = 9.5 ft NAVD88 berm width = 90 ft nearshore slope = 1:12	36.4	511,030
Bay Ave/Gurnet Rd – Alt 3	beach nourishment	berm elev. = 11 ft NAVD88 berm width = 100 ft nearshore slope = 1:15	41.5	527,740

Figure E-4. Nourishment alternatives considered for Bay Ave. and Gurnet Rd. Beaches.

4.1 Physical Impacts – Bay Ave. and Gurnet Rd. Beaches

Shoreline Change – Bay Ave/Gurnet Rd - Alt 1, Alt -2, and Alt -3 will move MHW seaward between 140 and 190 ft, depending on location along the beach. Although the background rate of erosion for this area of Marshfield and Duxbury will not change as a result of the nourishment alternatives, by placing additional sediment on the beaches, a portion of the material that would have naturally been transported to the region will be supplied. The sand placement will stem, at least temporarily, the current shoreline erosion through the replacement of material to the sand-starved beaches. A net benefit to the shoreline erosion will be achieved through these alternatives.

Sediments – Sediment used for construction of the nourishment for all three alternatives would be clean beach compatible material with a grain size distribution that falls within the envelope summarized in Table E-11. The average grain size would be approximately 5.12 mm, allowing for a mixture of cobble, gravel and sand to match the existing beach sediments. Prior to selection and approval of any sediment source for use at Bay Ave/Gurnet Rd Beaches the sediment characteristics will be evaluated and used to match the grain size envelopes shown in Table E-11. As such, the Bay Ave/Gurnet Rd Beach alternatives are not expected to alter the characteristics of the beach present prior to construction.

Table E-11. Grain Size Envelope for Bay Ave/Gurnet Rd Beach Alternatives.

	Coastal Beach (all Alternatives)			
	Cobble %	Gravel %	Sand %	Silt/Clay %
Min	0	0	1.0	0
Max	10.0	89.0	99.9	0.1

Sediment Transport – Beach and dune nourishment alternatives considered for Bay Ave and Gurnet Rd Beaches will not affect the existing sediment transport potential described in Section C.1.7. Sediment transport analyses indicate a divergence zone south of the Marshfield and Duxbury town line (Figure C-28 in Section C). Net transport of 6,600 cy/yr is shown to move in a northerly direction and 1,050 cy/yr is shown to move to the south. This potential assumes material is available for transport and will remain the same regardless of local changes made from the Bay Ave/Gurnet Rd - Alt 1, - Alt 2, or - Alt 3. Sediment placed in the active zone of littoral transport will be available for transport along the entire beach and may result in greater rates of erosion south of the town line in the divergence zone. From a coastal management perspective, the addition of sand to the sediment-starved shoreline will have a significant benefit, as more material will be available to the system, and the benefits can be felt at other eroding beaches to the north and south.

The potential for adverse impacts associated with increased rates of transport into the Federal navigation channel at Green Harbor were considered during the design process. To minimize northerly transport of sand into the channel, the design will include placement of higher percentages of cobble and gravel from Table E-11 at the northern end of the nourishment footprint. Backpasssing of sediment built up against the western jetty at Green Harbor will also be investigated during the local, state and federal permitting process. Backpassing would essentially provide a retention area where northerly moving sediment would be contained and prevented from entering the navigation channel.

4.2 Ecological Impacts – Bay Ave. and Gurnet Rd. Beaches

Wetland Resource Areas – Direct impacts to wetland resource areas from the three (3) alternatives for Bay Ave and Gurnet Rd Beaches are summarized in Table E-12. All three alternatives have direct impacts to the same wetland resources, including Land Under the Ocean, Coastal Beach, Barrier Beach, Land Containing Shellfish, Land Subject to Coastal Storm Flowage and Estimated Habitats of Rare Wildlife. Bay Ave/Gurnet Rd – Alt 1 has the greatest direct impact at 50.3 acres; Alt 2 has the smallest direct impact at 36.4 acres.

Table E-12. Resource Area Impacts with Bay Ave/Gurnet Rd Beach Alternatives.

Alternative	Area of Direct Impact (acres)							
	Land Under the Ocean	Coastal Beach	Coastal Dune	Barrier Beach	Land Containing Shellfish	Rocky Intertidal Shore	Land Subject to Coastal Storm Flowage	Estimated Habitats of Rare Wildlife
Bay Ave/Gurnet Rd- Alt 1	16.20	34.10	--	50.30	46.20	--	50.30	23.52
Bay Ave/Gurnet Rd- Alt 2	3.00	33.40	--	36.40	32.30	--	36.40	9.80
Bay Ave/Gurnet Rd- Alt 3	7.50	34.10	--	41.60	37.50	--	41.60	14.63

Benthic Habitat – Impacts to benthic habitat will occur with all three Bay Ave/Gurnet Rd alternatives due to placement of material below the MHW line. The largest direct impact to benthic habitat will occur with Alt 1 and the smallest impact will occur with Alt 2. However, impacts to the benthic habitat will be temporary, as disturbed organisms are expected to recolonize within one year of the nourishment, as is typical of nearshore sandy habitat recruitment (Burlas, M., Ray, G. L., & Clarke, D., 2001).

Fisheries Resources – Impacts to fisheries resources will occur with Bay Ave/Gurnet Rd – Alt 1, -Alt 2 and – Alt 3 due to placement of material below the MHW line. Alt 1 would have the greatest impact to fisheries habitat, while Alt 2 would have the smallest impact. However, impacts will be minimized by adhering to appropriate time of year (TOY) windows in coordination with Division of Marine Fisheries and National Marine Fisheries Service during the permitting process.

Habitat of Rare Wildlife – Bay Ave and Gurnet Rd Beaches contains priority and estimated habitat for the Piping Plover and Least Tern (See Section C.1.8.7). Engineering design elements for all three alternatives were developed to avoid adverse impacts to habitat for these species.

The coastal dune slopes for all three alternatives are 1V:5H and nearshore slopes for the beach nourishment range from 1V:12H to 1V:20H. Additionally, beach grass planting is not proposed for any portions of the dunes.

4.3 Selection of Preferred Alternative for Bay Ave/Gurnet Rd Beaches

Bay Ave/Gurnet Rd – Alt 1 was selected as the preferred alternative since it shows less scarping of the berm than the other alternatives while still providing protection from wave overtopping, requires the smallest volume of material and costs less.

5.0 Alternatives for Limiting Green House Gas Emissions

The MEPA Review process requires under the Greenhouse Gas (GHG) Emissions Policy and Protocol that the emission of greenhouse gases be assessed when determining if a project will result in damage to the environment. The goal of the Marshfield and Duxbury Beach and Dune Nourishment project is to restore sediment to critically eroded beaches and dunes to provide storm damage protection for public and private infrastructure. The GHG emissions associated with this project will be limited to indirect emissions during the construction period of the project. During construction, the Towns will incorporate alternative measures to avoid and minimize GHG emissions, such as limiting idling and using bio-fuels in off-road construction equipment. This project will contribute to the resiliency of the shoreline in the face of expected sea level rise and increasing severity and frequency of storms. Therefore, in regard to the Revised MEPA Greenhouse Gas Emissions Policy and Protocol, a de minimus exemption from the Policy is being requested.

Section E References Cited:

Burlas, M., G.L. Ray, and D. Clarke. 2001. "The New York District's Biological Monitoring Program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section Beach Erosion Control Project. Final Report". U.S. Army Engineer District, New York and U.S. Army Engineer Research and Development Center, Waterways Experiment Station.

Section F

Avoidance, Minimization, & Mitigation Measures

F. AVOIDANCE, MINIMIZATION AND MITIGATION MEASURES

During planning and design for the Town of Marshfield and Duxbury Beach and Dune Nourishment Project, steps were taken to avoid, minimize and mitigate environmental impacts. The towns are proposing to implement resource protection and construction mitigation measures to avoid, minimize and mitigate anticipated adverse effects to sensitive coastal resources. This section is organized as follows. Section 1.0 discusses mitigation of impacts to natural resources affected by the project. Section 2.0 discusses mitigation activities during construction.

1.0 Natural Resource Mitigation

1.1 Sediments and Water Quality

Material proposed for use as beach and/or dune nourishment will be clean sand, gravel and cobble that is compatible with the existing beach sediments. The sediments will be relatively coarse and will contain only small percentages of fines (smaller than fine sand). Therefore, turbidity and water quality during construction are not anticipated to be significant issues. However, to avoid adverse impacts to sensitive species, all nourishment activities will take place during a defined environmental window (November 15th. to March 31st) as permitted, and outside of the time period when sensitive species migrate, nest, or breed.

1.2 Benthic Habitat

Limited benthic resources such as epifauna and infaunal invertebrates are located in the beach nourishment footprints. The proposed nourishment will affect benthic habitats, but any anticipated impact will occur in the shallow nearshore zone. During ambient conditions, this area is commonly associated with a high degree of mobility due to the strong wave action and currents and has limited habitat potential. Therefore, species that typically inhabit these high energy zones are adapted to such seasonal disturbance and will recolonize rapidly. By restricting construction to the permitted environmental window, construction activities will coincide with biological dormancy and normal winter wave disturbance period. This will eliminate/minimize any significant impact to the benthic environment. There are no significant shellfish resources in the nearshore area in question, so no mitigation or special conditions are being proposed for shellfish resources.

1.3 Barrier Beach, Coastal Beach, and Coastal Dune

To avoid adverse impacts to areas outside the nourishment footprints, all boundaries of the proposed beach nourishment will be clearly marked showing the location and elevation of replenished sands. No heavy machinery will be allowed within the coastal dune system, except for the areas receiving nourishment.

1.4 Finfish

Construction activities, and beach nourishment operations will have little impact on finfish. Important sports fisheries are typically pelagic, and therefore can avoid construction areas. Since no significant increases in turbidity are expected due to the coarse nature of the nourishment material, there are no expected secondary impacts on other fisheries due to turbidity or sedimentation.

1.5 Wildlife

Wildlife impacts to avifauna, marine mammals, and marine reptiles were considered. The avifaunal impacts are associated with documented federal and state-listed species and will be discussed in the next paragraphs. There are no marine mammal or reptile impacts anticipated. The Northern Right Whale, Kemp's Ridley Turtle, and Loggerhead Turtle are listed species, and are known to use the offshore waters during the warmer months. Rarely, reptile individuals linger and sometimes become stranded during the winter months. The proposed environmental window does not coincide with normal marine mammal and reptile offshore use. No adverse environmental effects are anticipated relative to marine mammals or reptiles, as a result of the project.

1.6 Rare Species

Piping Plovers, Terns, and other shorebirds use portions of the Marshfield and Duxbury beaches proposed for beach and/or dune nourishment. To minimize impacts on these avifauna, the project has been designed to avoid direct impact, and to allow natural storm processes to continue to impact sensitive portions of the beach. The dunes at Rexhame Public Beach within shorebird nesting areas will be nourished and restored to a 1V:5H slope to meet the specific habitat requirements for threatened and endangered shorebirds. In Duxbury, the nourishment design within shorebird nesting habitat will have a nearshore slope of 1V:20H, which exceeds the requirements for beach slopes in threatened and endangered shorebird habitat. The project will add over eighteen (18) acres of suitable beach as potential nesting habitat within areas currently mapped as estimated and priority habitat for state listed shorebirds. All construction work in these areas will be completed prior to the nesting season for threatened and endangered shorebirds (by the end of March).

2.0 CONSTRUCTION MITIGATION

All proposed work will occur during the environmental/construction window from November 15 to March 31. This period represents a typical environmental window for shoreline and nearshore construction in Southern New England.

Construction access to the beaches will be limited to the following locations for each beach:

- Rexhame Public Beach – Parker St and/or the southern beach access between the parking lot and the beach.
- Winslow Ave. Beach – Rexhame Rd or Waterman Ave
- Fieldston/Sunrise Beaches – Rexhame Rd and Old Beach Rd,
- Bay Ave/Gurnet Rd Beaches – Bay Ave, Ocean Rd North, and Ocean Rd South

Heavy equipment (e.g., bulldozer, loader, trucks, crane) will be used to prepare the project site, and to regrade the beach and dune after completion of the sand placement. All portions of the construction access will be restored to pre-existing conditions (grade and vegetation) upon completion of the proposed work. To avoid adverse impacts to areas outside the nourishment footprint, all boundaries of the proposed beach nourishment will be clearly marked showing the location and elevation of replenished sands. No heavy machinery will be allowed within the coastal dune system, except for the areas receiving nourishment. All boundary markers will be maintained until project completion. The limit of work will serve as a visual and physical marker for construction activities.

The sand with either be hydraulically dredged and pumped from nearby areas (i.e. South River, or Green Harbor) through a pipe that extends to the beach or trucked in from upland sources. If dredged, as material is placed on the beach, it will dewater in place. After dewatering from hydraulic operations, or direct placement from upland trucking operations, the material will be reshaped to final design specifications and profiles using heavy equipment. Construction activities will have short-term impacts on the resource areas within the project region. The impacts will be minimized by appropriate construction techniques, well-defined work limits, and, most importantly, the winter construction window. The impacts will be temporary, and the project will provide beneficial long-term results.

Section G

List of Required Permits & Reviews

G. LIST OF REQUIRED PERMITS & REVIEWS

Issuing Agency	Application	Application or File No.	Permit Name
Executive Office of Energy and Environmental Affairs (EEA)	Expanded Environmental Notification Form & Request for Waiver of Mandatory EIR	TBD	Certificate of the Secretary of EEA & Final Record of Decision
Marshfield Conservation Commission	Notice of Intent Application	TBD	Order of Conditions
Duxbury Conservation Commission	Notice of Intent Application	TBD	Order of Conditions
DEP Waterways Regulation Program	Chapter 91 Waterways Permit Application for Marshfield Beach Nourishment	TBD	Chapter 91 Permit
DEP Waterways Regulation Program	Chapter 91 Waterways Permit Application for Duxbury Beach Nourishment	TBD	Chapter 91 Permit
MA Coastal Zone Management (CZM)	Request for CZM Federal Consistency for Marshfield Beach Nourishment	TBD	Consistency Determination
MA Coastal Zone Management (CZM)	Request for CZM Federal Consistency for Duxbury Beach Nourishment	TBD	Consistency Determination
U.S. Army Corps of Engineers	1 Joint Permit Application (for both Towns)	TBD	Two (2) Individual Permits, 1 for each Town.

Section H

Post Construction Monitoring Plan

H. POST CONSTRUCTION MONITORING PLAN

PROJECT AND POST-PROJECT MONITORING

The project design for each beach site has been developed to avoid and minimize adverse impacts to sensitive coastal resources, and where this was not possible mitigation has been proposed (See Section F). As a result, negative long-term adverse impacts are not expected from the project. However, prudence dictates ongoing monitoring to document the long-term effects of the project.

Beach and dune profiles: The intent of the beach profiles is to document pre-project and post project beach configurations, including the gradual equilibration of the project(s) to wind, wave and tide activity. Beach profiles will be surveyed at 500 ft intervals along the beach within the project area(s) and 500 ft beyond both ends of the project area(s). The beach profiles will run from the landward side of the dune or top of the shore protection structures, to the limit of wading depth, with elevations measured approximately at 20-foot intervals and at marked breaks in slope. All elevation data will be referenced to the vertical datum of NAVD88. Beach profile data will be collected twice each year, once during a winter-time period, and once during a summer-time period, in order to sample seasonal changes. Profiles will be plotted, compared with previous profiles, and data provided to the resource agencies upon request. Beach profiles will be surveyed for a total of 3 years following project construction, at which time the need for continued beach profile monitoring will be evaluated. Depending on available resources, the Towns will continue annual monitoring of the nourished beaches and dune after the 3-year period is over in order to qualify for federal disaster assistance.

Beach grass monitoring: The Town of Marshfield will conduct visual surveys of the areas where beach grass planting is proposed along the back (landward) side of the dunes at Rexhame Public Beach. The survey will include estimations of the area covered by beach grass and its health (density, propagation, etc.). Surveys will be conducted once per year for the first 3 years following project completion.

Coastal bird monitoring: The Town of Marshfield will continue to coordinate with Mass Audubon's Coastal Waterbird Program to conduct inventory, mapping, and monitoring of coastal nesting birds at Rexhame Public Beach. Mass Audubon will conduct biological monitoring of state and federally listed coastal nesting bird species and will monitor abundance, distribution, reproductive success, causes of nest and/or chick loss, causes of disturbance, and responses to habitat management at Rexhame Public Beach. Monitoring will begin no later than April 1. The data collected on coastal breeding birds will be recorded on field data sheets and entered in a database. The surveys will be conducted each year during the bird nesting season. Surveillance surveys for new species and new colony sites will also take place at Fieldston and Sunrise Beaches and Bay Ave. Beach. The Town of Duxbury will contract with Mass Audubon to conduct surveillance surveys along Gurnet Rd. Beach.

Biological monitoring of state and federally listed shorebirds will begin April 1 and continue until all clutches have failed or fledged. Surveys will be conducted a minimum of twice per week until Piping Plover egg-laying begins (mid-late April); thereafter, surveys will be conducted a minimum of 5 days per week, weather permitting. Monitors will record the following during each visit for Piping Plovers and Least Terns.

- The total number of resident pairs, unpaired and non-resident birds will also be recorded, as observed.
- The location of all nests (taken by GPS upon location of the nest), total number of eggs in each nest.
- Causes of nest abandonment and/or failure, if known.
- Nest status, including number of eggs/incubating, hatching, or loss.
- The total number of eggs hatched from each nest.
- The total number of chicks observed from each brood and total number of adults.
- The number of chicks to successfully fledge (defined as able to fly 50' or more).
- Causes of chick loss, if known.
- Any cases of adult injury or mortality, with information regarding cause, if known.

The Towns of Marshfield and Duxbury will work in cooperation with the Mass Audubon Coastal Waterbird Program to provide physical protection for Piping Plovers and Least Terns through protective fencing, signage, on-the-beach engagement with public and diversion of adverse activities, and nest/chick guarding as necessary during peak recreational use days. Symbolic fencing will be installed and maintained around shorebird nesting areas according to the MA NHESP "Guidelines for Managing Recreational Use of Beaches to Protect Piping Plovers, Terns and their Habitats in Massachusetts" as well as the US Fish and Wildlife Service "Guidelines for Managing Recreational Activities in Piping Plover Breeding Habitat on the US Atlantic Coast to Avoid Take Under Section 9 of the Endangered Species Act. The fencing will be adjusted as necessary throughout the season and during monitoring to comply with guidelines. Symbolic fencing installation will begin in late March on known plover breeding territories to prepare for the start of plover pair bonding and territory establishment in early April. Fencing will be removed in late August or when the unfledged chicks are no longer on the beach. Furthermore, the Towns will ensure that all maintenance activities on the beach are staffed appropriately to ensure chicks and adults are not harassed, killed, or injured, and the Towns will advance public education through the development and production of educational signage for use at nesting sites and educational kiosks on the beach.

Section I

Review of Consistency w/CZM Policies

I. Review of Consistency with Coastal Zone Management Policies

The Towns of Marshfield and Duxbury's proposed Beach and Dune Nourishment (Project), includes coastal beach and/or dune nourishment. The Project complies with the enforceable program policies of the Massachusetts approved coastal management program and will be conducted in a manner consistent with such policies.

The proposed Project complies with the following Coastal Zone Management policies:

COASTAL HAZARDS

COASTAL HAZARD POLICY #1 - Preserve, protect, restore, and enhance the beneficial functions of storm damage prevention and flood control provided by natural coastal landforms, such as dunes, beaches, barrier beaches, coastal banks, land subject to coastal storm flowage, salt marshes, and land under the ocean.

> **This Project will not reduce the ability of natural coastal landforms to provide storm damage prevention. Rather, it will enhance storm damage protection and flood control and mitigate wave action impacting existing seawalls. The proposed project consists of costal beach and/or dune nourishment on Rexhame Public Beach, Winslow Ave. Beach, Fieldston and Sunrise Beaches, and Bay Ave and Gurnet Rd. Beaches. The height and width of the coastal beach and dune will be increased, dissipating wave energy and mitigating erosion of these natural buffers. The coastal beach and dune will be nourished using a clean sand/gravel/and cobble mixture compatible the existing beach sediment. The grain size of the cobble dune nourishment material will be compatible with the existing cobble present on Winslow Avenue Beach, mimicking the natural surrounding cobble beach environment. Nourishment of the existing beach and dune habitat areas will dissipate wave energy on the beach before the waves can impact the landward seawalls, which will provide enhanced storm damage prevention and flood control for landward residential and commercial developments.**

COASTAL HAZARD POLICY #2 - Ensure construction in water bodies and contiguous land areas will minimize interference with water circulation and sediment transport. Flood or erosion control projects must demonstrate no significant adverse effects on the Project site or adjacent or downcoast areas.

> **The proposed project is designed to address the exacerbated severe storm damage that has occurred along the project site in recent years, by adding grain-size compatible nourishment material along four (4) Marshfield and Duxbury beaches. Nourishment material placed on the beach and dune will be a clean sand/gravel/and cobble mixture compatible the existing beach sediment. The cobble berm nourishment on Winslow Avenue will be rounded cobbles. Both of these materials will settle quickly, having only minor, short-term impacts to turbidity and water quality and little to no impact on water circulation. The proposed project provides improved storm protection and flood control for inland residential communities and**

commercial properties, without adversely impacting water circulation or sediment transport. The nourished beaches and dunes are expected to experience profile evolution and erosion over time, which will supply compatible sediment to adjacent beaches.

COASTAL HAZARD POLICY #3 - Ensure that state and federally funded public works projects proposed for location within the coastal zone will:

- Not exacerbate existing hazards or damage natural buffers or other natural resources.
- Be reasonably safe from flood and erosion-related damage.
- Not promote growth and development in hazard-prone or buffer areas, especially in velocity zones and ACECs.
- Not be used on Coastal Barrier Resource Units for new or substantial reconstruction of structures in a manner inconsistent with the Coastal Barrier Resource/Improvement Acts.

This project has been jointly funded by the Towns of Marshfield and Duxbury and a Massachusetts Office of Coastal Zone Management Coastal Resiliency funded grant. All components of the proposed project will:

- **Not exacerbate any existing hazards or damage any existing natural buffers or resources. In fact, the proposed beach and dune nourishment will provide additional protection to the coastal beach resource area and will therefore improve its stability and overall habitat value. Cobble berm nourishment will also enhance natural buffers as the cobble berm will be designed to dissipate wave energy on the beach providing increased erosion and flood protection.**

- **Have been designed to provide reasonable protection given certain levels of expected storms to avoid flooding and wave overtopping. The beach profiles for the beach restoration were designed with a 10-yr storm in mind. The cobble dune has been designed to provide protection during the 10-yr storm event and to mitigate damaged caused by the 50-yr event. given certain levels of expected storms to avoid flood and erosion-related damage, as well as be designed to be resilient to future sea level rise impacts.**

- **Not promote any growth or development. The project site is comprised of coastal dunes and beaches, which will not be further developed. The goal of the Project is to maintain natural coastal habitats that provide nature-based storm damage protection for inland developed areas.**

- **Not be used for Coastal Barrier Resource Units or for reconstruction of any structures.**

COASTAL HAZARD POLICY #4 - Prioritize acquisition of hazardous coastal areas that have high conservation and/or recreation values and relocation of structures out of coastal high hazard areas, giving due consideration to the effects of coastal hazards at the location to the use and manageability of the area.

NA – This project does not involve acquisition of hazardous coastal areas.

ENERGY

ENERGY POLICY #1 - For coastally dependent energy facilities, access siting in alternative coastal locations. For non-coastally dependent energy facilities, assess siting in areas outside of the coastal zone. Weigh the environmental and safety impacts of locating proposed energy facilities at alternative sites.

NA – This Project does not involve energy facilities.

ENERGY POLICY #2 - Encourage energy conservation and the use of alternative sources such as solar and wind power in order to assist in meeting the energy needs of the Commonwealth.

NA – This Project does not involve energy facilities.

GROWTH MANAGEMENT

GROWTH MANAGEMENT POLICY #1 - Encourage sustainable development that is consistent with state, regional, and local plans and supports the quality and character of the community.

NA – This Project does not involve community development.

GROWTH MANAGEMENT POLICY #2 - Ensure that state and federally funded infrastructure projects in the coastal zone primarily serve existing developed areas, assigning highest priority to projects that meet the needs of urban and community development centers.

NA – This Project does not include state or federally funded infrastructure in an urban area or community development area.

GROWTH MANAGEMENT POLICY #3 - Encourage the revitalization and enhancement of existing development centers in the coastal zone through technical assistance and financial support for residential, commercial and industrial development.

NA – This Project does not involve community development.

HABITAT

HABITAT POLICY #1 - Protect coastal, estuaries, and marine habitats - including salt marshes, shellfish beds, submerged aquatic vegetation, dunes, beaches, barrier beaches, banks, salt ponds, eelgrass beds, tidal flats, rocky shores, bays, sounds, and other ocean habitats – and coastal freshwater streams, ponds, and wetlands to preserve critical wildlife habitat and other important functions and services including nutrient and sediment attenuation, wave and storm damage protection, and landform movement and processes.

The proposed beach and dune nourishment will provide additional protection to the coastal beach and dune resource areas and will therefore improve their stability and overall habitat value. Beach and dunes will be graded to slopes of 12H:1V or 20H:1V to accommodate the unique habitat needs of nesting shorebirds. Additionally, placing beach compatible nourishment material along the project site will provide a sediment source for the eroded areas downdrift of beach nourishments. This will provide an overall benefit to the beach and dune habitats since the amount of material transported from updrift has dwindled due to loss of sandy material at the source. The proposed cobble berm has been designed to reduce wave action, while mimicking the natural surrounding cobble beach environment, meaning the existing habitat is not expected to be adversely impacted by the placement of the cobble nourishment. Footprints of all beach, dune, and cobble nourishments were also designed to have no permanent impacts on rocky intertidal shore habitat areas.

HABITAT POLICY #2 – Advance the restoration of degraded or former habitats in coastal and marine areas.

The project area has a history of on-going storm damage and overwash of seawalls, which threatens private residential homes, public infrastructure, and commercial development landward of the seawalls, as well as recreational use of beaches within Marshfield and Duxbury. Costly and extensive damage to the beach, dune, and developed areas will continue to occur without intervention. The proposed beach and dune nourishment will advance the restoration of the beach and dune by providing added storm protection for the dune while increasing the size of the habitat and providing a significant sediment source for future storms. Although the proposed cobble berm will not restore a degraded habitat, it will mitigate wave impacts, providing protection for adjacent habitat areas and inland development. Cobble berm nourishment will also help to maintain the width of the buffer zone which enhances habitat value for upland and coastal species alike.

OCEAN RESOURCES

OCEAN RESOURCES POLICY #1 - Support the development of sustainable aquaculture, both for commercial and enhancement (public shellfish stocking) purposes. Ensure that the review process regulating aquaculture facility sites (and access routes to those areas) protects significant ecological resources (salt marshes, dunes, beaches, barrier beaches, and salt ponds) and minimizes adverse effects on the coastal and marine environment and other water-dependent uses.

NA – This Project does not involve aquaculture.

OCEAN RESOURCES POLICY #2 – Except where such activity is prohibited by the Ocean Sanctuaries Act, the Mass. Ocean Management Plan, or other applicable provision of law, the extraction of oil, natural gas, or marine minerals (other than sand and gravel) in or affecting the coastal zone must protect marine resources, marine water quality, fisheries and navigational, recreational and other uses.

NA – This Project does not involve oil, gas or mineral extraction.

OCEAN RESOURCES POLICY #3 - Accommodate offshore sand and gravel extraction needs in areas and in ways that will not adversely affect marine resources, navigation, or shoreline areas due to alteration of wave direction and dynamics. Extraction of sand and gravel, when and where permitted, will be primarily for the purpose of beach nourishment or shoreline stabilization.

NA – This Project does not involve offshore sand or gravel extraction.

PORTS AND HARBORS

PORTS AND HARBORS POLICY #1 - Ensure that dredging and disposal of dredged material minimize adverse effects on water quality, physical processes, marine productivity and public health and take full advantage of opportunities for beneficial re-use.

Sediment material used for beach, dune, and cobble berm nourishments may be obtained from a variety of sources, possibly including from the annual dredging of Green Harbor or dredging projects from the upland. Regardless of source, beach and dune nourishment material will be compatible with existing sediment currently present at the project site. The dredging component of the project will be permitted under a separate application. When nourishment material is placed, temporary impacts to water quality in the immediate vicinity of the placement may occur, such as increases in turbidity. However, this will be offset by the long-term benefits to overall ecosystem structure and function. The placement of dredged material will not result in any permanent impacts to water quality, physical processes, marine productivity, or public health. In addition, sediments from the dredge footprint will be tested for chemical contaminants prior to aquatic and/or upland placement. Therefore, no contaminants will be mobilized during dredging.

PORTS AND HARBORS POLICY #2 - Obtain the widest possible public benefit from channel dredging and ensure that Designated Ports Areas and developed harbors are given highest priority in the allocation resources.

NA – This project does not involve channel dredging. Sediment material used for beach and dune nourishment may come from the annual dredging of Green Harbor, which will be permitted under a separate application.

PORTS AND HARBORS POLICY #3 - Preserve and enhance the capacity of Designated Port Areas (DPAs) to accommodate water-dependent industrial uses and prevent the exclusion of such uses from tidelands and any other DPA lands over which an EEA agency exerts control by virtue of ownership or other legal authority.

NA – This Project is not located within or near a Designated Port Area.

PORTS AND HARBORS POLICY #4 – For development on tidelands and other coastal waterways, preserve and enhance the immediate waterfront for vessel-related activities that require sufficient space and suitable facilities along the water's edge for operational purposes.

NA – This Project does not involve development on tidelands or coastal waterways.

PORTS AND HARBORS POLICY #5 - Encourage, through technical and financial assistance, expansion of water dependent uses in Designated Port Areas and developed harbors, re-development of urban waterfronts, and expansion of physical and visual access.

NA – This Project is not located within or near a Designated Port Area or urban waterfront.

<u>**PROTECTED AREAS**</u>

PROTECTED AREAS POLICY #1 - Preserve, restore, and enhance coastal Areas of Critical Environmental Concern, which are complexes of natural and cultural resources of regional or statewide significance.

NA – This Project is not located in an Area of Critical Environmental Concern.

PROTECTED AREAS POLICY #2 - Protect state designated scenic rivers in the coastal zone.

NA – This Project is not located in a designated scenic river.

PROTECTED AREAS POLICY #3 - Ensure that proposed developments in or near designated or registered historic places respect the preservation intent of the designation and that potential adverse effects are minimized.

NA – This Project is not located in or near a registered historic place.

<u>**PUBLIC ACCESS**</u>

PUBLIC ACCESS POLICY #1 - Ensure that development (both water-dependent or nonwater-dependent) of coastal sites subject to state waterways regulation will promote general public use and enjoyment of the water's edge, to an extent commensurate with the Commonwealth's interests in flowed and filled tidelands under the Public Trust Doctrine.

The proposed beach and dune nourishment will restore coastal beach habitat, which will equate to a larger area for recreational beach use by the general public, who access the beach year-round. Additionally, by increasing the coastal resiliency of the beach and by mitigating storm damage, the proposed project ensures the continuation of public access to this area. Habitat restoration also benefits the general public by increasing opportunities for recreation such as fishing, fowling, and enjoyment of waterside areas, consistent with the Public Trust Doctrine. The cobble berm will also preserve recreational use of beaches within Marshfield and Duxbury by mitigating damage to the costal dune and habitat areas as a result of severe storms and wave action.

PUBLIC ACCESS POLICY #2 - Improve public access to existing coastal recreation facilities and alleviate auto traffic and parking problems through improvements in public transportation and trail links (land or water-based) to other nearby facilities. Increase capacity of existing recreation area by facilitating multiple use and by improving management, maintenance, and public support facilities. Ensure that the adverse impacts of developments proposed near existing public access and recreation sites are minimized.

Although the proposed beach/dune and cobble berm nourishments will not improve public access to beaches within Marshfield and Duxbury, it will increase coastal resiliency along the shoreline, which will ensure continued public access and recreational use of the area. Additionally, this increase in costal resiliency will also help to mitigate storm damage and flooding after storm events, minimizing post-storm maintenance. Public infrastructure behind seawalls, such as roads providing access to beaches within Marshfield and Duxbury, will experience enhanced protection from storm damage.

PUBLIC ACCESS POLICY #3 - Expand existing recreation facilities and acquire and develop new public areas for coastal recreational activities, giving highest priority to regions of high need or limited site availability. Provide technical assistance to developers of both public and private recreation facilities and sites that increase public access to the shoreline to ensure that both transportation access and the recreational facilities are compatible with social and environmental characteristics of surrounding communities.

While this project does not expand recreation facilities, it provides increased storm protection and coastal resiliency for the recreation areas that are present at Marshfield and Duxbury beaches. Increasing storm protection via beach, dune, and cobble berm nourishments will ensure continued public access to the costal beach and will protect public infrastructure behind seawalls, such as beach access roads.

WATER QUALITY

WATER QUALITY POLICY #1 - Ensure that point-source discharges and withdrawals in or affecting the coastal zone do not compromise water quality standards and protect designated uses and other interests.

During construction, machinery and equipment will be carefully maintained and monitored to ensure no oil or other mechanical fluid is released into the coastal zone. The completed project will consist of natural restored habitat, which will have no point-source discharges.

WATER QUALITY POLICY #2 – Ensure the implementation of nonpoint source pollution controls to promote the attainment of water quality standards and protect designated uses and other interests.

Beach, dune, and cobble berm nourishments will utilize only natural materials and will not adversely affect nonpoint source pollution control. Erosion and sedimentation controls will be incorporated during all phases of project construction to limit secondary impacts to coastal resource areas.

WATER QUALITY POLICY #3 - Ensure that subsurface waste discharges conform to applicable standards, including the siting, construction, and maintenance requirements for on-site wastewater disposal systems, water quality standards, established Total Maximum Daily Load limits, and prohibitions on facilities in high-hazard areas.

NA – This Project does not include subsurface waste discharges.

Section J

Engineering Memorandums

WOODS HOLE GROUP FOR EARTH, FROM SPACE
A CLS COMPANY

TECHNICAL MEMORANDUM

DATE April 26, 2020 **JOB NO.** 2018-0231

TO Greg Guimond, Town of Marshfield Planner
Valerie Massard, Town of Duxbury Planner

FROM Woods Hole Group, Inc.

Beach and Dune Nourishment at Critically Eroded Beaches in Marshfield & Duxbury – Wave Modeling Methods and Model Development Memo

Analysis Approach

To accurately characterize sediment transport along a coastline to inform beach nourishment or erosion mitigation structural design, the offshore wave climate, and how energy is transferred into the near-shore zone, must be first understood. Wave transformation modeling provides information as to how offshore waves interact with complex nearshore bathymetry features and propagate toward the shoreline. Wave transformation processes include wave refraction, diffraction, and breaking which determine how much wave energy reaches the shore. Wave energy that is distributed along the shoreline in varying directions determine the amount and direction of sediment transport that will occur.

Wave transformation modeling was previously conducted by Woods Hole Group for the coast of Duxbury, MA (Woods Hole Group, 2016). The goal of the current modeling effort was to extend the wave transformation model northward to include the coast of Marshfield, MA, using newly collected bathymetry data that accurately captures the irregular nearshore features off the coast of Marshfield. From these wave transformation model results, a sediment transport model was developed to characterize sediment fluxes and divergence on the Marshfield coastline. This report describes the wave model development, results for average annual conditions and results for extreme events along the Marshfield, MA coastline.

Wave Model Description

CMS-Wave version 3.2 (Lin et al, 2011), a spectral wave model, was chosen to model wave transformation processes for the Marshfield region. CMS-Wave, (formerly known as WABED, Wave-Action Balance Equation Diffraction) is a 2-dimensional, finite-difference, steady-state nearshore spectral wave model that solves the wave-action balance equation (Mase, 2001) on a uniform or non-uniform cartesian grid. The wave-action balance equation (eq. 1,2) is as follows:

$$\frac{\partial(C_x N)}{\partial x}+\frac{\partial(C_y N)}{\partial y}+\frac{\partial(C_\theta N)}{\partial \theta}=\frac{\kappa}{2\sigma}\left[\left(CC_g \cos^2\theta N_y\right)_y-\frac{CC_g}{2}\cos^2\theta N_{yy}\right]-\varepsilon_b N-S \quad (1)$$

where

$$N=\frac{E(\sigma,\theta)}{\sigma} \quad (2)$$

CMS-Wave has the capability to model and resolve wave processes such as wave refraction, diffraction, breaking, shoaling and interaction with shoreline structures (Lin et al., 2012). The spectral wave model runs as part of the Coastal Modeling System (CMS) developed by the Coastal Inlets Program of the U.S. Army Corps of Engineers (USACE) Research and Development Center (ERDC) and the USACE Coastal Hydraulics Laboratory (CHL).
For this modeling effort, CMS-WAVE was run in half-plane mode where only waves directed onshore are simulated, which was deemed suitable for this application.

Grid Development
The bathymetric source for the offshore region of Marshfield was the 2016 USGS CoNED (1887-2016) New England topobathymetric digital elevation model, extracted relative to NAVD88 from NOAA's Data access viewer (https://coast.noaa.gov/dataviewer/#/lidar/search). For the nearshore region of Marshfield (out to a depth of approximately 40 feet), bathymetric data collected by Woods Hole Group in November, 2019 were merged with the offshore data and interpolated to the grid to improve the local detail of the model's bathymetry.

The wave modeling was conducted using a nested grid approach that included two grids (Table 1). The first was a regional-scale, 50-m resolution parent grid, which covered the region of Marshfield and extended seaward to the 56-meter depth contour, which coincided with the general location and depth of the USACE Wave Information Study (WIS) station 63060 in Massachusetts Bay (Figure 1). The second grid was a local scale grid, which was nested within the parent grid and included the Marshfield shoreline and extended to just offshore of Brant Point (Figure 2). The resolution of this child grid was 10-meters, which was determined sufficient for both capturing necessary shoreline detail as well as remaining computationally efficient.

Table 1. Grid Information.

Details	Regional-Scale Parent Grid	Local-Scale Child Grid
Grid Type	Uniform cartesian	Uniform cartesian
Resolution	50 m	10 m
X origin (MA State Plane Meters)	280634.27	269709.02
Y origin (MA State Plane Meters)	885628.69	878706.45
Grid Orientation	202.08 °	202.08 °
Depth at Boundary	56 m	12 m
Length of Seaward Boundary (km)	16.43 km	11.29 km

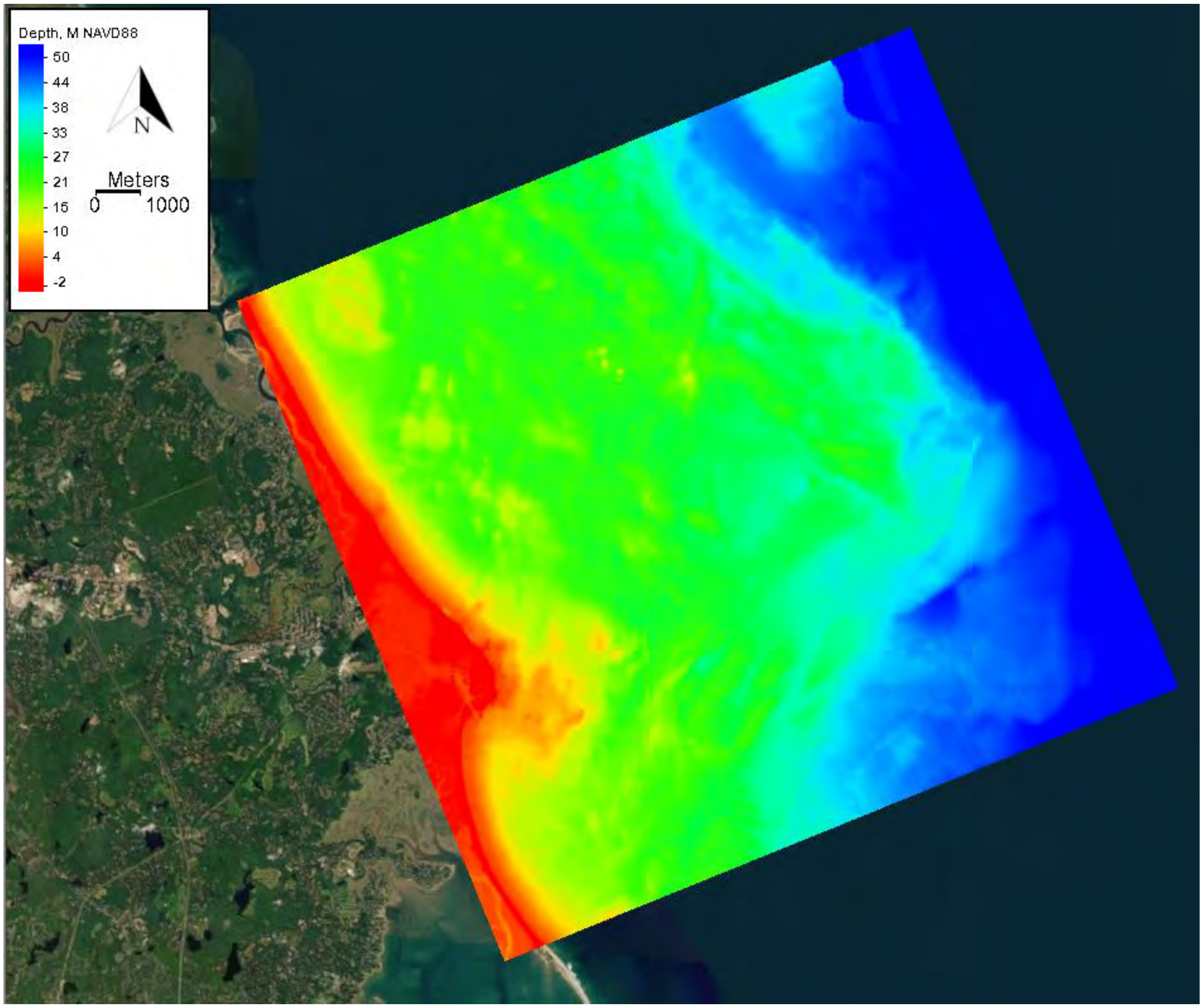


Figure 1: Full extent of the 50-meter resolution parent grid. The grid boundary terminates at the 56-m NAVD88 depth contour, which coincides with the depth of the WIS buoy in Massachusetts Bay.

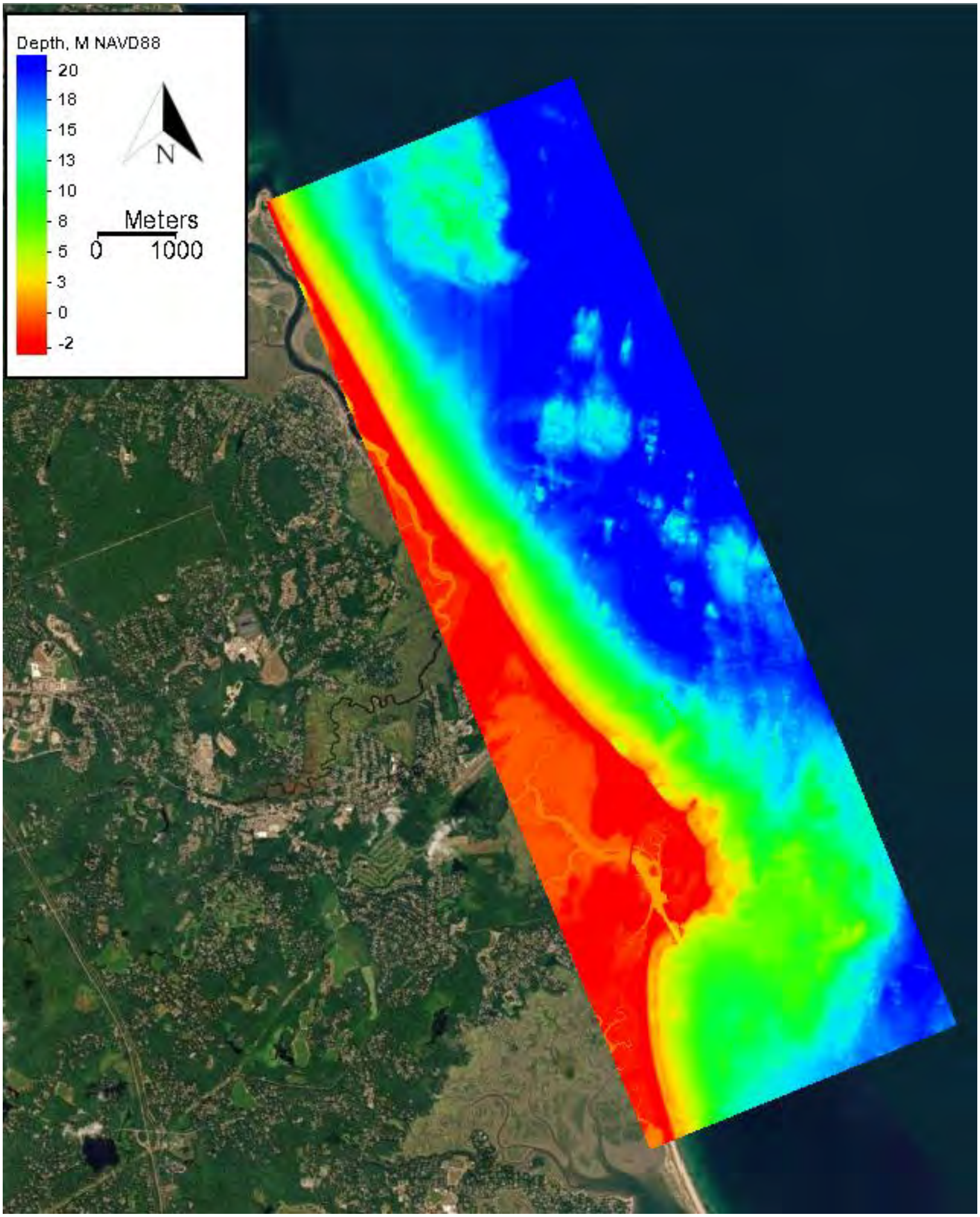


Figure 2: The full extent of the 10-meter resolution nested grid, which incorporates the bathymetry from the Woods Hole Group December 2019 bathymetric survey, as well as the beach profiles collected by MA Coastal Zone Management and Woods Hole Group in November of 2019.

Offshore Wave Climate

There were two potential sources for wave data in the Marshfield offshore region of Massachusetts Bay. The first was from the National Oceanic and Atmospheric Administration's National Data Buoy Center (NOAA NDBC) station 44013. The second was the WIS station 63060. WIS information is produced from a hindcast wave model (WISWAVE) that predicts the local wave climate based on local and regional wind conditions (Resio and Tracy, 1983). WIS is a reasonable and widely-used option when considering long-term average annual conditions. The locations of the two data buoys is presented in Figure 3.

Figure 3: Locations of offshore wave buoys in the vicinity of Marshfield, MA.

Due to the proximity and matching depth of the seaward boundary of this model, WIS station 63060 was chosen to develop offshore boundary conditions for the wave transformation model. The 33-year hourly averaged wave information from WIS station 63060 is presented as a wave rose in Figure 4. These data were subdivided into 22.5-degree directional bins to develop representative spectral inputs for the wave model. Table 2 presents the analysis results of the 33- year dataset used to create the average annual conditions for the wave transformation modeling for Marshfield, MA. The results show the highest wave energy arrives from the NE directional bin (44.5 to 68 degrees) while the most frequent waves arrive from the E-ESE (90.5 to 113 degrees).

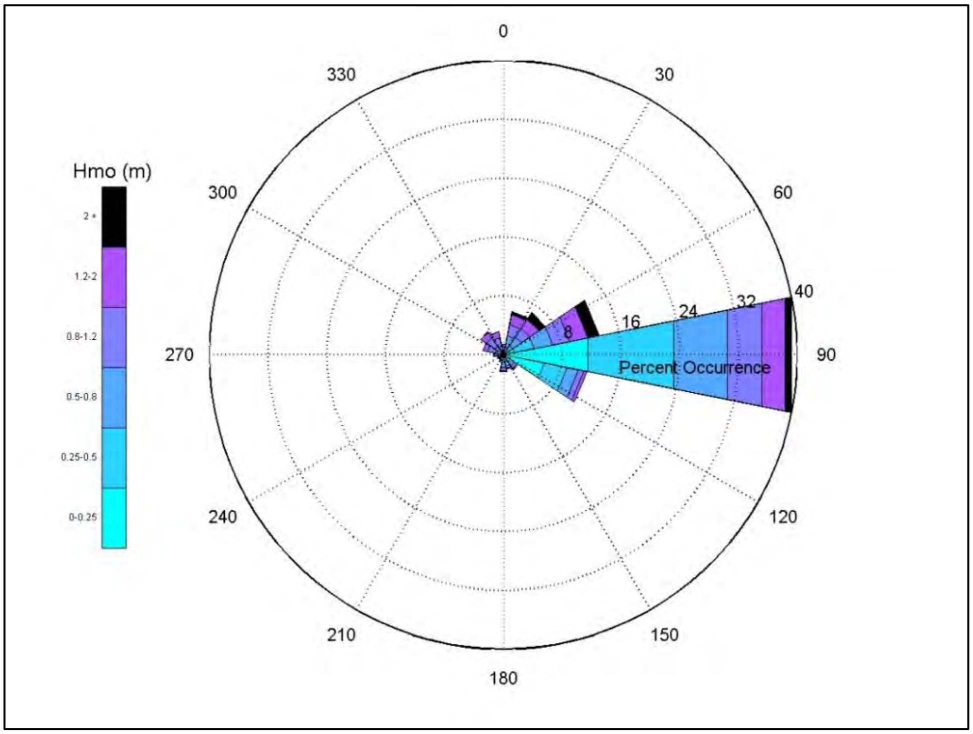


Figure 4: 33-year hourly averaged wave heights and directions (in wave rose format) from WIS station 63030. Hmo is wave height in meters, and direction is given in degrees [0°= N].

Table 2. Input Conditions and Directional Bin Scenarios for the Wave Transformation Modeling.

Directional Bin (0°=N)	Approach Direction	Percent Occurrence	Sig. Wave Height (m)	Peak Period (sec)	Peak Direction (0°=N)
338 to 0.5	NNW	3.10	0.98	4.56	349.17
0.5 to 23.0	N - NNE	3.60	0.99	4.84	12.15
23.0 to 44.5	NNE-NE	5.50	1.14	5.35	34.96
44.5 to 68	NE	8.50	1.20	6.16	57.22
68.0 to 90.5	NE-E	27.70	0.76	7.84	81.31
90.5 to 113.0	E- ESE	30.0	0.43	7.58	98.99
113.0 to 135.5	SE	3.30	0.63	5.29	122.64
135.5 to 158.0	SSE	2.20	0.62	4.54	146.38
Calm	--	16.10	--	--	--

Extreme Events

High waves and increased sediment transport on open coastlines most often occur during high energy, or storm events. USACE has completed as part of the WIS project a series of analyses for extreme event return periods at station 63060. The results of these extreme event return-period analyses are presented in Figure 5. For this modeling effort, two high energy return-period scenarios were chosen to use as inputs into the wave transformation model, details of which are presented in Table 3. The wave heights and for these two scenarios were chosen from the return period analysis of the 33-year wave hindcast at station 63060. The wave period corresponding to each high-energy wave height was derived using the relationship between peak wave height and wave period for storm events. The wave direction was calculated as the mean wave direction of all storms used in the WIS station 63060 return-period analysis. Storm surge elevations corresponding to each scenario were collected from USACE's Tidal Flood Profiles of the New England Coast (USACE, 1988).

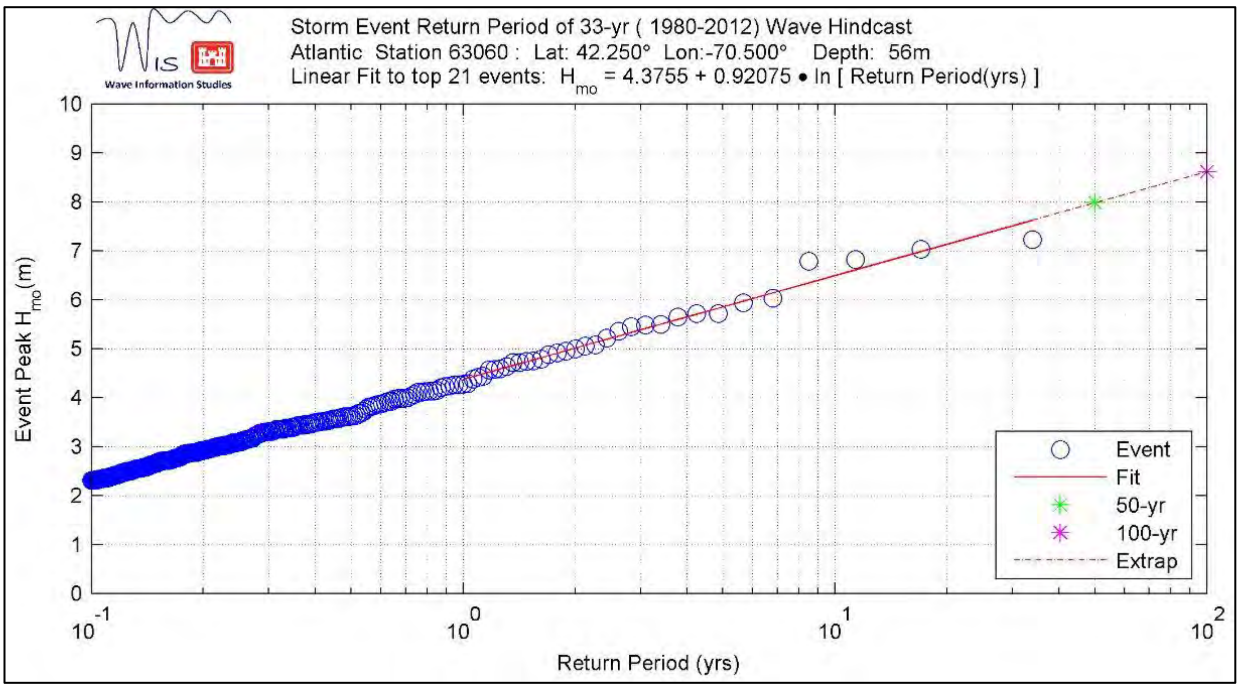


Figure 5: Extreme storm return period analysis for the 33-year dataset at Station 63060, off the coast of Marshfield (USACE, 2012).

Table 3. Wave Input Conditions for High Energy Events.

Event	Storm Surge [m_NAVD88]	Wave Height [m]	Wave Period [sec]	Wave Direction [0°=N]
10-Year	2.47	6.5	12.0	55.4
50-Year	2.77	8.0	13.3	55.4

Wave Model Validation

Before modeling average annual and extreme storm conditions, the wave model performance was first evaluated by running the model and comparing the results to a wave ADCP that was deployed by Woods Hole Group in May-June, 2015. Time-series of significant wave height (m), period (s) and wave direction (degrees) output from the model were compared with the ADCP measurements are presented in Figure 6. Considerable noise (high-frequency oscillations) is present in the ADCP data for wave period and direction during periods of low wave energy, which is expected. The model was found to capture key high energy events as well as reasonably predict wave conditions during calm periods but tends to over-predict wave heights at the location of the ADCP. This can be attributed to the spatially constant wind forcing in the model from a single point offshore. The wind inputs from the NDBC buoy may not be fully representative of the winds occurring at the ADCP location, which explains the increased wave heights. Visually however, the model follows the trend of the observations well and captures periods of high and low energy. This indicates reasonable model-data fit, which demonstrates the model is sufficient for characterizing wave transformation processes in the region.

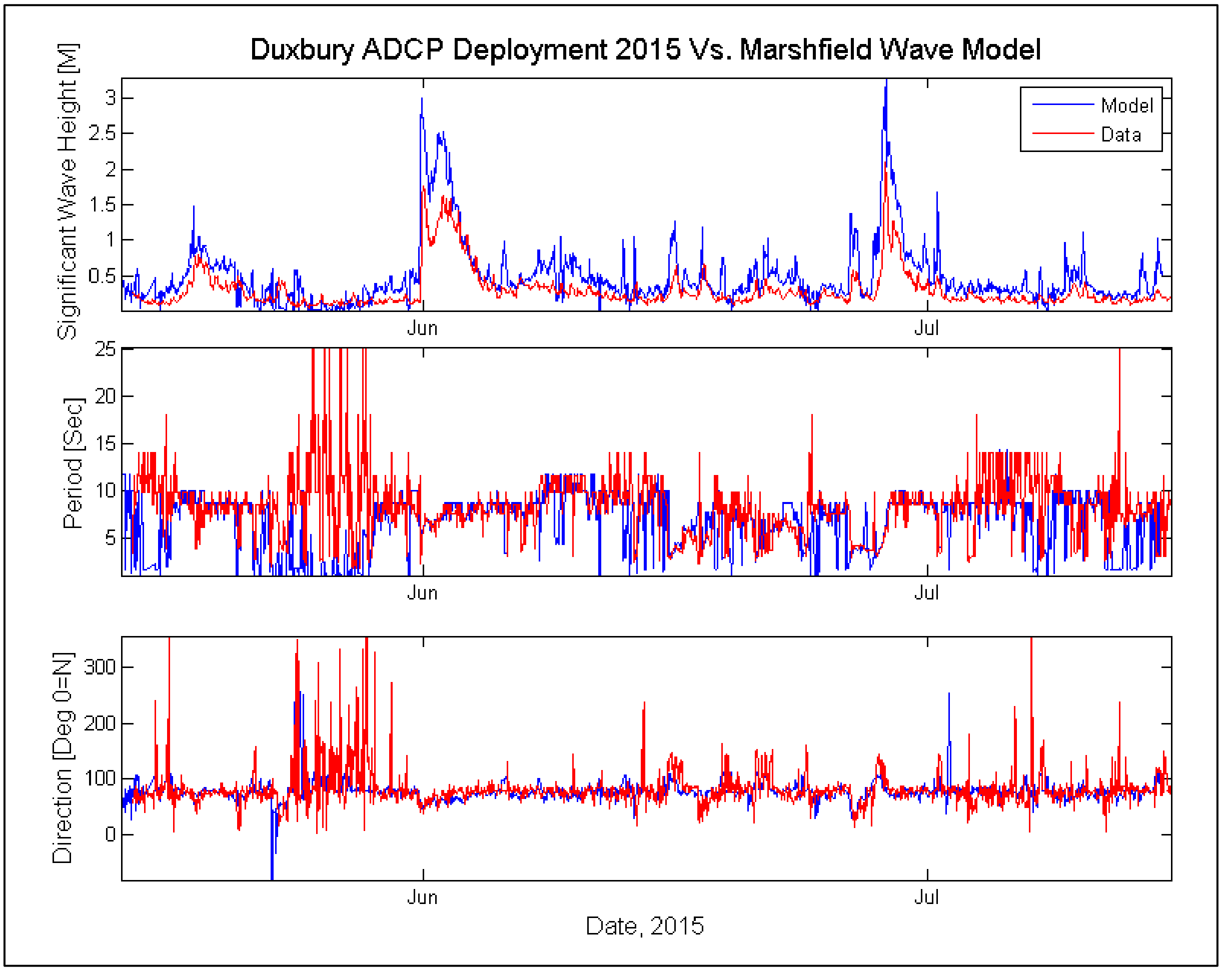


Figure 6. Observational data collected from a wave ADCP deployed in May, 2015 compared to CMS-Wave model output for wave direction, wave period and significant wave height for the validation run. For the validation, a model hindcast was conducted for the same time period as the ADCP deployment using input wave spectra from NDBC 44013. Model output is represented in blue, and the ADCP observational data is represented in red.

Results and Discussion of the Transformation-Scale Wave Model for Marshfield, MA

Wave transformation model simulations were performed for each of the average annual and storm conditions listed in Tables 2 and 3. An example of the CMS-Wave model output for one of the more energetic directional bins (44.5 to 68 degrees) is shown in Figure 7. Figures showing the model results for all conditions simulated are included in Appendix A.

The wave model results shown in Figure 7 are for waves arriving from NE–ENE and indicate wave heights are larger along the sections of the shoreline due to energy focusing. The increases in wave height occur where waves refract around shallow rocky formations in the nearshore, or in the vicinity of shoreline structures (groins).

A close-up view of the wave model results around Brant Rock is shown as an inset in Figure 7. This is an area of increased wave energy as the nearshore bathymetric features cause waves to shoal, refract, and diffract in this region. The Ocean Bluff and Hewitt's Point areas of Marshfield also show increased wave energy for this wave approach direction.

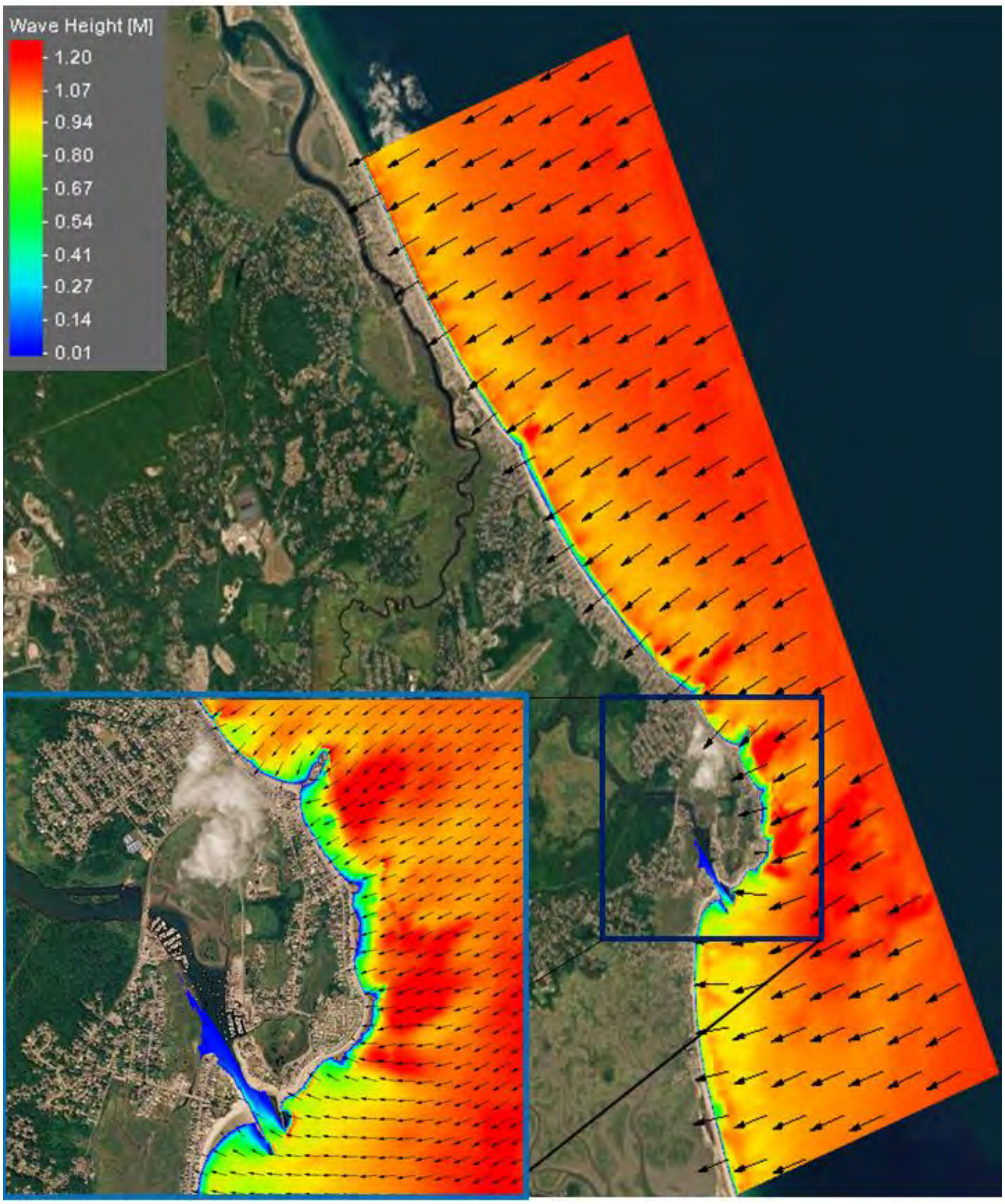
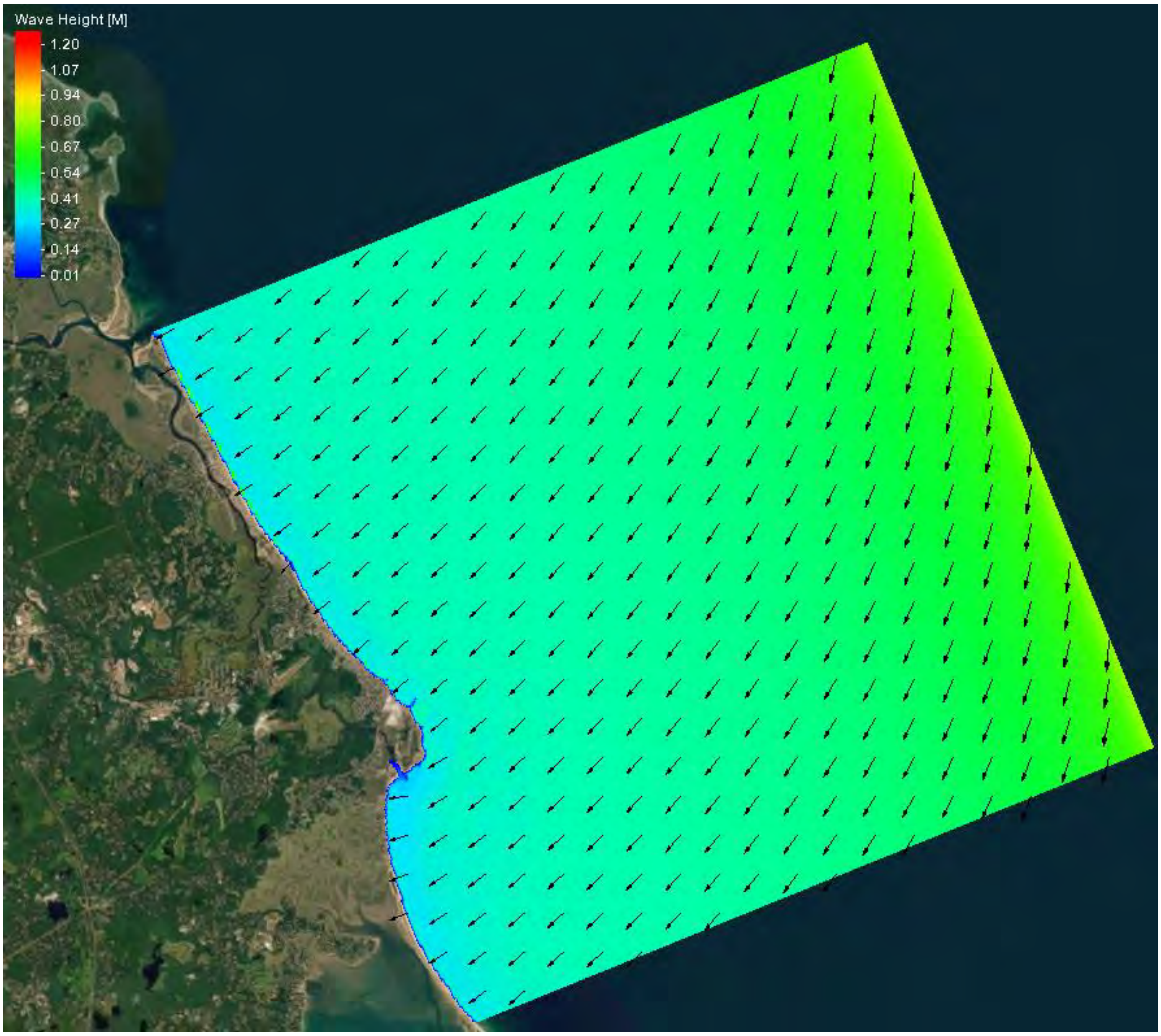
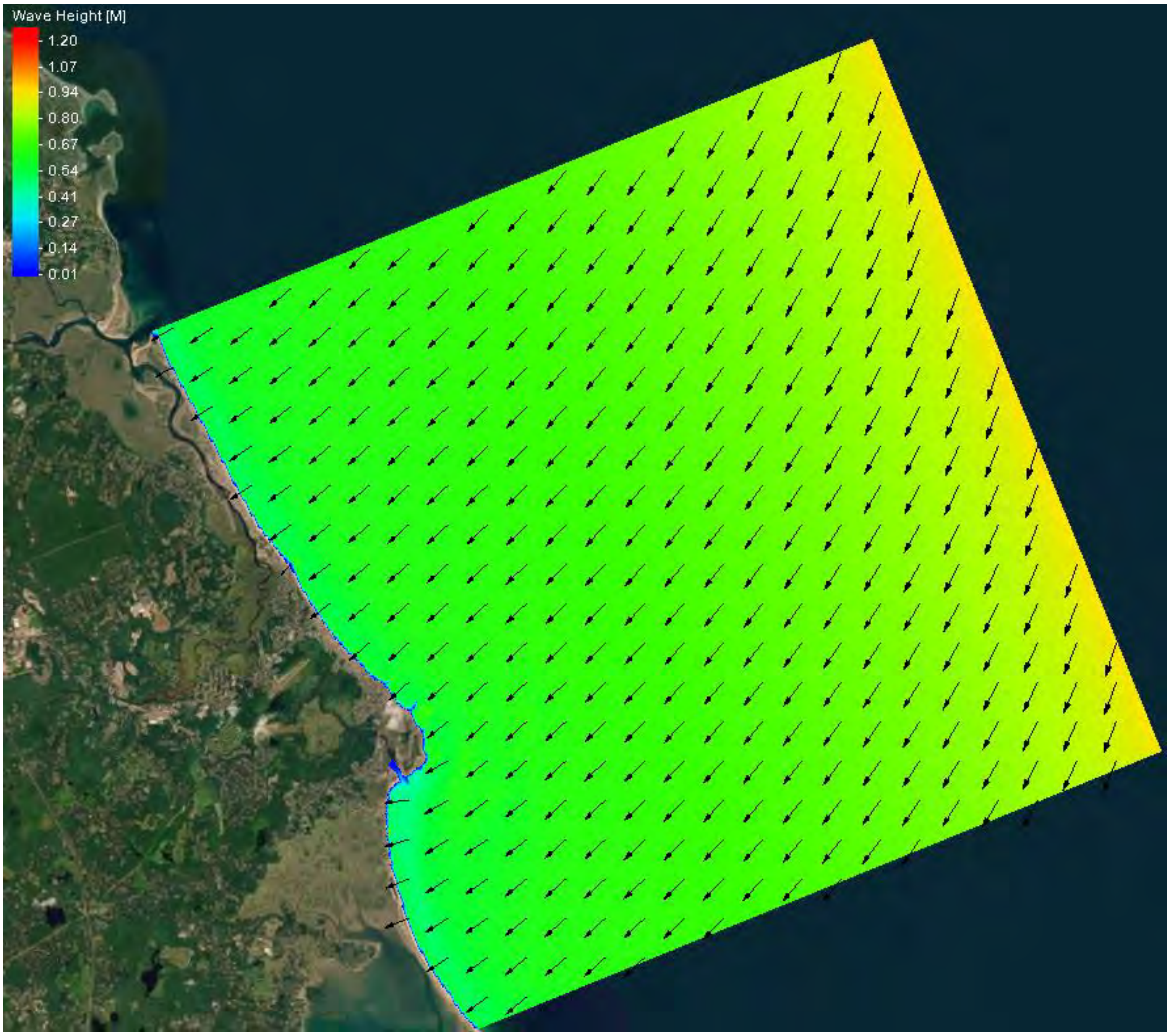


Figure 7: Results of the local wave model for the NE-ENE approach direction (44.5° to 68.0 ° [N = 0°])

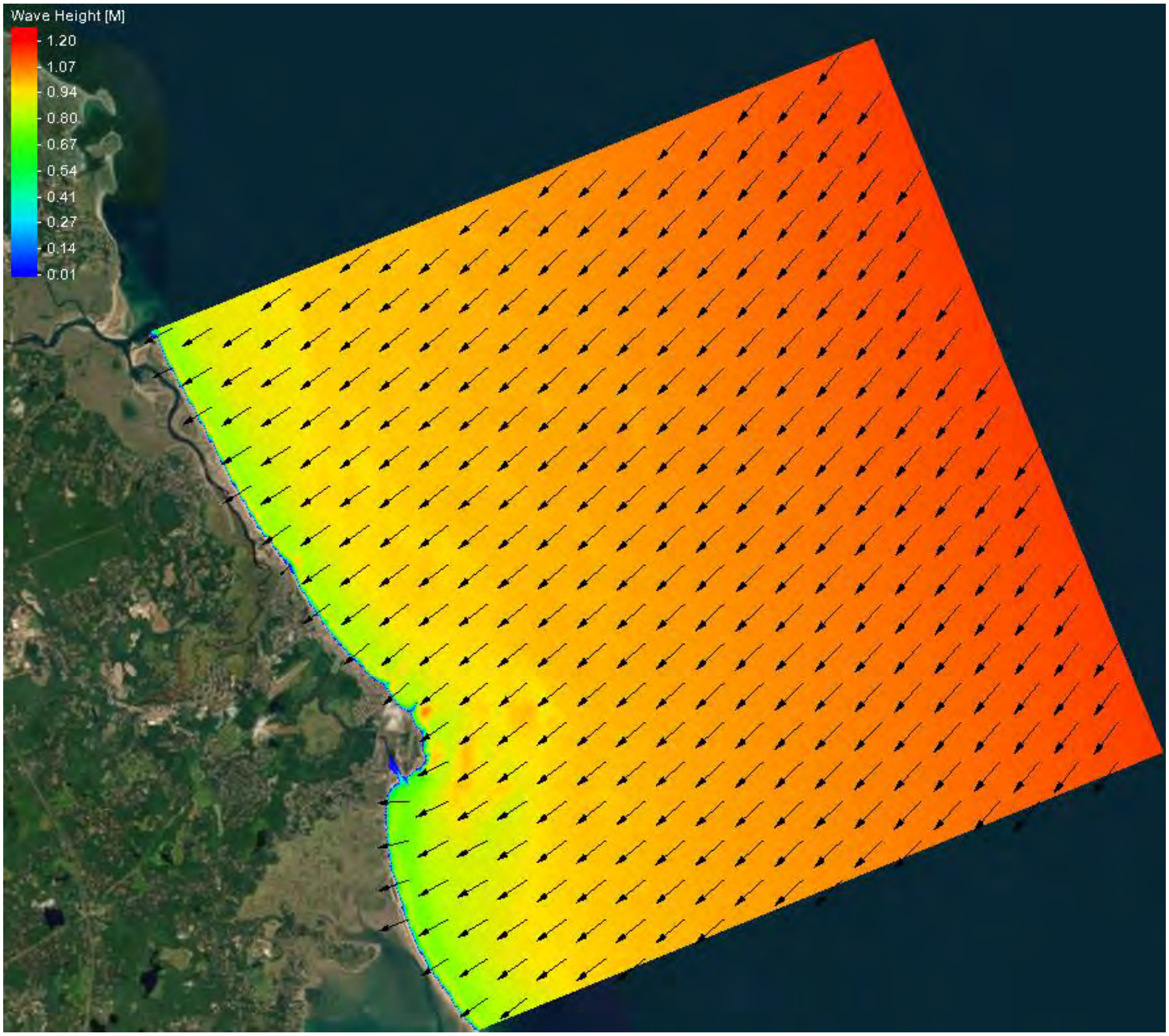
Appendix A



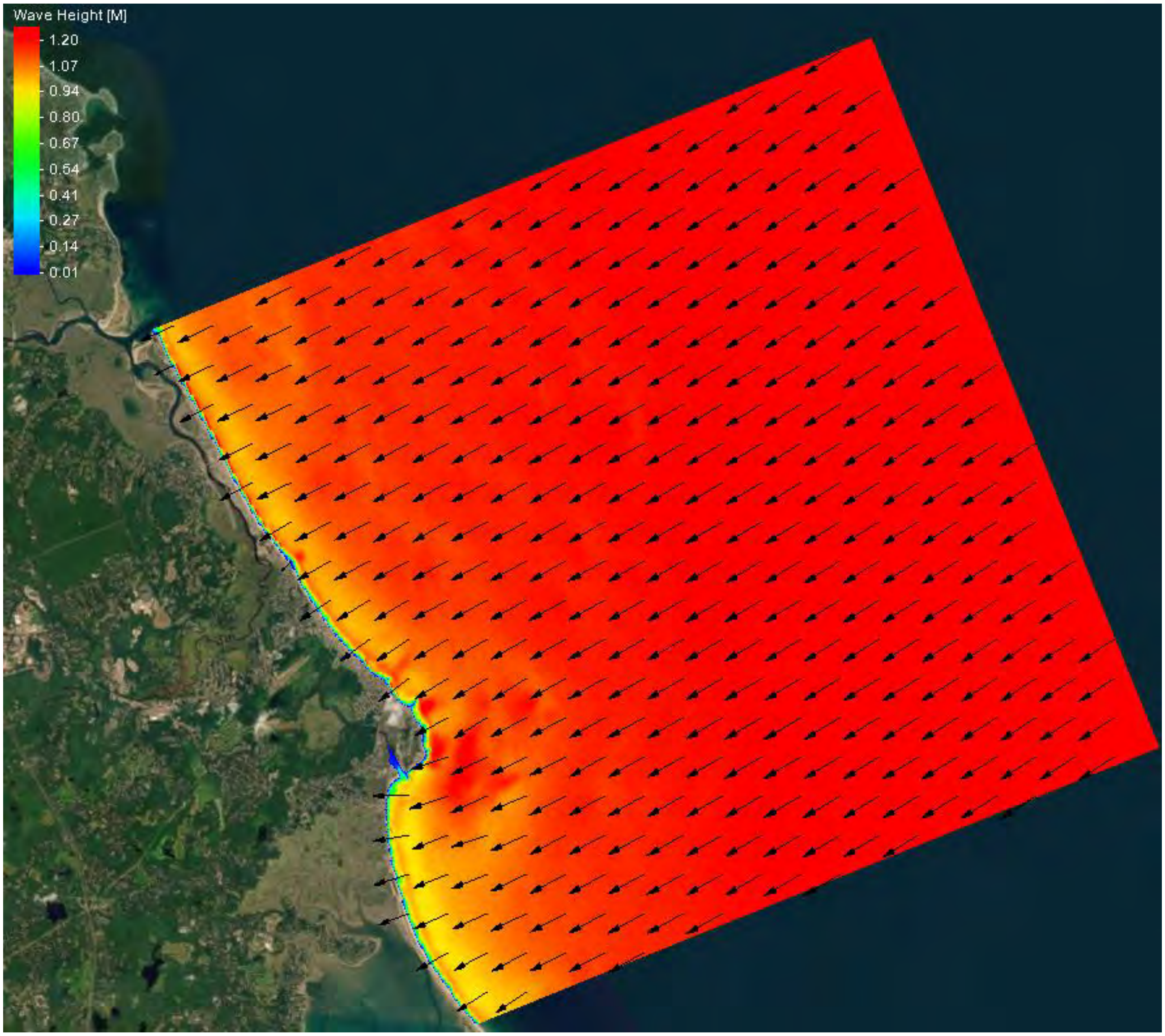
A-1: Results of the regional wave model for the NNW approach direction (338° to 0.5 ° [N = 0°])



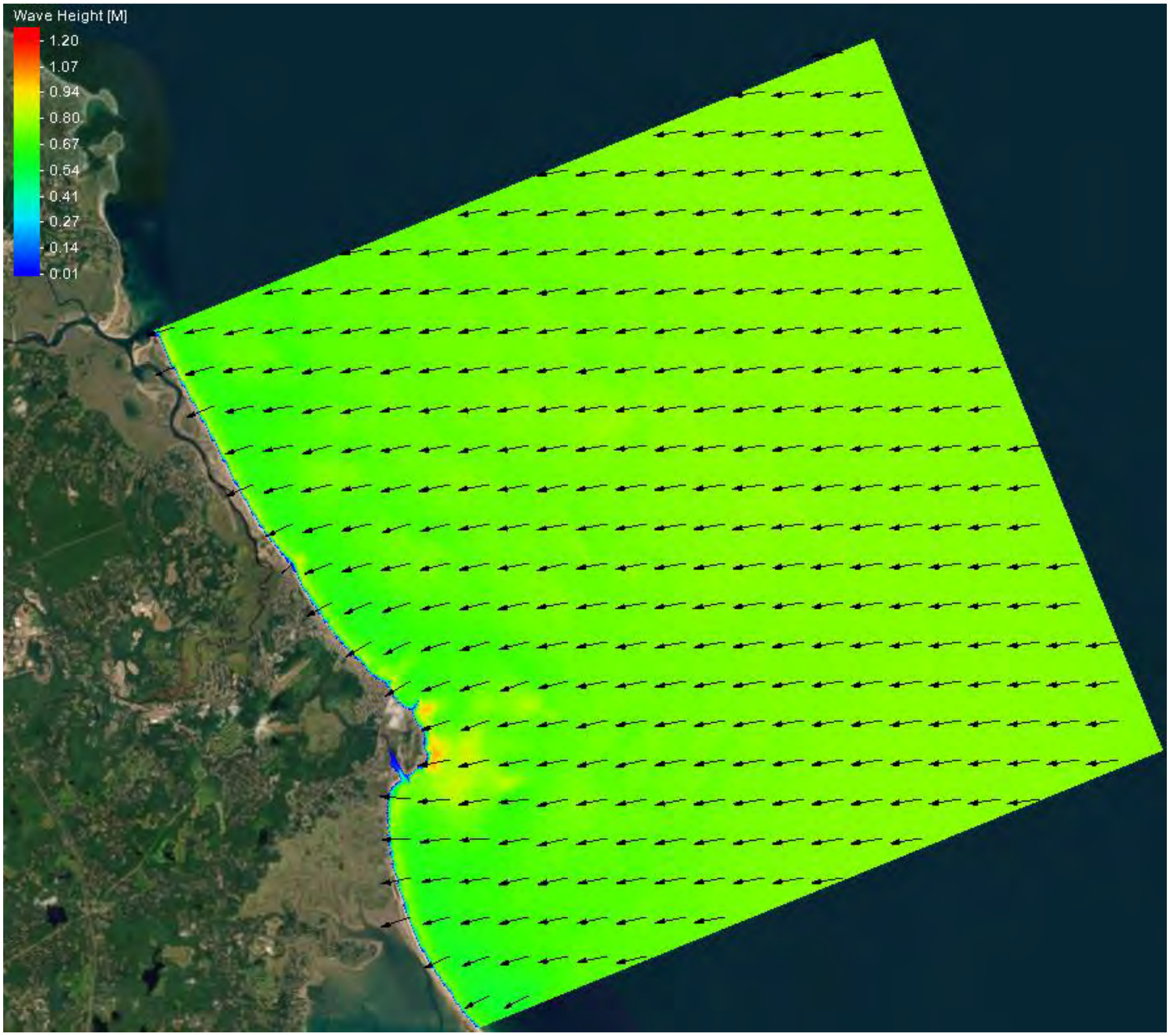
A-2: Results of the regional wave model for the N-NNE approach direction (0.5° to 23.0 ° [N = 0°])



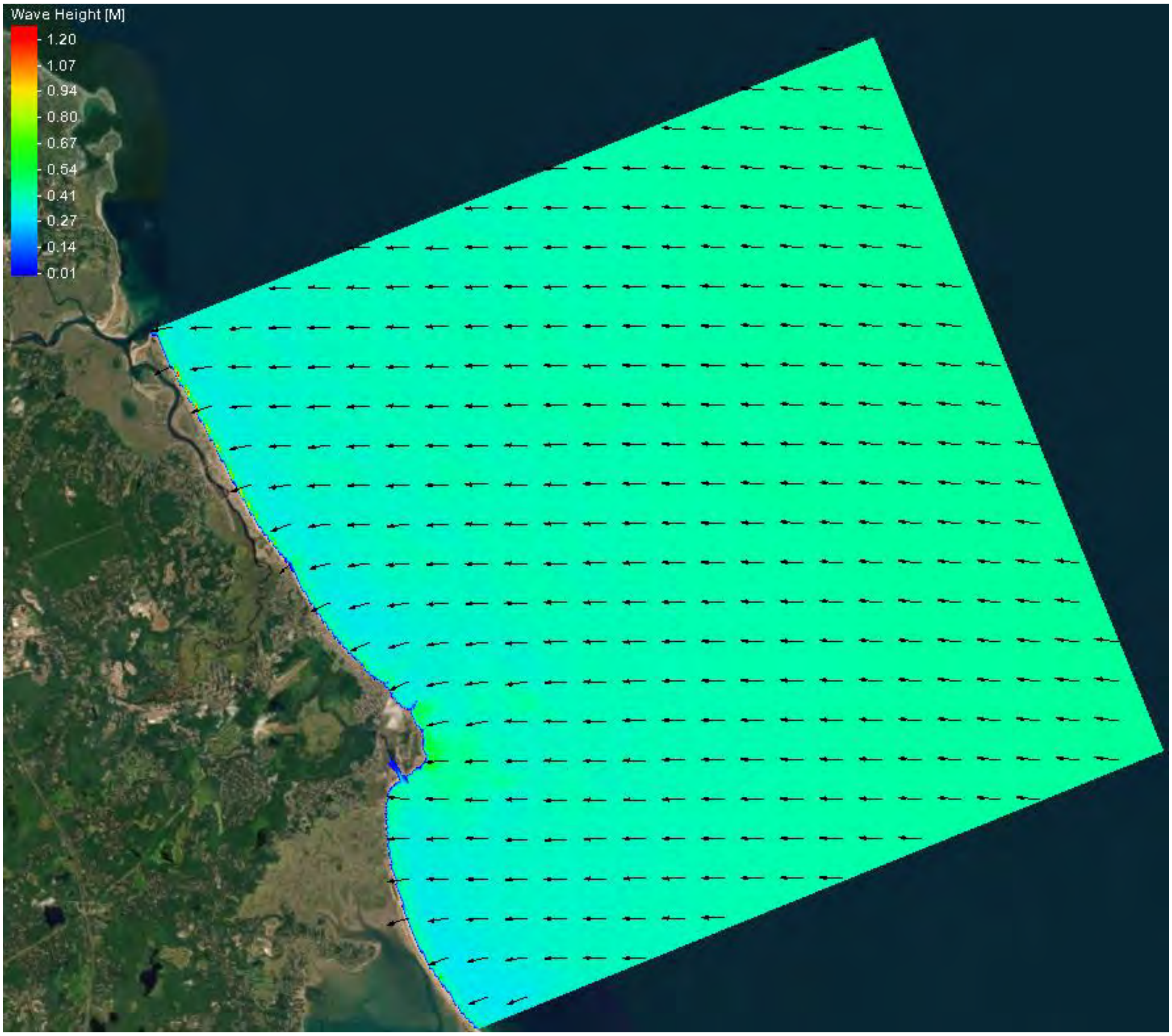
A-3: Results of the regional wave model for the NE approach direction (23.0° to 44.5 ° [N = 0°])



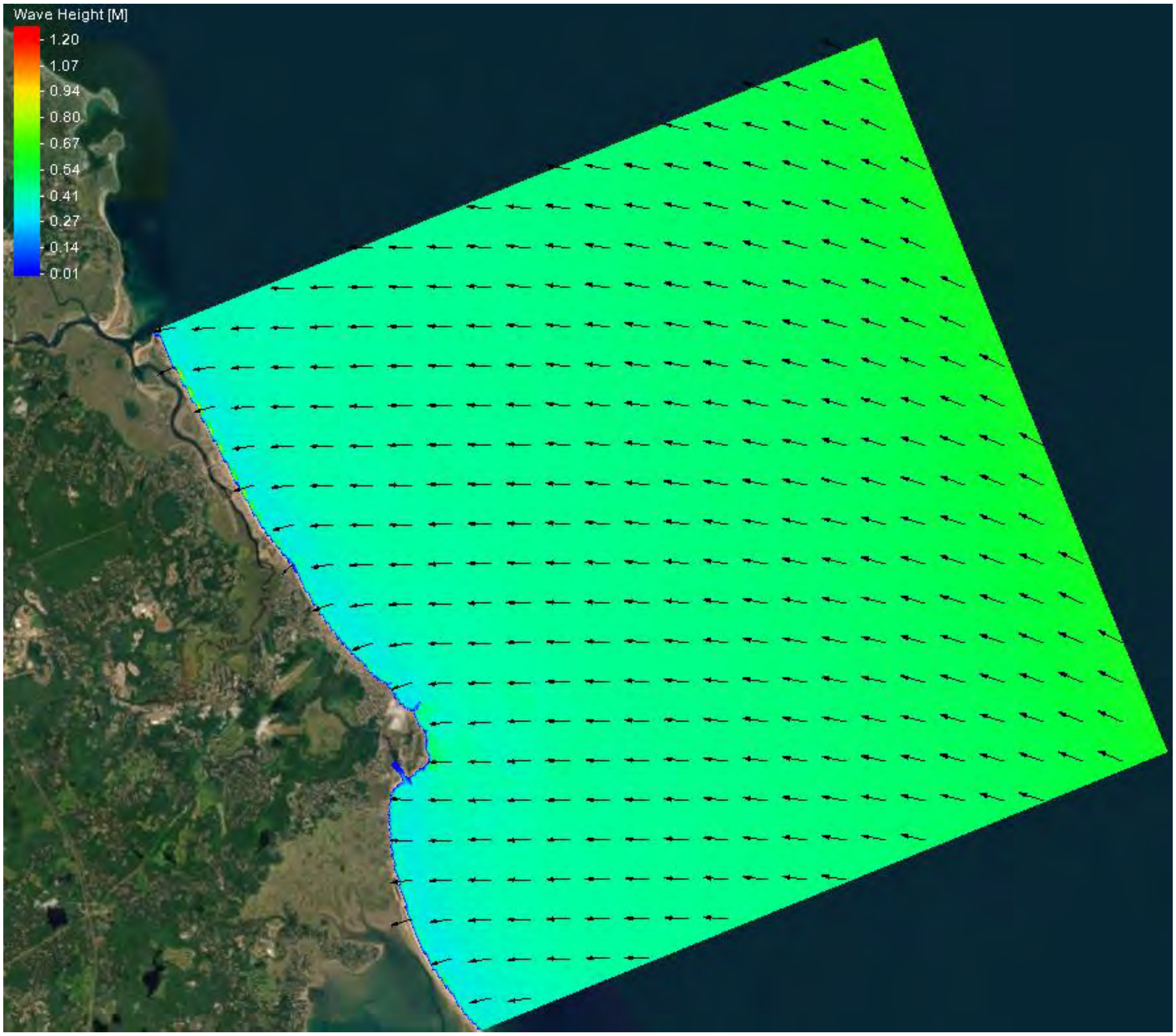
A-4: Results of the regional wave model for the NE-ENE approach direction (44.5° to 68.0 ° [N = 0°])



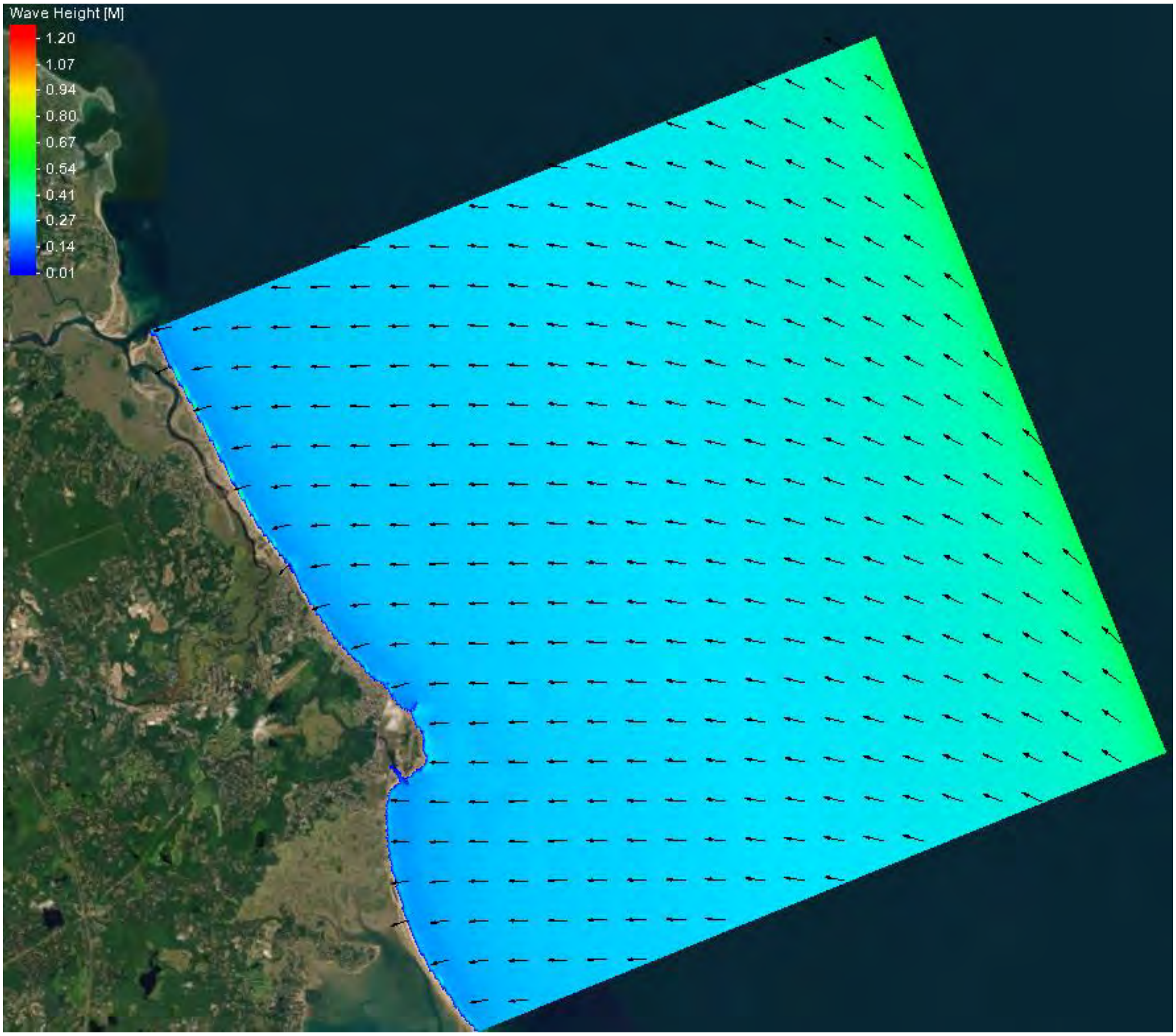
A-5: Results of the regional wave model for the ENE-E approach direction (68.0° to 90.5 ° [N = 0°])



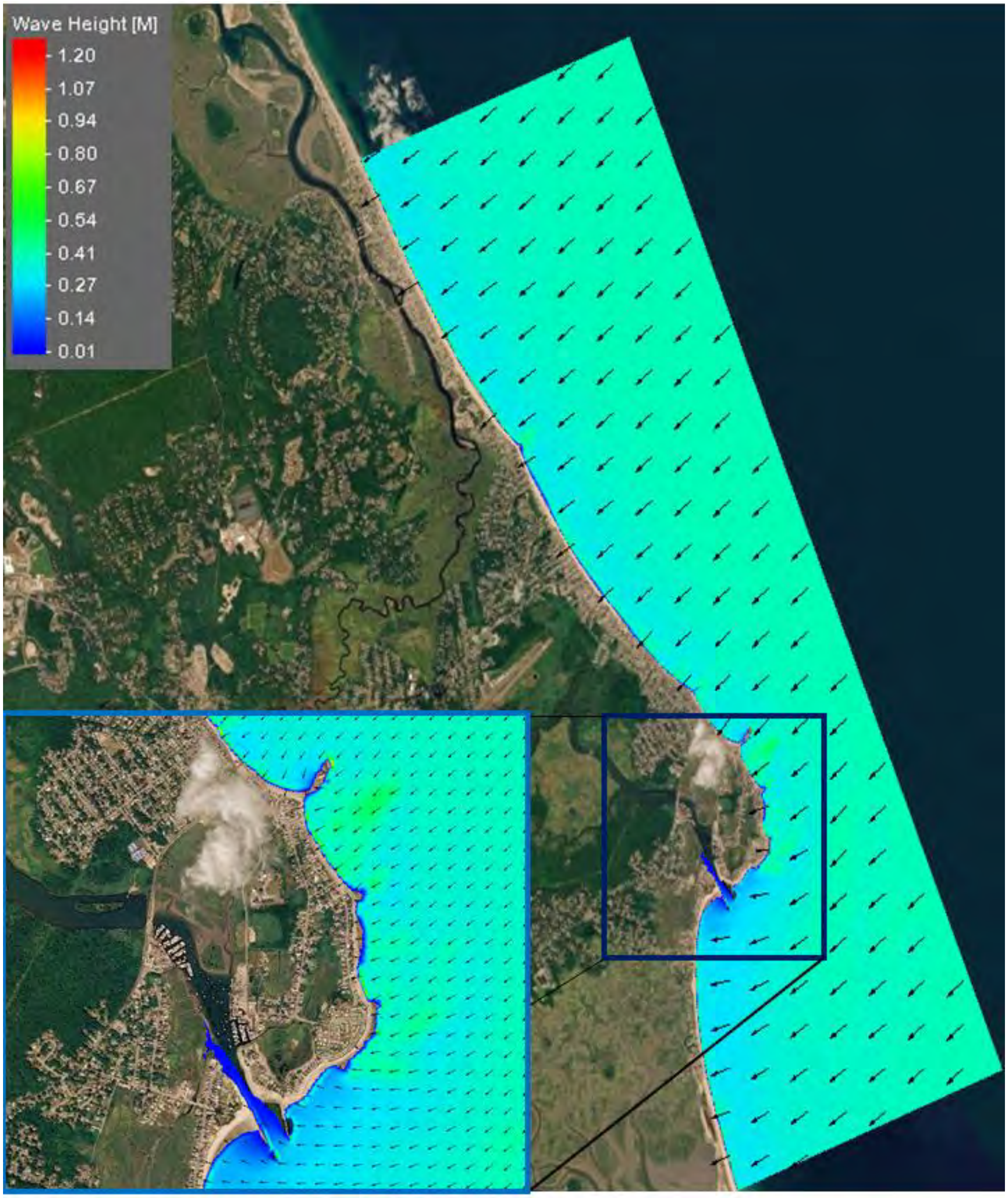
A-6: Results of the regional wave model for the E-ESE approach direction (90.5° to 113.0 ° [N = 0°])



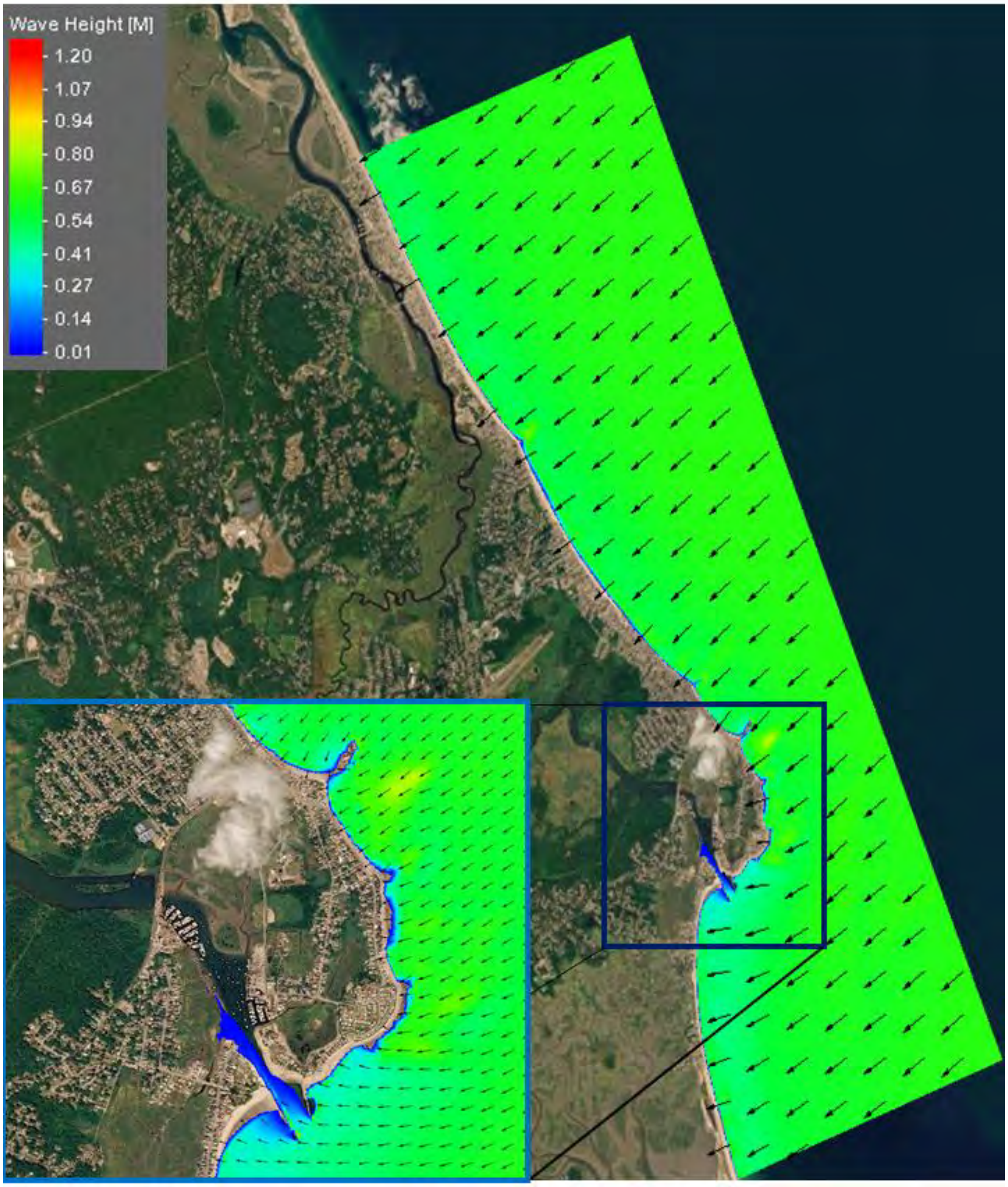
A-7: Results of the regional wave model for the ESE-SE approach direction (113.0° to 135.0 ° [N = 0°])



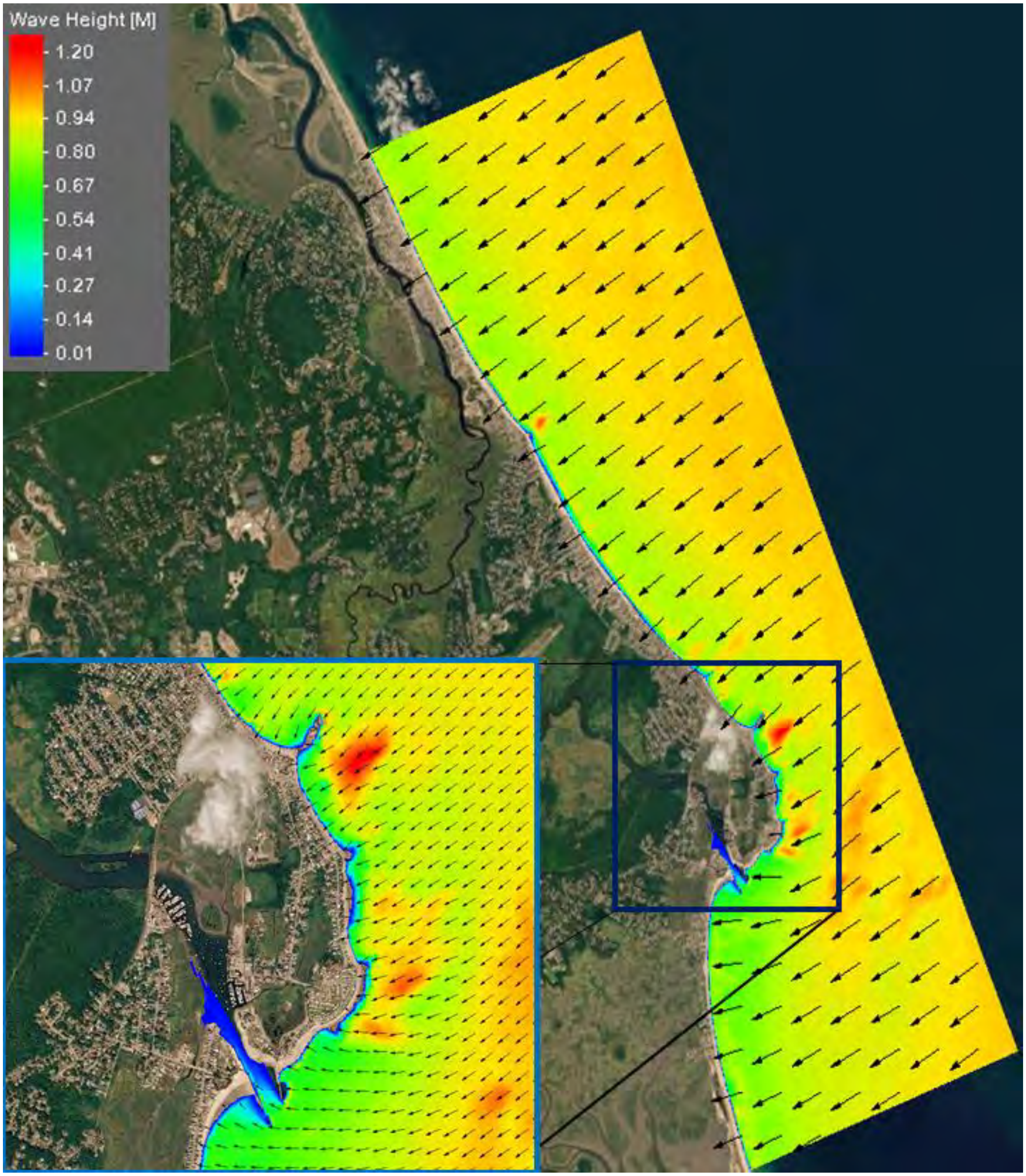
A-8: Results of the regional wave model for the SE-SSE approach direction (135.0° to 158.0 ° [N = 0°])



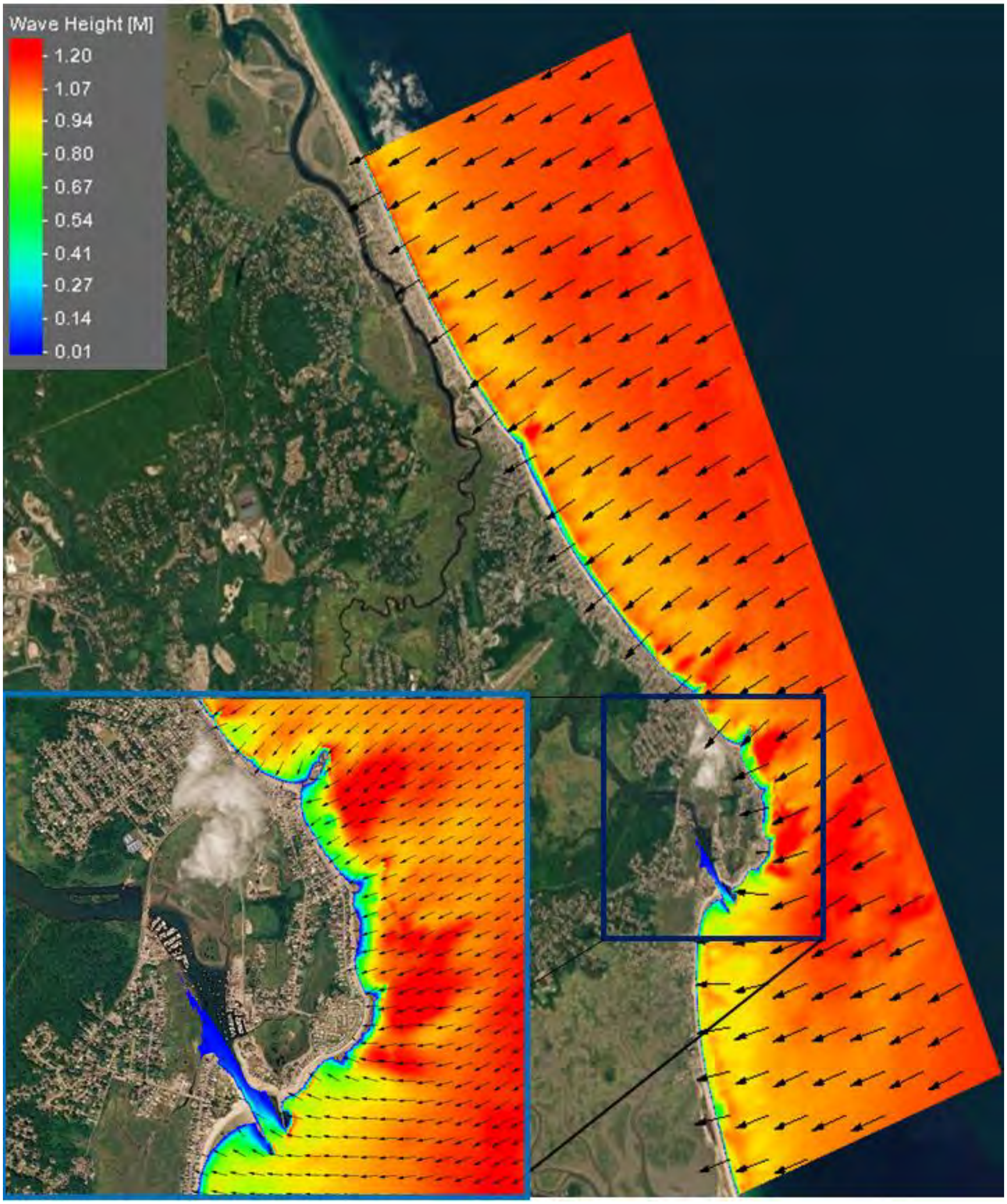
A-9: Results of the local wave model for the NNW approach direction (338° to 0.5 ° [N = 0°])



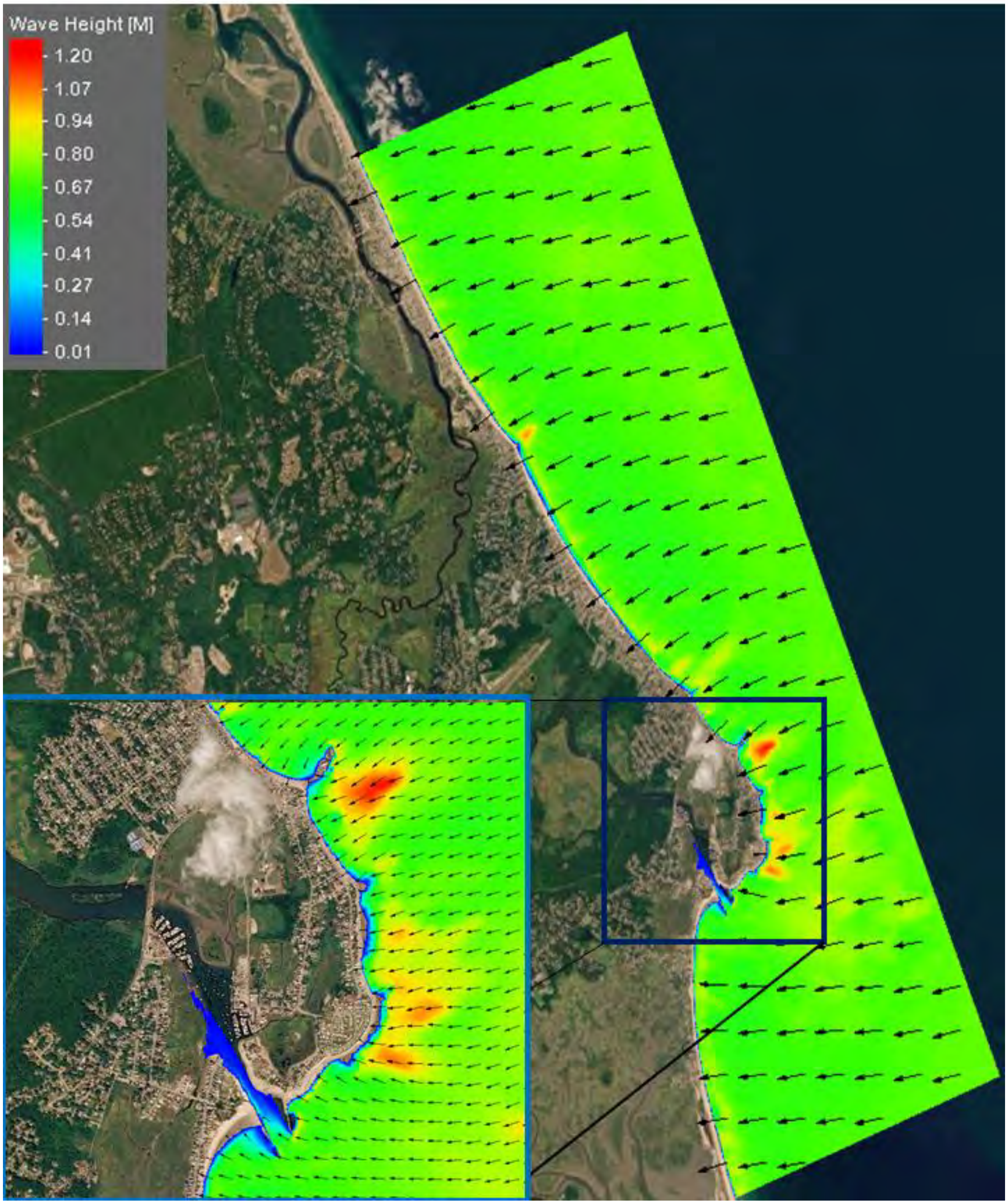
A-10: Results of the local wave model for the N-NNE approach direction (0.5° to 23.0 ° [N = 0°])



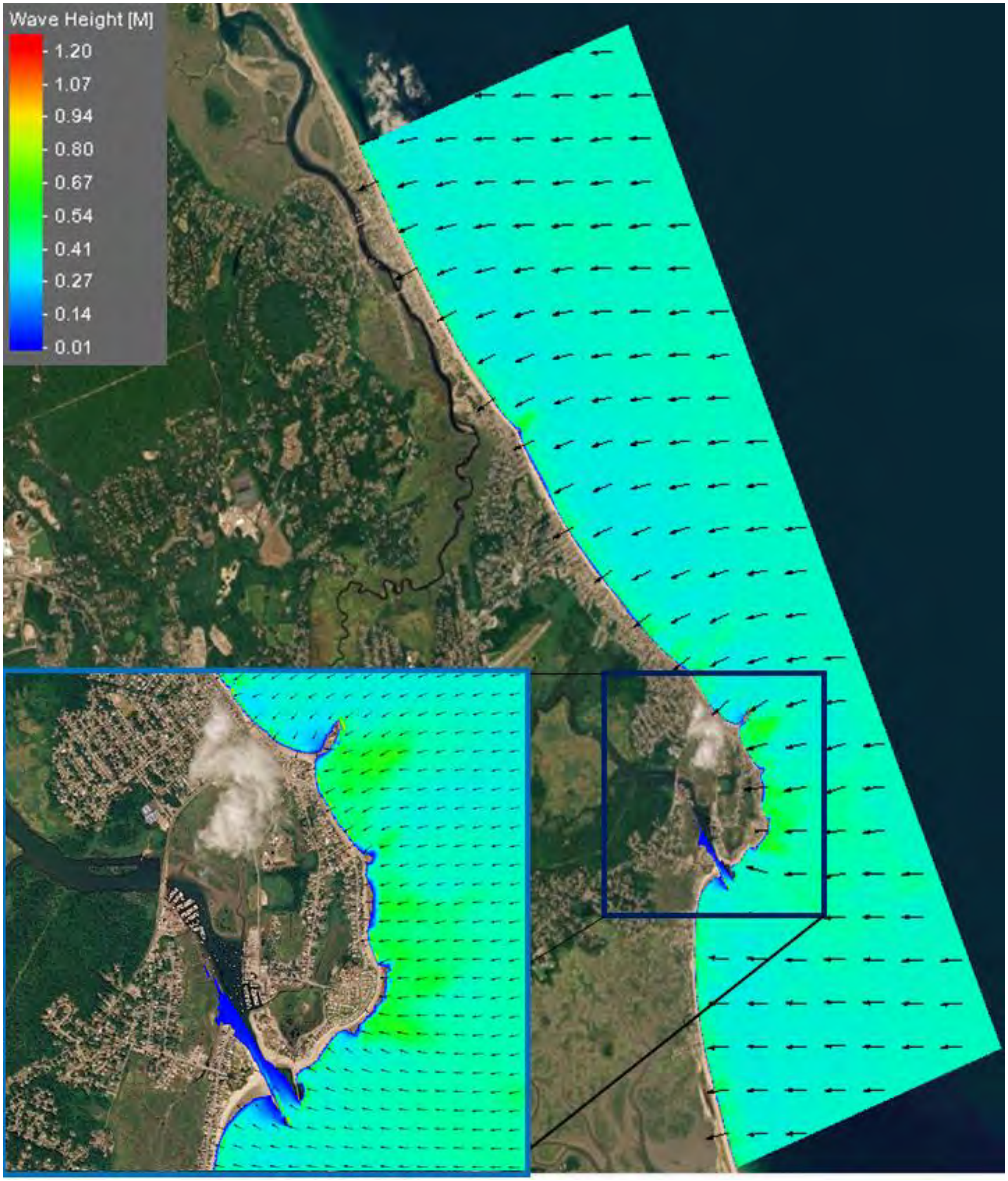
A-11: Results of the local wave model for the NE approach direction (23.0° to 44.5 ° [N = 0°])



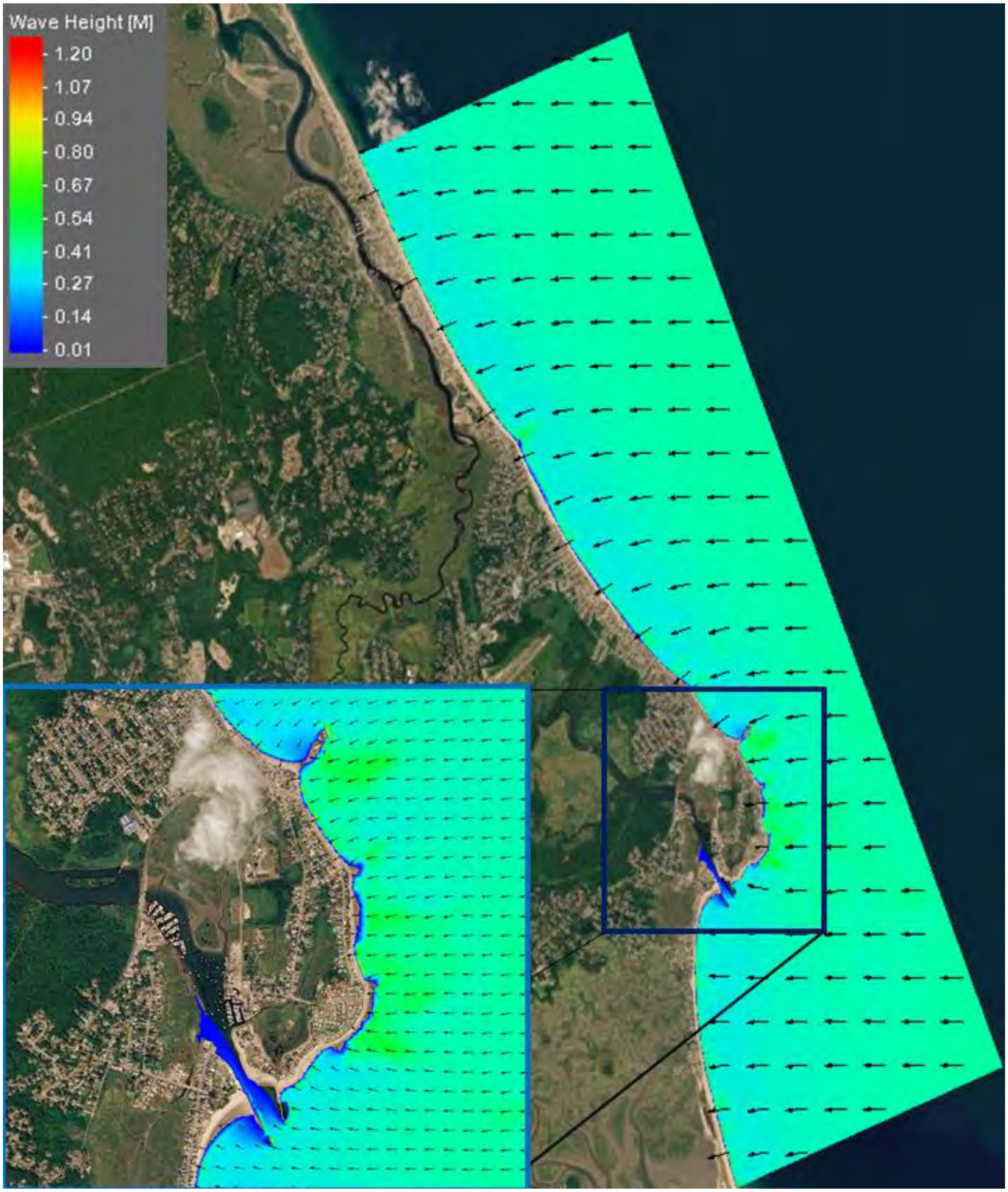
A-12: Results of the local wave model for the NE-ENE approach direction (44.5° to 68.0 ° [N = 0°])



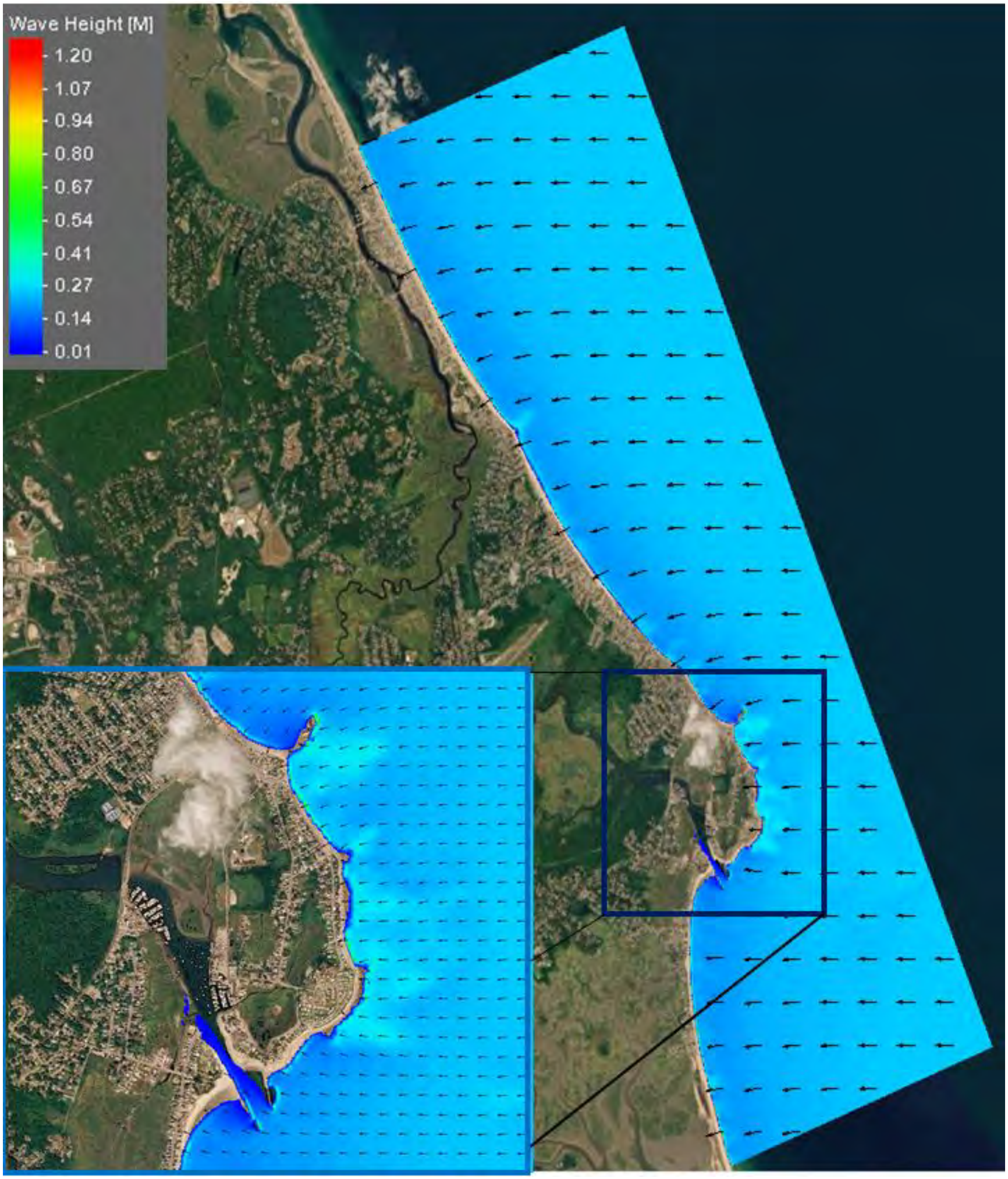
A-13: Results of the local wave model for the ENE-E approach direction (68.0° to 90.5 ° [N = 0°])



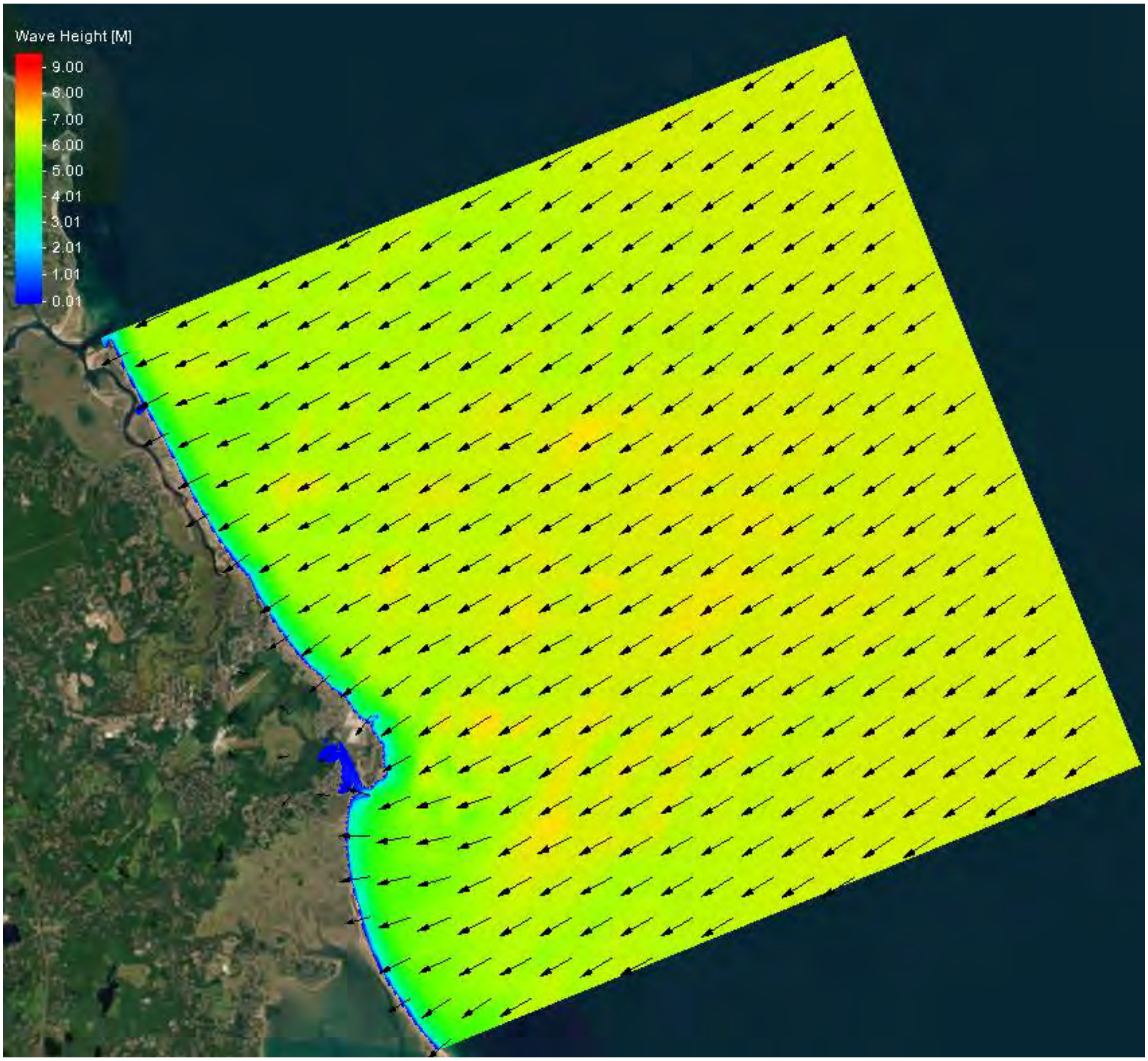
A-14: Results of the local wave model for the E-ESE approach direction (90.5° to 113.0 ° [N = 0°])



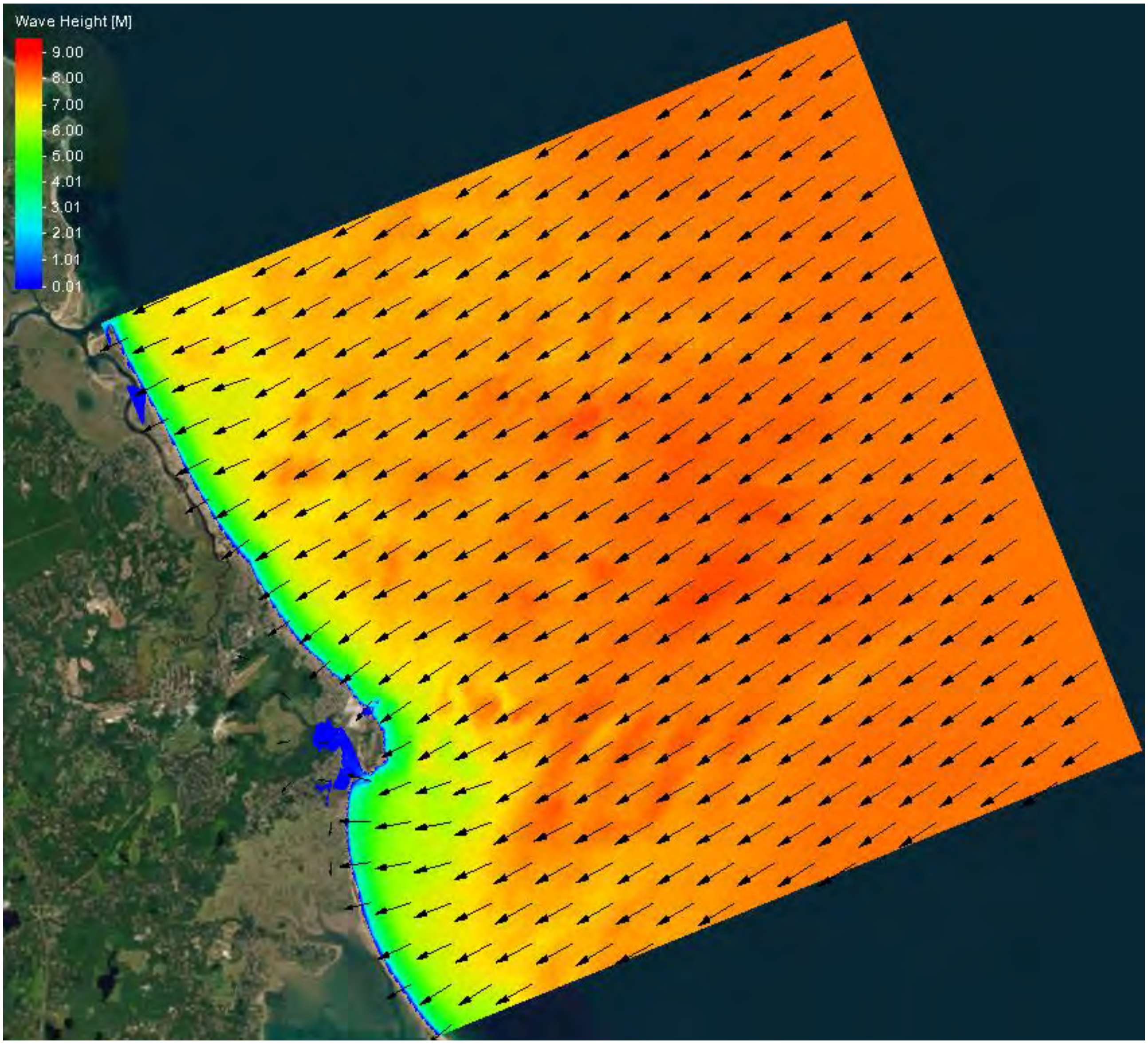
A-15: Results of the local wave model for the ESE-SE approach direction (113.0° to 135.0 ° [N = 0°])



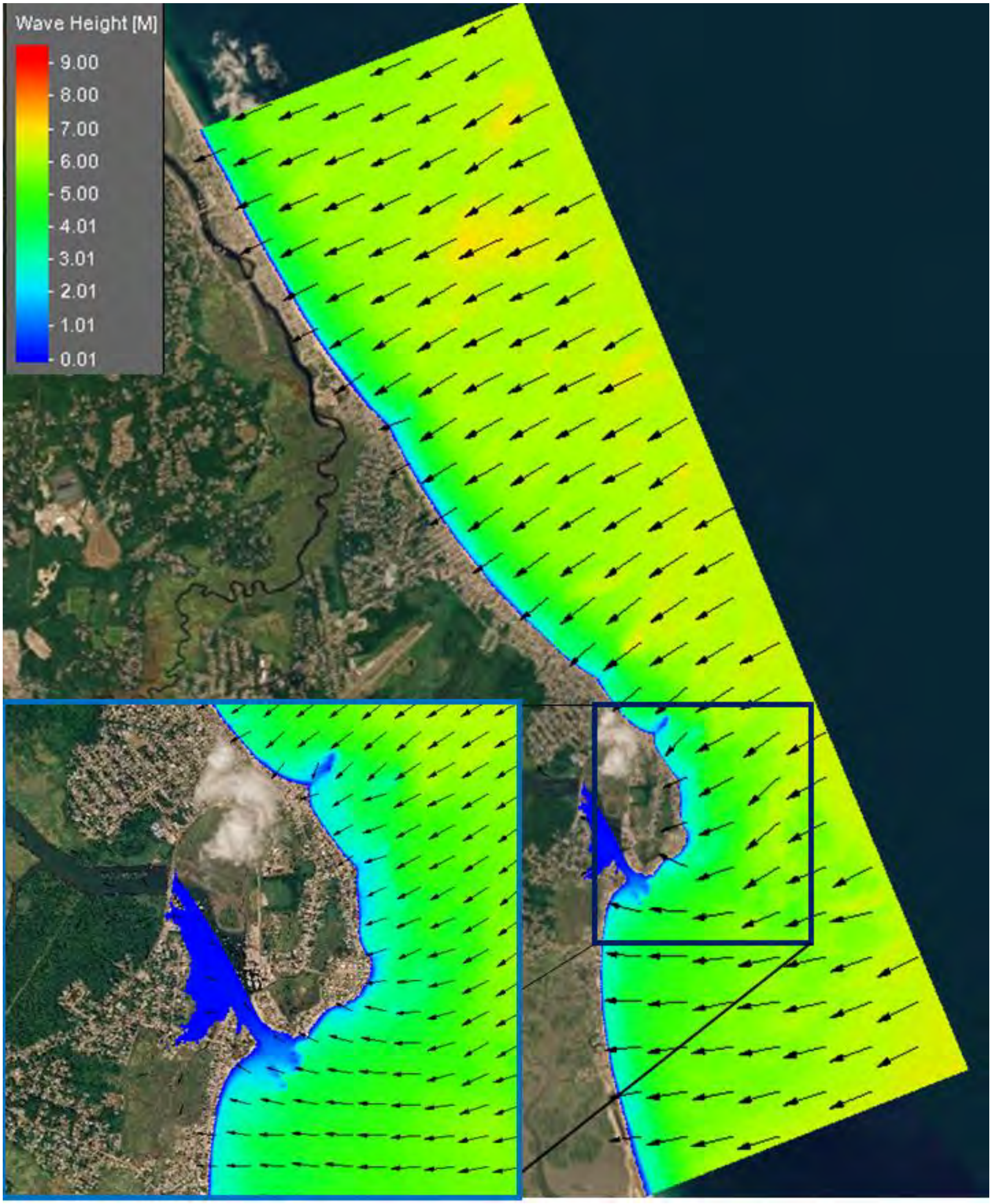
A-16: Results of the local wave model for the SE-SSE approach direction (135.0° to 158.0 ° [N = 0°])



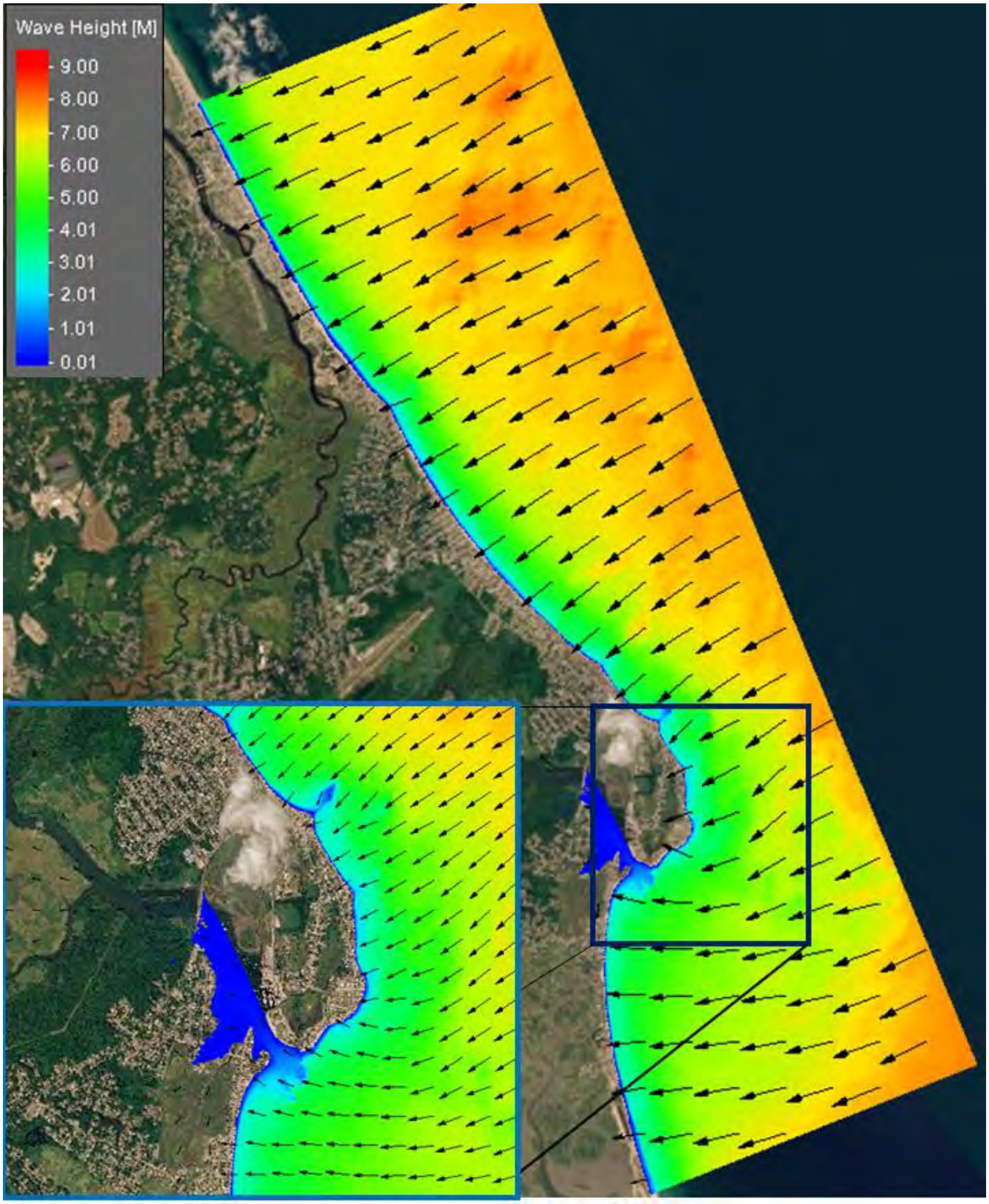
A-17: Results of the regional wave model for a 10 -year return period storm.



A-18: Results of the regional wave model for a 50 -year return period storm.



A-19: Results of the local wave model for a 10 -year return period storm.



A-20: Results of the local wave model for a 50-year return period storm.

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WOODS HOLE GROUP FOR EARTH, FROM SPACE
A CLS COMPANY

TECHNICAL MEMORANDUM

DATE May 5, 2020 **JOB NO.** 2018-0231

TO Greg Guimond, Town of Marshfield Planner
Valerie Massard, Town of Duxbury Planner

FROM Woods Hole Group, Inc.

Beach and Dune Nourishment at Critically Eroded Beaches in Marshfield & Duxbury – Sediment Transport Modeling Memo

Introduction

An understanding of how waves interact with the complex nearshore bathymetry is important to determine estimates of sediment movement in the nearshore region. The results of the transformation-scale wave modeling conducted for Marshfield and Duxbury, therefore, act as the key input for alongshore sediment transport modeling and evaluation of beach nourishment activities. The intent of the sediment transport modeling is to represent the alongshore currents and sediment transport driven by breaking waves in the surf zone. The model provides estimates of sediment flux to identify trends of erosion and accretion along the shoreline. This section describes the development of the physical process-based sediment transport model for Marshfield and Duxbury, the model inputs, and results of the sediment transport modeling.

Sediment Characteristics

To accurately model sediment transport processes along the Marshfield and northern Duxbury coastline, the characteristics of the naturally occurring sediments on the beach must first be identified. Grain-size characterization is also important for the design of beach nourishment and erosion mitigation alternatives developed as part of this study.

The grain-size information for the sediment transport modeling was sourced from the sediment sampling that was completed by Woods Hole Group, with results of this sampling presented in Table 1. During three different sampling efforts conducted between 2017 and 2019, 29 surface-grab and large volume grab samples were collected from the dunes and beach. Further information regarding this sediment sampling effort is discussed in Section C.1.4.

Sediments along the coastline in the project area are characterized by a mixture of gravel and sand, with isolated areas of cobble sized sediment. The average sediment type is a granular sand with a D_{50} (median grain-size) of 6.5 mm. The smallest D_{50} occurs for a predominantly-sand sample at station 12-MTL-SAN (south end of Sunrise Beach), with a value of 0.25 mm. The largest D_{50} occurs for a predominantly cobble sample at station 12-MTL-COB (south end of Sunrise Beach), with a value of 32 mm. The median sand grain size for the beach is 1.75 mm occurring at station 16-MTL-SAN (Gurnet Rd Beach) and the median gravel/pebble grain size is 19 mm occurring at station 8-MTL-COB (Winslow Ave. Beach). These values were used as the representative grain-sizes for sand and cobble, respectively, in the mixed-grain size sediment transport analysis.

Table 1. Summary Grain Size Statistics for Project Area Beaches.

Sample ID	D_{50} (mm)	% Cobble	% Gravel	% Sand	% Silt & Clay
Beach & Dune Samples (listed north to south)					
Rexhame Beach	0.32	0	0.3	99.4	0.3
01-DU-SAN	0.35	0	0.0	99.8	0.2
02-MTL-SAN	8.70	0	83.0	16.9	0.1
02-MTL-COB	14.40	4	93.0	3.0	0.0
03-MHW-SAN	0.55	0	1.0	98.9	0.1
04-MTL-SAN	7.50	0	71.0	28.9	0.1
05-MHW-SAN	0.50	0	20.0	79.9	0.1
06-MTL-SAN	0.53	0	37.0	62.6	0.4
07-DU-SAN	0.30	0	0.0	99.9	0.1
08-MTL-SAN	6.9	0	77.0	22.9	0.1
08-MTL-COB	19.0	4	90.0	6.0	0.0
09-MTL-SAN	1.14	0	41.0	58.8	0.2
10-MTL-SAN	4.00	0	70.0	29.8	0.2
10-MTL-COB	11.4	11	82.0	7.0	0.0
Sunrise/Fieldston	0.37	0	10.8	88.5	0.7
11-MTL-SAN	5.7	0	65.0	34.7	0.3
12-MTL-SAN	0.25	0	2.0	97.3	0.7
9th Street	3.36	0	11.4	87.9	0.7
12-MTL-COB	32.00	34	53.0	13.0	0.0
13-MTL-SAN	5.90	0	78.0	21.9	0.1
Brant Rock	0.42	0	39.8	59.8	0.4
Green Harbor	0.37	0	0.5	99.0	0.5
Pearl Street	4.87	0	8.9	90.5	0.6
14-MTL-COB	13.40	4	68.0	28.0	0.0
14-MTL-SAN	0.34	0	22.0	77.9	0.1
15-MTL-SAN	1.76	0	36.0	63.9	0.1
16-MTL-COB	13.10	10	89.0	1.0	0.0
16-MTL-SAN	1.75	0	40.0	59.9	0.1
17-MTL-SAN	0.23	0	0.0	99.9	0.1
Average	**6.5**	**1.5**	**50.0**	**48.3**	**0.1**

Analysis Approach

Sediment transport in the coastal zone is controlled by the interaction between onshore wave energy and nearshore features together with sediment grain size and available sediment supply. Numerical modeling sediment transport in the coastal zone involves solving the physics of wave energy and sediment transport with simplifying assumptions. The sediment transport model used for this modeling effort is a process-based model which identifies patterns of regional sediment transport in the presence of a time-varying wave field. Due to the mixed-granular characteristics of the natural sediments occurring along the Marshfield and Duxbury coastline, a sediment transport approach that incorporates multiple grain sizes, along with their relative contributions, was developed and utilized for this modeling effort. This approach is described in the following sections.

Model Description

The sediment transport model used to simulate sediment fluxes on the Marshfield and Duxbury coastline is a process-based numerical model which solves the steady-state, depth averaged mass and momentum equations, coupled with the calculations for long-shore sediment transport adopted from the methodology developed by Haas and Hanes (2004). Technical details of the sediment transport model are provided in Appendix A.

The sediment transport model uses a series of cells covering the section of beach and surf zone where wave-induced sediment transport occurs. Based on the wave model results, a cell can either accumulate sediment or lose sediment as the wave energy is applied. Cells that gain more sediment than they lose are described as accreting (sediment is converging in the cell), whereas cells that lose more sediment than they gain are described as eroding (sediment is diverging in the cell). A cell that loses the same amount of sediment than it gains is described as stable, indicating no accretion or erosion is occurring.

Modeling Grid

A high-resolution bathymetric grid was generated using the nearshore bathymetry/topography from the transformation-scale wave model (CMS-WAVE) for Marshfield and northern Duxbury. The grid for the sediment transport model was the higher resolution local grid developed for the wave transformation model, with 10-meter cells spanning 11.29 km in the along-shore direction and 3.4 km in the onshore direction. Results from the wave transformation model for both average annual conditions and the high-energy events were used as input to the high-resolution sediment transport model. Table 2 presents the information for the grid used in the sediment transport model. The orientation of the grid was altered for the portion of shoreline south of Green Harbor to more accurately represent a shore-normal orientation.

Table 2. Grid Information.

Details	Sediment Modeling Grid
Grid Type	Uniform cartesian
Resolution	10 m
Scale	Local
X origin (MA State Plane Meters)	269709.02
Y origin (MA State Plane Meters)	878706.45
Grid Orientation	202.08 °
Depth at Boundary	12 m
Length of Seaward Boundary (km)	11.29 km

Results

To identify erosional and accretional patterns on specific sections of the project coastline, sediment transport trends were characterized using modeled rates and directions of sediment transport. The model computes the sediment flux, a representation of the rate of sediment moving along the coastline, in cubic meters per year. Positive and negative fluxes indicate the direction of sediment movement relative to the model's grid orientation. It is important to note that the model computes the potential for sediment transport. The calculations assume that sediment is infinitely available for transport, and therefore the model overpredicts rates of transport along stretches of shoreline that are sediment starved, like the Marshfield and Duxbury shorelines.

The transformation-scale wave model results (Section C.1.6) were used as input into the sediment transport model. Sediment transport was first evaluated for average annual conditions by simulating each average directional wave case (Figure 1; Table 3). This was completed using the representative grain sizes listed above. Storms were also evaluated to determine the episodic transport which occurs during extreme storm events.

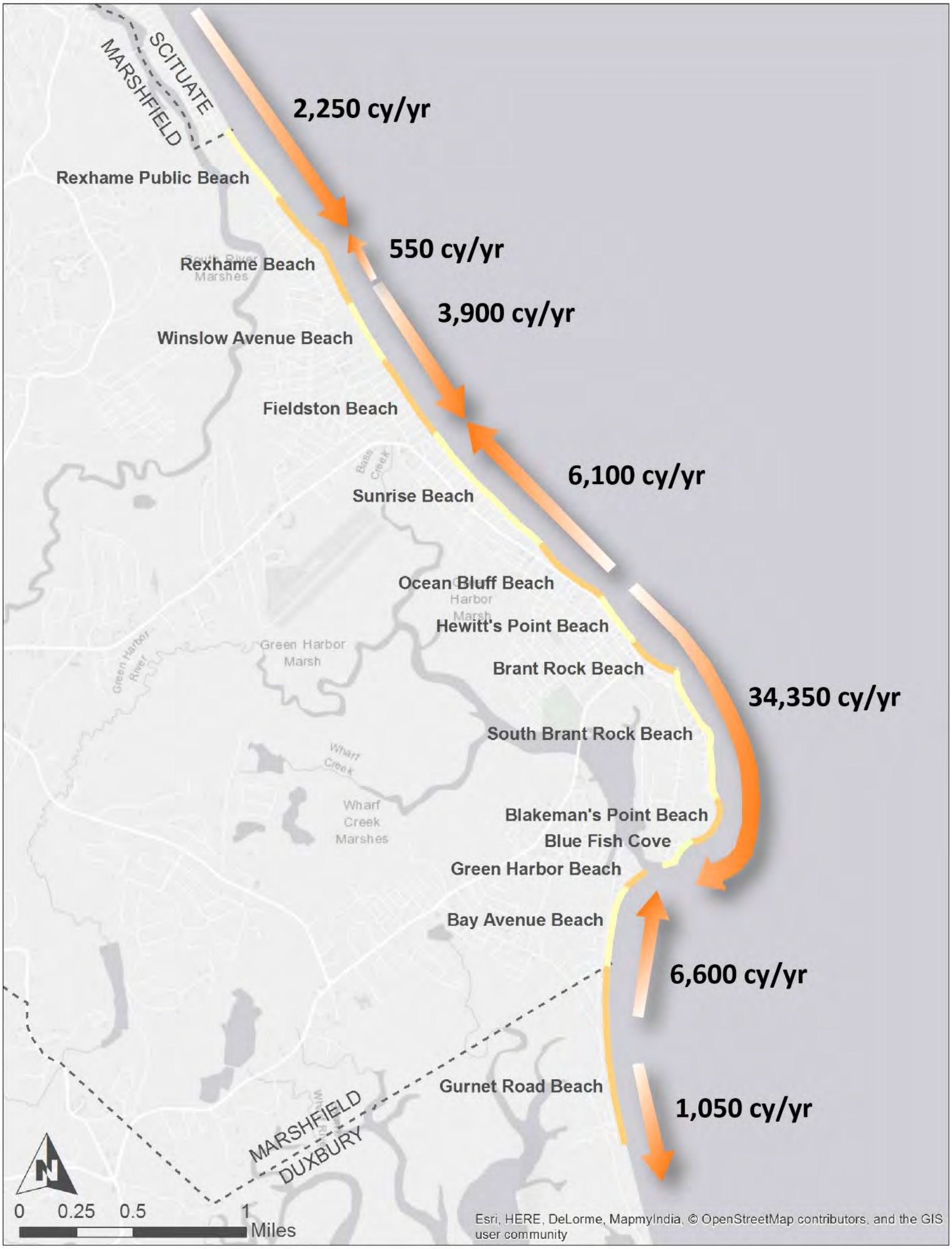

Figure 1: Sediment transport from the average annual wave bin condition.

Table 3: Table of Sediment Transport Results for Average Annual Conditions

Beach	Sediment Flux (y^3 /y)	Direction
Rexhame Beach (North)	2,250	Southward
Rexhame Beach (South)	550	Northward
Winslow Avenue Beach/Fieldston	3,900	Southward
Sunrise/Ocean Bluff	6,100	Northward
Green Harbor Beach/Bay Ave Beach	6,600	Northward
North Duxbury	1,050	Southward

Summary

A physically based numerical sediment transport model was developed to obtain estimates of the alongshore sediment flux and divergence in the Marshfield and northern Duxbury region. The model was used to simulate sediment transport during average annual conditions. The model results indicate areas of potential erosion and accretion to help characterize trends in sediment movement for the project coastline and help identify needed mitigation and placement strategies for beach replenishment.

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TECHNICAL MEMORANDUM

DATE June 11, 2020 **JOB NO.** 2018-0231

TO Greg Guimond, Town of Marshfield Planner
Valerie Massard, Town of Duxbury Planner

FROM Woods Hole Group, Inc.

Beach and Dune Nourishment at Critically Eroded Beaches in Marshfield & Duxbury – Engineering Design: Cross-Shore Modeling Memo

As part of work to plan, design, and permit beach nourishment and dune enhancement projects at vulnerable coastal beaches along the shorelines of the towns of Marshfield and Duxbury, Woods Hole Group has conducted cross-shore modeling at four (4) sites around the project areas. While much of the shoreline along Marshfield and Duxbury is protected by hard engineering structures, the beaches throughout the town are critically eroded. This beach erosion has left the structures throughout the Towns vulnerable to damage and has increased wave overtopping in storms causing frequent flooding in areas throughout the Towns.

The goal of the overall project is to explore beach and dune alternatives to improve management of the shoreline in the face of impacts of rising sea levels. Task 1 and Task 2 of the overall project included characterizing existing conditions at beaches throughout the Towns and assessing benefits and limitations of various possible coastal resiliency solutions that could be applied to achieve improved coastal resiliency in the Towns. Task 3 of the project included the evaluation of various engineering design templates designed as part of Task 2 of this project, with respect to storm damage protection and design life. Part of Task 3 includes cross-shore modeling of possible dune and beach restoration projects. A cross-shore model was used to simulate the effects of storm conditions on the existing beach, as well as the different beach and dune nourishment design templates evaluated as part of Task 2. This memo serves to summarize the cross-shore modeling accomplished as part of Task 3.

Cross-shore Model Description

In order to evaluate the conceptual design configurations of beach and dune nourishments at the potential Marshfield and Duxbury project sites, estimate service life, and to determine the protective level of the proposed designs during high-energy storm events, a cross-shore sediment transport model (XBeach) was utilized. XBeach is an open-source numerical model developed to simulate wave, hydrodynamic and morphodynamic processes. It has been developed with support of various agencies including the US Army Corps of Engineers, Rijkswaterstaat and the EU, together with a consortium of UNESCO-IHE, Deltares (formerly WL|Delft Hydraulics), Delft University of Technology, and the University of Miami. The newest version of the model (XbeachX) was utilized for the purposes of this study. Xbeach was originally designed to assess hurricane impacts on sandy beaches. However with funding from the Dutch Public Works Department the model has been extended, applied and validated for storm impacts on dune and urbanized coasts, and, with further support from the European Commission Xbeach has been validated on a number of dissipative and reflective beaches throughout the EU.

For its original purposes, Xbeach was designed as a short-wave averaged, wave group resolving model (surf-beat mode) but has been since been updated to allow for a variety of hydrodynamic options. Additionally, Xbeach now allows for a variety of different sediment transport formulations. These options, as well as others included in the model, allow for flexibility in the types of scenarios in which Xbeach may be used for simulation purposes.

For the purposes of this study two different formulations of the model were utilized. For simulating beaches where sand is the dominant material, the default surf-beat mode wave formulation was utilized with the Van Thiel-Van Rijn transport equations (van Rijn, 2007) used for sediment transport calculations. For gravel dominated beaches, the XBeach-G formulation was used. XBeach-G is a branch of the main XBeach development that was designed to simulate storm impacts on gravel beaches. The development of XBeach-G is a collaboration between Plymouth University and Deltares. XBeach-G uses the non-hydrostatic wave model included in XBeach (wave-resolving) and the bed load transport equation included in van Rijn, 2007 excluding coefficients for silt for the calculation of sediment transport on gravel dominated beaches.

The surfbeat module of XBeach includes the hydrodynamic processes of short-wave transformation (refraction, shoaling and breaking), long wave (infragravity wave) transformation (generation, propagation, and dissipation), wave-induced setup and unsteady currents, and overwash and inundation. The non-hydrostatic wave model used in the Xbeach-G formulation includes all wave processes included in the surfbeat module, in addition to including short wave motions (not averaged as is the case with the surfbeat module). The non-hydrostatic module is utilized for gravel beaches because due to the steep slopes typical at gravel beaches, swash motion is mainly at incident wave frequencies, and infragravity wave motion, which dominates the inner surf and swash zone on sandy beaches during storms, is of secondary importance. The morphodynamic processes included in the XBeach formulation used for sandy beaches includes bed load and suspended sediment transport, dune face avalanching, bed update and breaching. In addition, Xbeach-G includes a groundwater dynamics model to correctly account for upper swash infiltration losses and exfiltration effects on lower swash hydrodynamics. Interaction between swash flows and the beach groundwater table are considered particularly important on gravel beaches due to the relatively large hydraulic conductivity of the sediment, while on sandy beaches this process is of significantly less importance. Additionally, the Xbeach-G formulation does not include suspended sediment transport. Further details of both the general XBeach model as well as the Xbeach-G formulation and the theory behind the model can be found in the XBeach Technical Reference (Deltares, 2018).

XBeach Model Setup

To assess the proposed conceptual designs for the project, existing and design profiles were evaluated using X-Beach. 1-dimensional representations of each conceptual design as well as existing conditions were created for simulation in the model. The 1-D transects were set through representative portions of the proposed project areas. Figure 1 shows a plan view map of the four model transects simulated as part of this project. Figure 2 shows an overview map of where the transects are located within the Towns.

These four model transects were selected to be representative of larger project areas that had similar designs and existing conditions parameters. Transect 3 was selected to be representative of the Rexhame Public Beach project area, with the transect running through the dune abutting the Rexhame Beach parking lot. Transect 9 was selected to be representative of the Winslow Beach project area. Transect 12 was selected to be representative of the Sunrise / Fieldston Beach project areas. Transect 19 was selected to be representative of the section of Beach south of Green Harbor, running through a thinner portion of the Green Harbor Beach area.

Figure 1. Xbeach 1-D cross sectional transects assessed for this project.

The 1-D grids utilized in Xbeach were created with a resolution ranging from 10-meter grid spacing at the offshore portions of the transects down to 0.1-meter grid spacing at the more nearshore portions of the transects. The topography and bathymetry used to define the model grids was based on the most up-to-date available data. As part of this larger project, topographic surveys were collected at locations around Marshfield and Duxbury (Figure 2). Additionally, bathymetric data was collected as shown in Figure 3. These more up-to-date and highly resolved surveys were augmented with data from the CoNED project topobathymetric elevation model (OCM Partners, 2016) where necessary (offshore of the bathymetric survey, as well as onshore of the topographic surveys). Each model transect extended from the project site, approximately perpendicular to the beach, offshore to approximately -31 feet elevation relative to NAVD88. Site specific grain-size information collected as part of the existing conditions portion of this project were utilized to define each model transects' model simulation parameters.

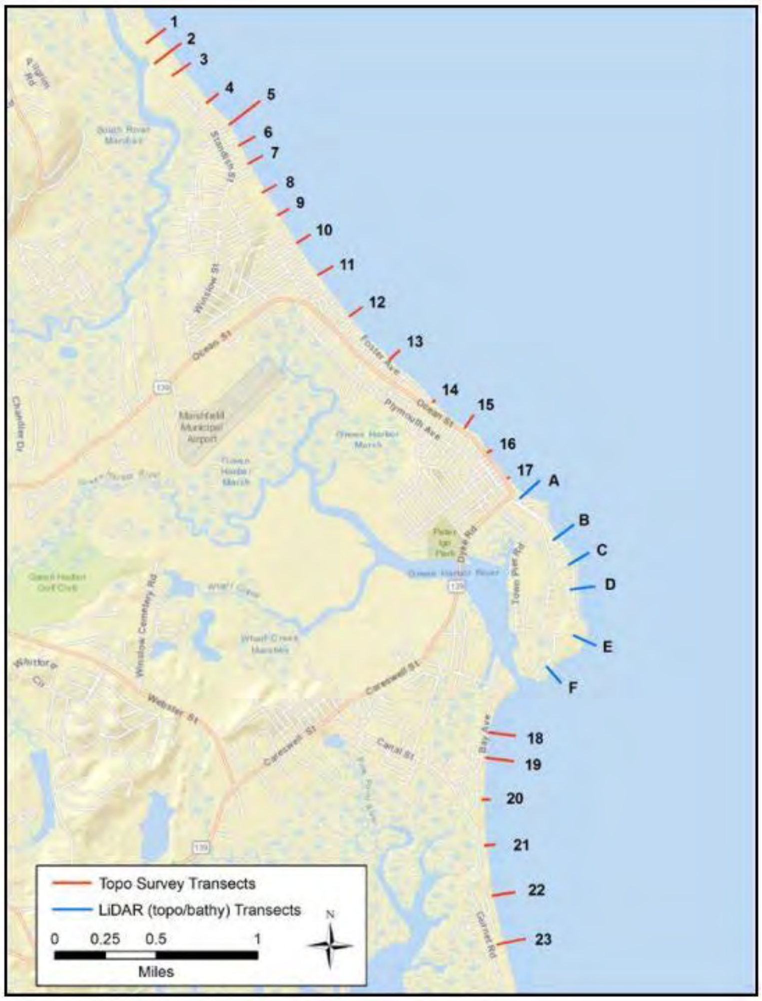

Figure 2. Locations of topographic survey transects assessed as part of this project.

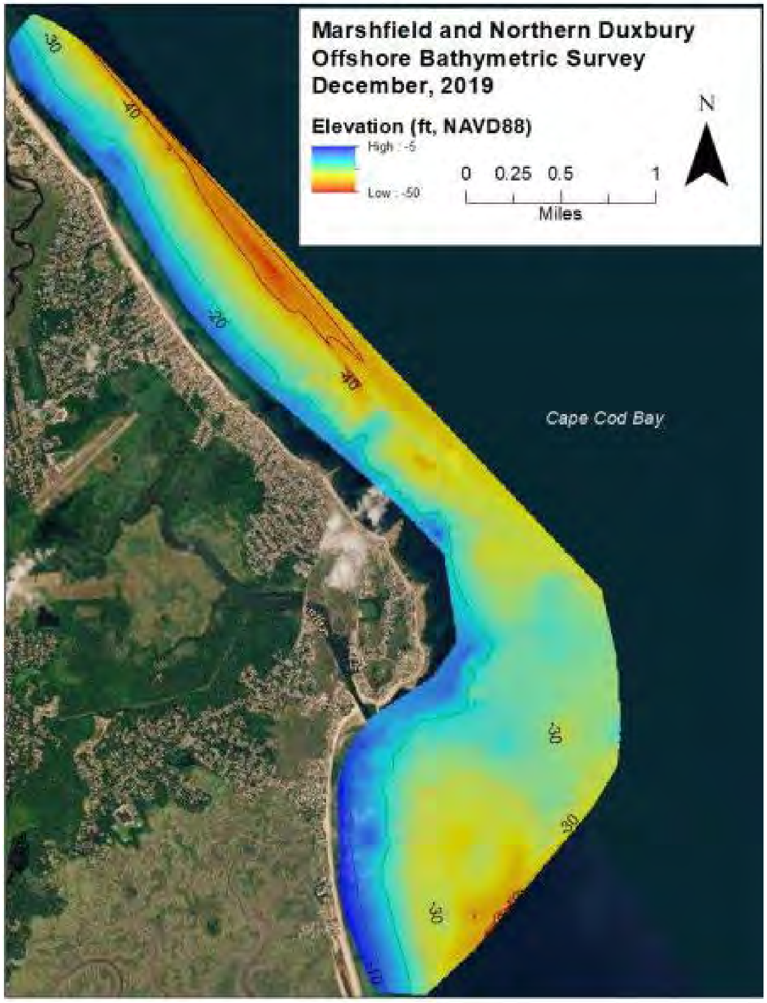

Figure 3. Bathymetric survey data collected for the study area offshore of Marshfield and northern Duxbury in November and December 2019.

Boundary conditions for each simulation were created to be applied at the offshore boundary of the 1-Dimensional Xbeach grid. Four different boundary conditions were utilized for this study. Not all boundary conditions were applied at every site.

1. A 1-year return period storm surge level combined with a 1-year return period wave condition
2. A 2-year return period storm surge level combined with a 2-year return period wave condition
3. A 10-year return period storm surge level combined with a 10-year return period wave condition
4. A 50-year return period storm surge level combined with a 50-year return period wave condition

To establish wave and water level boundary conditions for each of these simulation cases, site specific wave model results and an existing analysis of extreme water levels for the area were utilized. Storm surge elevations corresponding for each scenario were collected from USACE's Tidal Flood Profiles of the New England Coast (USACE, 1988). Wave conditions for each model transect were determined from the WIS study (USACE, 2014). Extreme waves from the WIS output station (station 63060) were transformed to the start of the XBeach transect utilizing the CMS-wave wave transformation model created for this project (Figure 4). The CMS-Wave model is described in further detail in the existing conditions memo previously provided for this project. Each storm case was simulated over a 24-hour period with the peak wave heights lined-up to correspond with the peak water levels, and with the wave and storm surge conditions gradually increasing and declining to normal conditions.

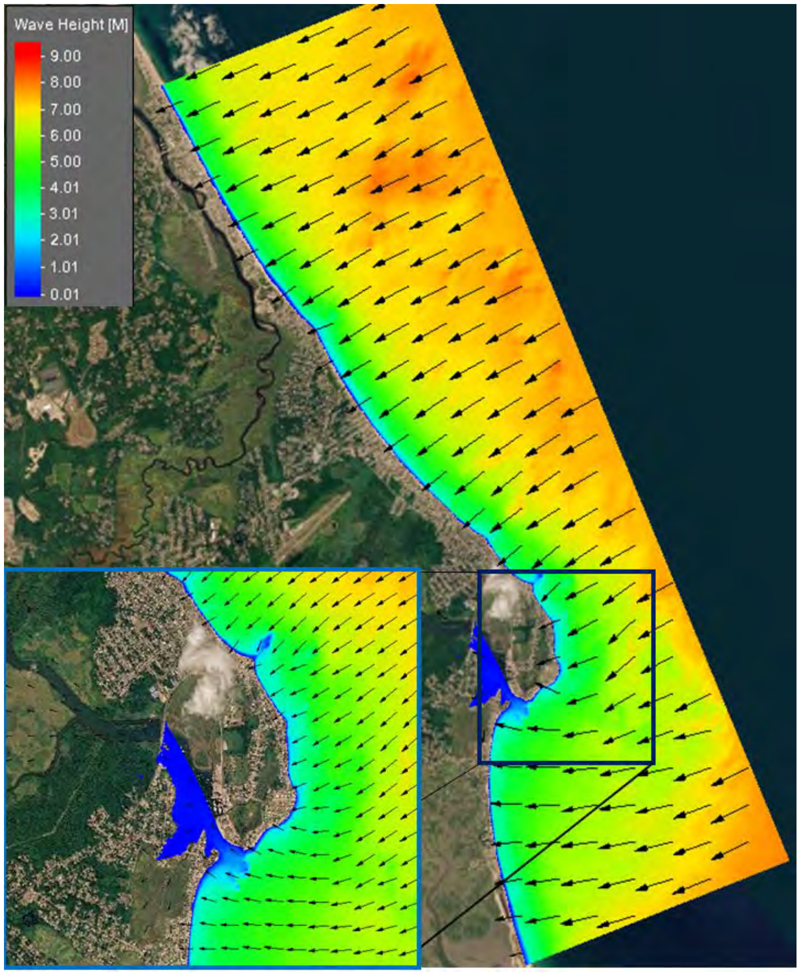

Figure 4. Example of CMS-Wave transformation model results for Marshfield and Duxbury. Results from the wave transformation model were utilized as boundary conditions for Xbeach simulations.

In order to simulate the conditions at each of the project sites, a combination of Xbeach model simulations with different parameters was required. For sites where the existing and project material is primarily sand, the default Xbeach formulation as described in the above cross-shore model description section was utilized. However, for sites where gravel was the primary material, the Xbeach-G formulation was utilized. For sites with a mixed grain size (gravel and sand) a combination of the two models were utilized. This was required because there does not exist a singular model that is appropriate for “mixed-grain” type beaches. The gravel/sand size threshold utilized as a definition for this project was defined as the threshold between sand and pebbles as defined by Wentworth (1922). Grain sizes for each simulation was calculated based on the D_{50} of the sand fraction / gravel fraction for the Xbeach / Xbeach-G formulation simulations, respectively. For the mixed-grain size simulations, once each simulation was conducted, the results were combined based on the fraction of the material made up of sand or gravel. For the purposes of this study, both sites where this analysis was necessary were assumed to have a 50%/50% mix of sand / gravel. This was based upon analysis of the grain size samples collected around each site, as well as the dynamic nature of both sites.

Transect 3, where the project is mainly focusing on the dune and dune restoration was simulated with the default Xbeach parameters, which are appropriate for sandy beaches. The Xbeach-G formulation was utilized for Transect 9 where the beach is primarily gravelly, and the project is focusing primarily on the enhancement of the existing gravel berm. For transects 12 and 19, a combination of the two model formulations had to be utilized. These two sites (at Fieldston/Sunrise Beaches and Green Harbor) are extremely dynamic sites with a combination of grain sizes that vary seasonally and with storm impacts. For this reason, these two transects were simulated using both the regular Xbeach formulation as well as with the Xbeach-G formulation.

The model output from each of the simulations conducted consists of wave height, water surface elevation, and velocity along the profile for each model output timestep, along with changes in the bottom profile showing areas of erosion and deposition. The final profile for each case was extracted from the model simulations for comparisons with the initial profile to determine possible impacts to the beach from storm conditions under existing conditions and for comparison with potential alternatives. Results from the Xbeach simulations was also utilized to inform the overtopping analysis performed at sites where that was relevant. The following sections describe the results of the model simulations conducted for each site.

Transect 3 Results – Rexhame Beach

Three engineering alternatives as well as existing conditions were evaluated for Transect 3 using Xbeach. The three engineering alternatives evaluated with XBeach for Transect 3 were alternative 4, alternative 6, and alternative 7. These three alternatives consisted of a dune enhancement project, a dune enhancement project with a raised beach berm, and a beach nourishment consisting of a raised beach berm for alternatives 4, 6, and 7, respectively. These alternatives are further described in the engineering alternatives memo. For the purposes of this analysis all alternatives were assumed to use material comparable to that within the Rexhame Public Beach dune.

These three alternatives as well as existing conditions were simulated for both a 10-year return period storm event as well as a 50-year return period storm. Results from these two storm cases for each of the alternatives are shown in Figures 5 and 6. The figures show the cross-shore profile for the initial existing conditions and engineering alternatives, as well as the eroded profiles under the different storm cases. The profiles are plotted with elevation in terms of feet, NAVD88 on the y-axis, and distance along the model transect on the x-axis.

Results from the storm condition scenarios show how the existing conditions profile, as well as the potential alternatives might be expected to perform during storm events of various sizes (return periods). The two storm events simulated both result in retreat of the existing dune scarp, with alternatives with a berm abutting the dune showing less scarping of the dune. Under existing conditions (as well as with the engineering alternatives) the dune is not overtopped in either of the two storm events simulated. During the erosion of the dune and berm, material is transported offshore (below 0 ft NAVD88) and therefore may become a source of material for beaches downstream of Rexhame depending on alongshore transport mechanisms. The simulations conducted for transect 3 were conducted using the regular Xbeach formulation (appropriate for sandy beaches) and as such, gravel material in the beach portion of Rexhame may be expected to act differently from what is simulated here.

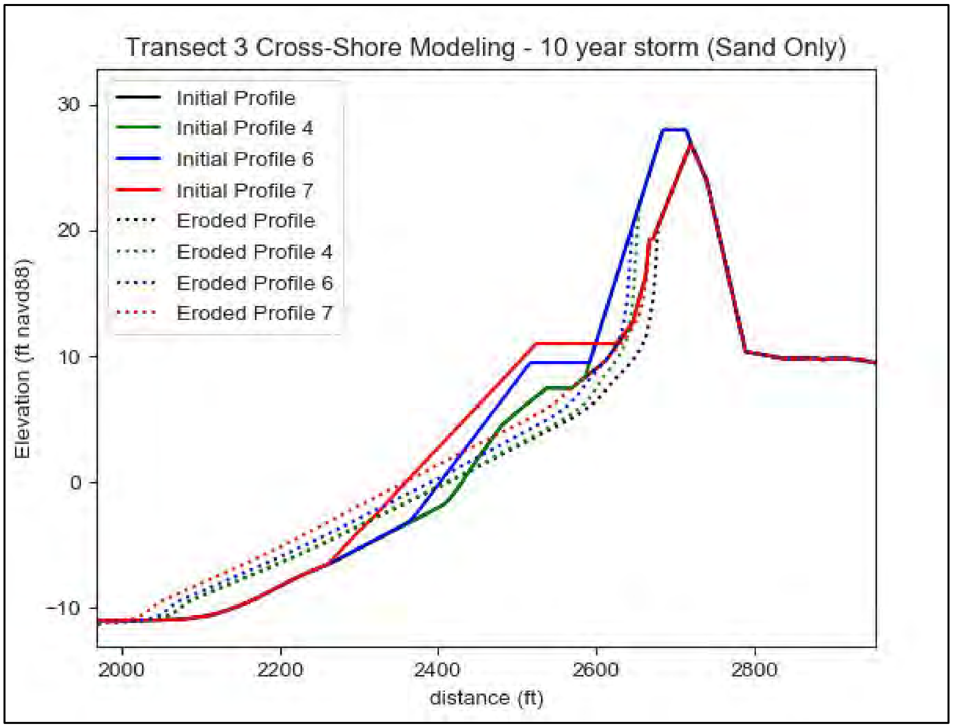

Figure 5. XBeach results for Transect 3 after a 10-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

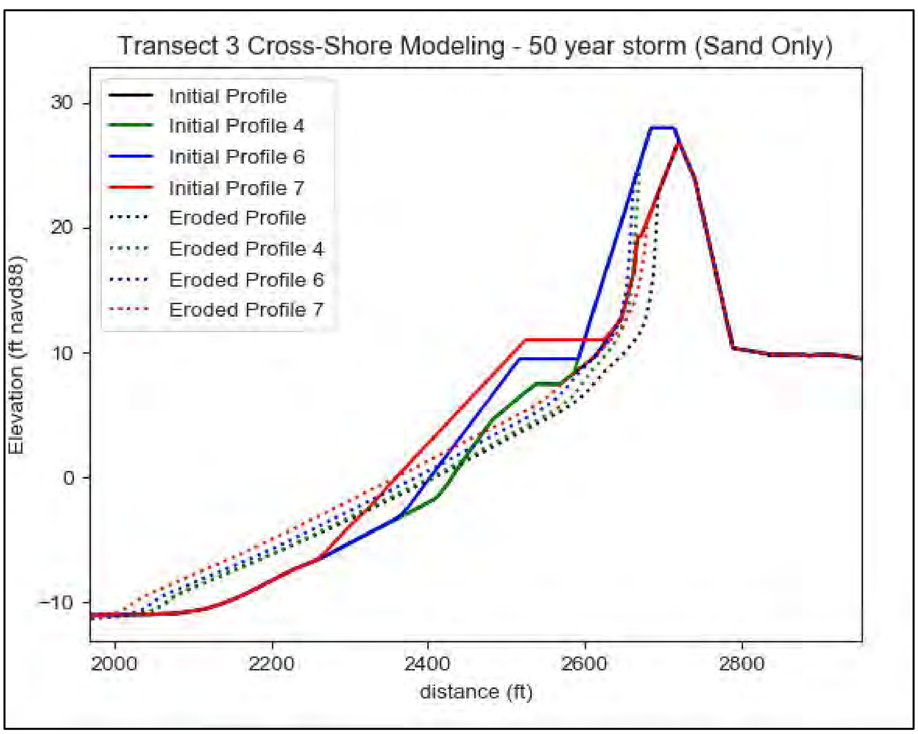

Figure 6. XBeach results for Transect 3 after a 50-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

Transect 9 Results – Winslow Beach

Two engineering alternatives as well as existing conditions were evaluated for Transect 9 using Xbeach-G. The two engineering alternatives evaluated with XBeach-G for Transect 9 were alternative 6, and alternative 7. These two alternatives both consisted of an enhancement of the existing gravel berm. Alternative 6 is a slightly smaller gravel berm enhancement than alternative 7. These alternatives are further described in the engineering alternatives memo. For the purposes of this analysis all alternatives were assumed to use material comparable to the existing gravel on the beach.

The two alternatives as well as existing conditions were simulated for both a 10-year return period storm event as well as a 50-year return period storm. Results from these two storm cases for each of the alternatives are shown in Figures 7 and 8. The figures show the cross-shore profile for the initial existing conditions and engineering alternatives, as well as the eroded profiles under the different storm cases. The profiles are plotted with elevation in terms of feet, NAVD88 on the y-axis, and distance along the model transect on the x-axis.

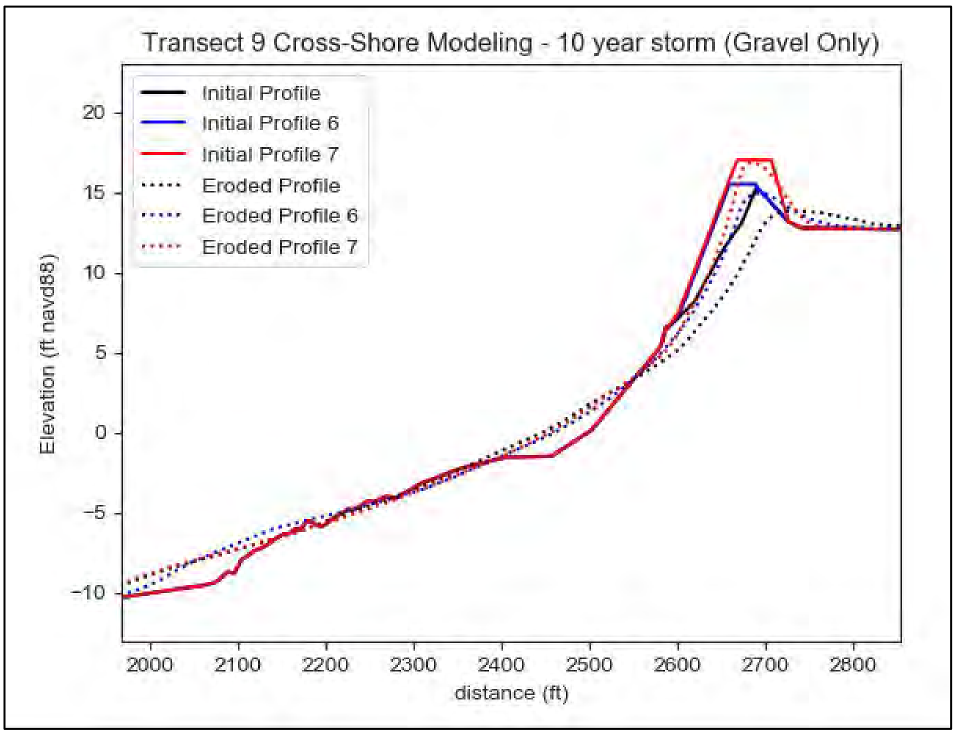

Figure 7. XBeach results for Transect 9 after a 10-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

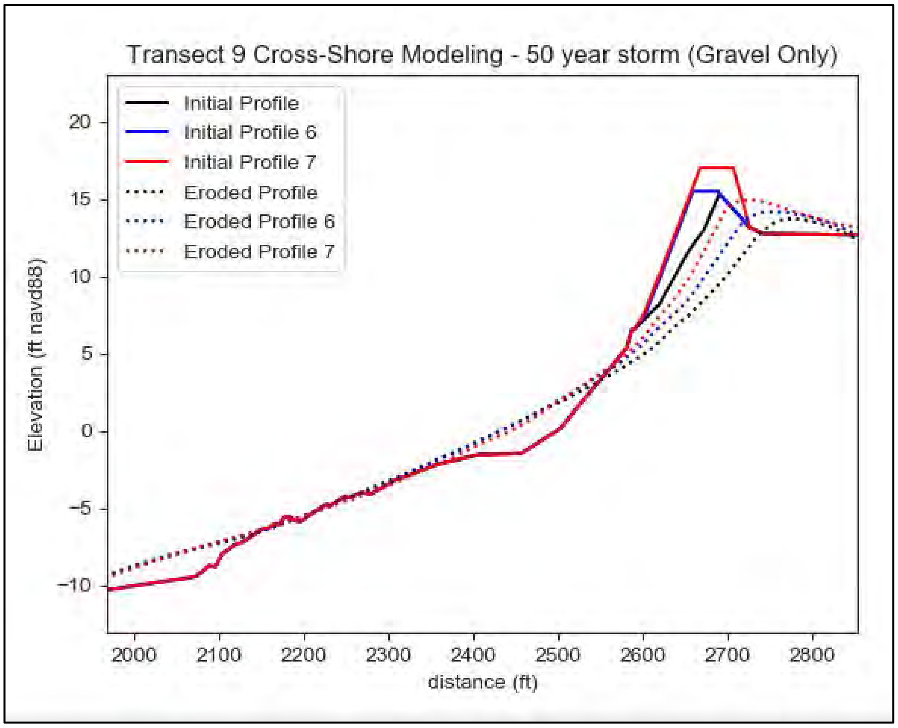

Figure 8. XBeach results for Transect 9 after a 50-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

Results from the storm condition scenarios show how the existing conditions profile, as well as the potential alternatives might be expected to perform during storm events of various sizes (return periods). The two storm events simulated both result in overtopping of the gravel berm, with material pushed further landward. The larger berm enhancement resulted in less overtopping of the berm, and less material moved landward. Alternative 6 (smaller gravel berm enhancement) after a 10-year storm event resulted in a final eroded profile approximately at the location of the present-day initial profile. In contrast, the larger gravel berm enhancement (Alternative 7) resulted in a similar profile to the existing initial conditions profile after a 50-year storm event (although slightly more eroded).The simulations conducted for transect 9 were conducted using the Xbeach-G formulation (appropriate for gravel) and as such, sand material in the beach portion of Winslow may be expected to act differently from what is simulated here.

Transect 12 Results – Fieldston/Sunrise Beaches

Three engineering alternatives as well as existing conditions were evaluated for Transect 12 using a combination of Xbeach and Xbeach-G. The three engineering alternatives evaluated for Transect 12 were alternative 4, alternative 6, and alternative 7. These three alternatives consisted of beach nourishments with a raised berm, with varying offshore slopes, as well as small dunes created abutting the seawall. These alternatives are further described in the engineering alternatives memo. For the purposes of this analysis all alternatives were assumed to use material comparable to that on the existing beach.

The three alternatives as well as existing conditions were simulated for 1-year, 2-year, and a 10-year return period storm events. For this transect all model cells landward of the seawall were made unerodable, which allows the simulation of the effects of the seawall including reflection. Simulations were conducted twice for each alternative, for each storm case, with both the regular Xbeach formulation and the Xbeach-G formulation, in order to capture the response of the different grain size materials present. The results of the two simulations for each case were combined based on the percentage of gravel/sand for each site. Final combined results from these three storm cases for each of the alternatives are shown in Figures 9, 10, and 11. The figures show the cross-shore profile for the initial engineering alternatives, as well as the eroded profiles under the different storm cases. The profiles are plotted with elevation in terms of feet, NAVD88 on the y-axis, and distance along the model transect on the x-axis.

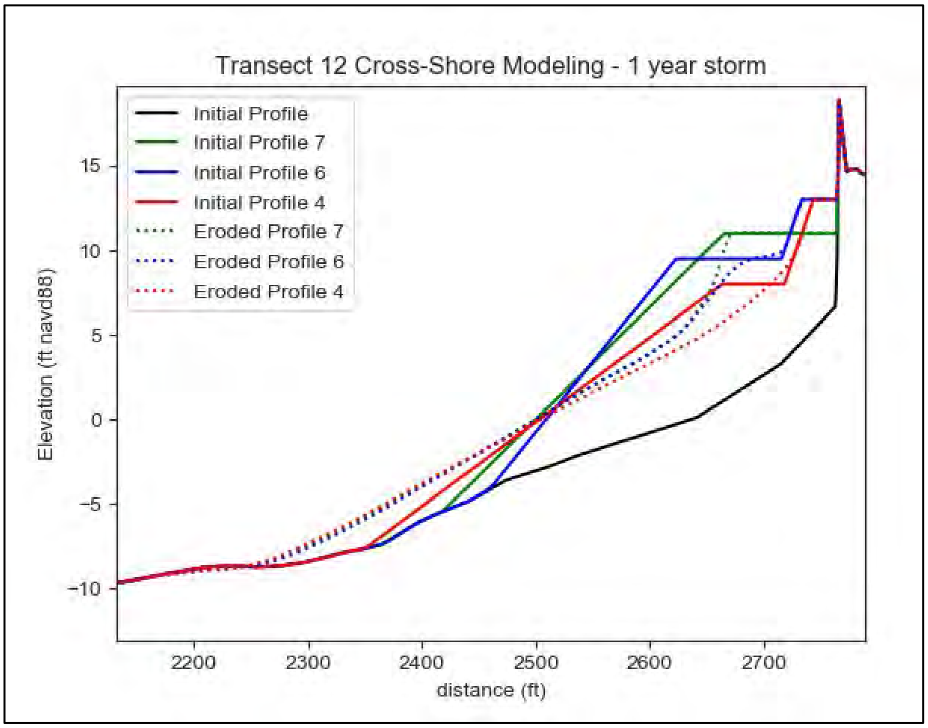

Figure 9. XBeach results for Transect 12 after a 1-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

Results from the storm condition scenarios show how the potential alternatives might be expected to perform during storm events of various sizes (return periods). The 10-year event simulations show all three engineering alternatives responding approximately the same, with the beach eroding back to the seawall, with the elevation of the beach lowering, as well as material being pushed further offshore. During the 1-year event, alternative 7 is eroded back to the top of the berm, resulting in a large scarp on the beach. In the same storm, alternatives 4 and 6 are eroded further back (closer to the seawall), but this results in a milder scarp in the final profile. In the 2-year storm cases the three alternatives are eroded back closer to the wall, but material is piled up higher in alternatives 4 and 6 close to the wall. In all cases evaluated, more gravel material is pushed close to the wall, with sand transported further offshore. This phenomenon can be expected to result in a more gravelly beach after storm events, with sand being gradually transported beachward post-storm. The simulations conducted for transect 12 were conducted using a combination of Xbeach and the Xbeach-G formulation to determine how the beaches may react with the two different grain size types, with the results being combined after the simulations. However, because the simulations were performed separately, there is some uncertainty in the results related to the interaction of sand and gravel material during erosion that is not captured in the modeling approach employed here.

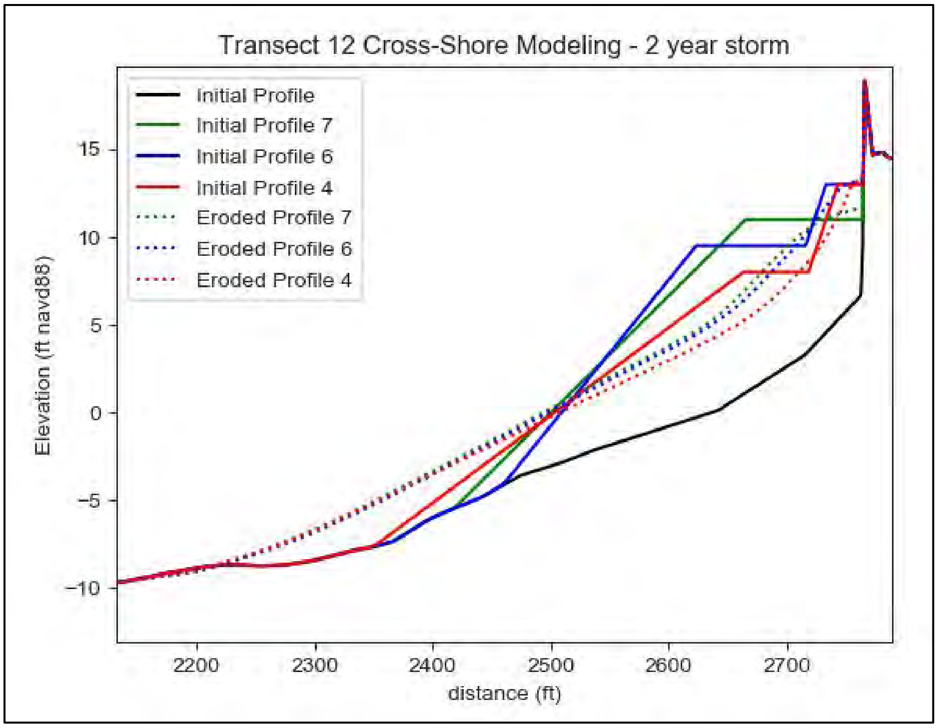

Figure 10. XBeach results for Transect 12 after a 2-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

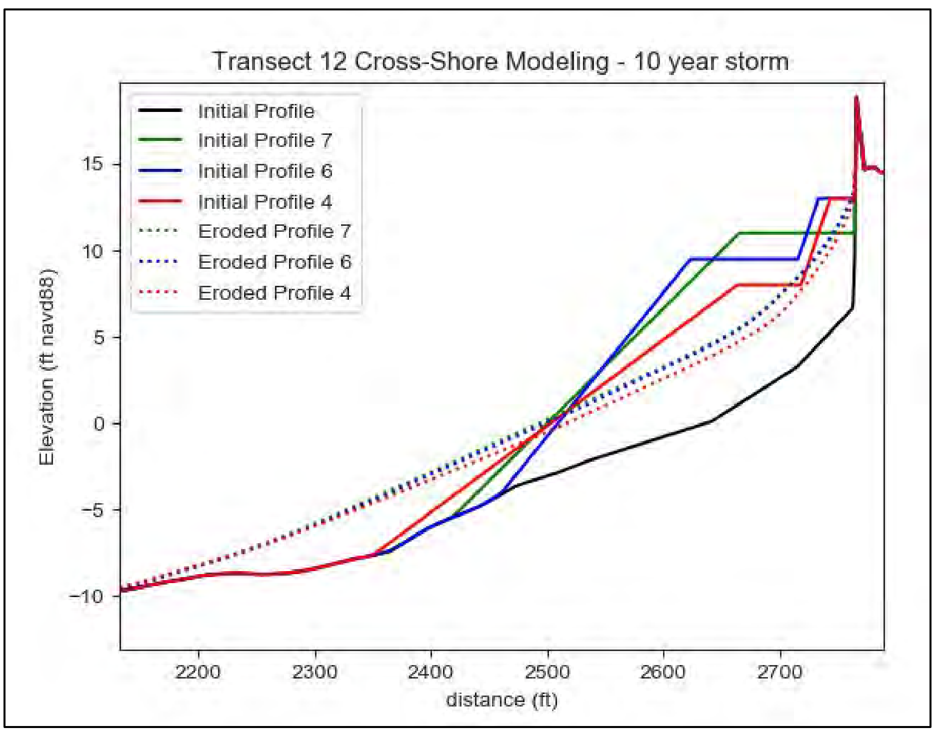

Figure 11. XBeach results for Transect 12 after a 10-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

Transect 19 Results – Green Harbor

Three engineering alternatives as well as existing conditions were evaluated for Transect 19 using a combination of Xbeach and Xbeach-G. The three engineering alternatives evaluated Transect 19 were alternative 4, alternative 6, and alternative 7. These three alternatives consisted of beach nourishments with a raised berm, with varying offshore slopes, as well as small dunes created abutting the seawall. These alternatives are further described in the engineering alternatives memo. For the purposes of this analysis all alternatives were assumed to use material comparable to that on the existing beach.

The three alternatives as well as existing conditions were simulated for both a 1-year, 2-year, and a 10-year return period storm. For this transect all model cells landward of the seawall were made unerodable, which allows the simulation of the effects of the seawall including reflection. Simulations were conducted twice for each alternative for each case, with both the regular Xbeach formulation and the Xbeach-G formulation to capture the response of the different grain size materials. The results of the two simulations for each case were combined based on the percentage of gravel/sand for each site. Final combined results from these three storm cases for each of the alternatives are shown in Figures 12, 13, and 14. The figures show the cross-shore profile for the initial engineering alternatives, as well as the eroded profiles under the different storm cases. The profiles are plotted with elevation in terms of feet, NAVD88 on the y-axis, and distance along the model transect on the x-axis.

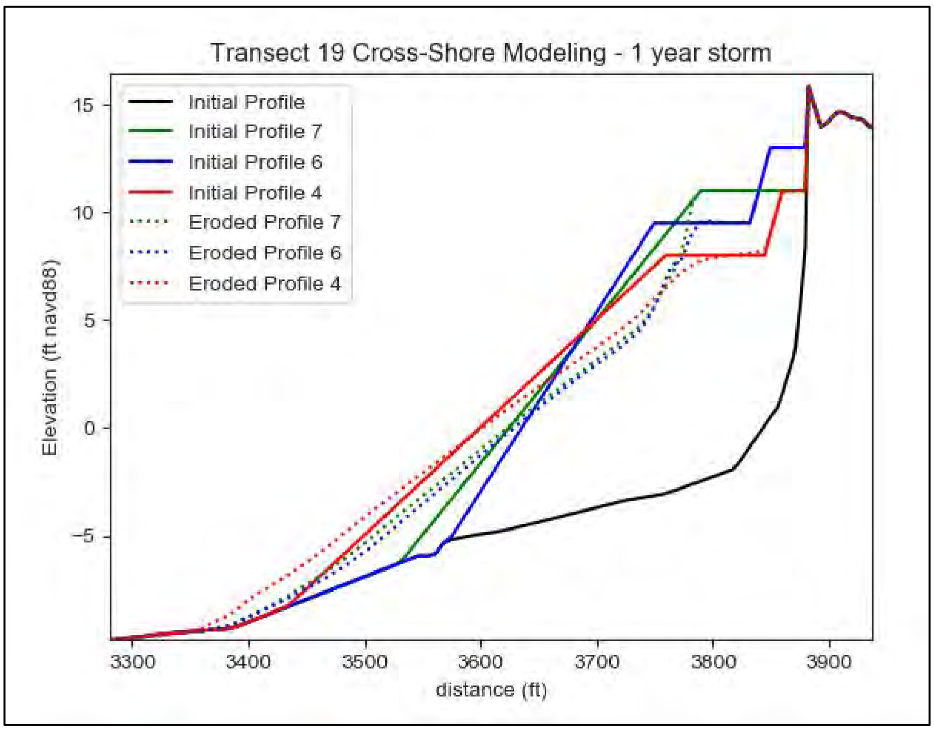

Figure 12. XBeach results for Transect 19 after a 1-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

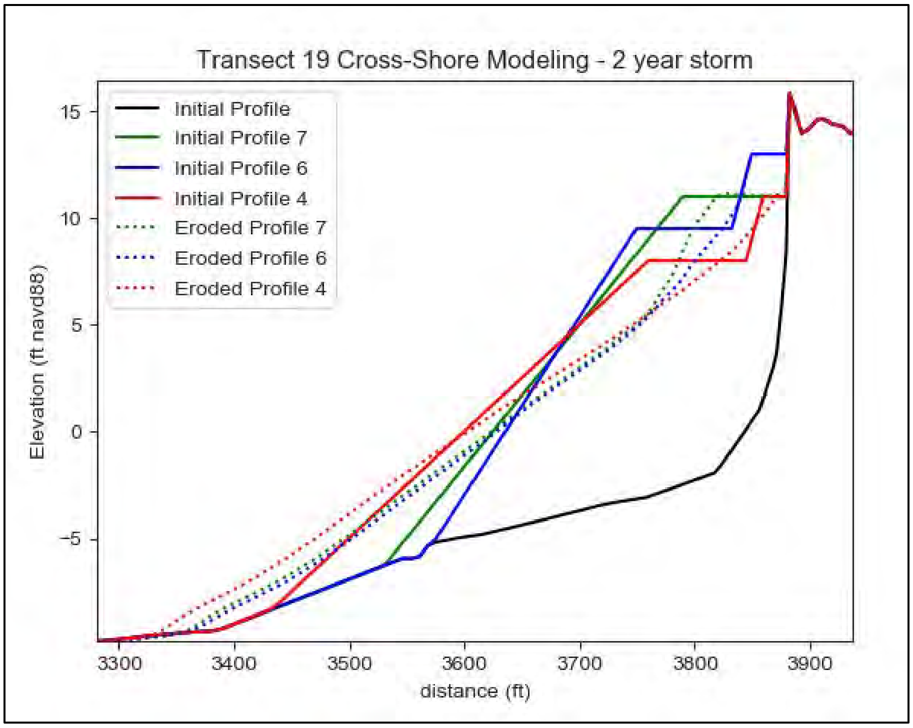

Figure 13. XBeach results for Transect 19 after a 2-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

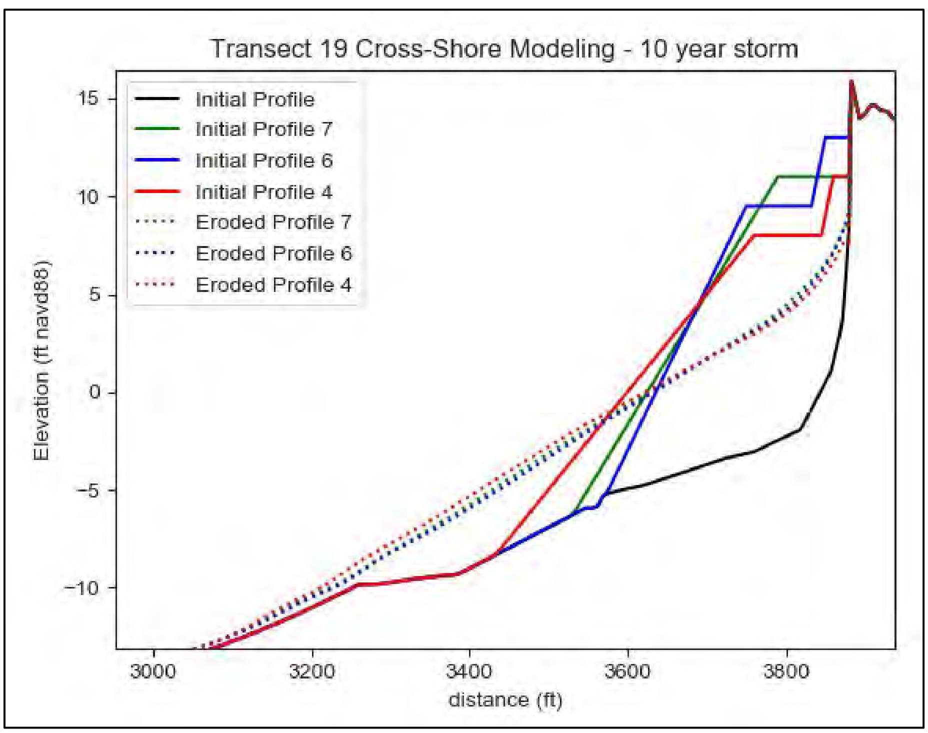

Figure 14. XBeach results for Transect 19 after a 10-year return period storm event. Initial profiles are shown as solid lines. Final eroded profiles are shown as dotted lines.

Results from the storm condition scenarios show how the potential alternatives might be expected to perform during storm events of various sizes (return periods). The 10-year event simulations show all three engineering alternatives responding approximately the same, with the beach eroding back to the seawall, with the elevation of the beach lowering, as well as material being pushed further offshore. During the 1-year event, alternatives 6 and 7 are eroded back to the top of the berm, resulting in a large scarp on the beach for both alternatives. In the same storm, alternative 4 is eroded further back (closer to the seawall), but this results in a milder scarp in the final profile, but with a lower berm. In the 2-year storm cases alternative 4 erodes back to the wall, while alternative 7 and 6 erode back less, with alternative 6 still maintaining the small dune abutting the seawall. In all cases evaluated, more gravel material is pushed close to the wall, with sand transported further offshore. This phenomenon can be expected to result in a more gravelly beach after storm events. The simulations conducted for transect 12 were conducted using a combination of Xbeach and the Xbeach-G formulation to determine how the beaches may react with the two different grain size types, with the results being combined after the simulations. However, because the simulations were performed separately, there is some uncertainty in the results related to the interaction of sand and gravel material during erosion that is not captured in the modeling approach employed here.

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Section K

Sediment Grain Size Data

Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 12/31/19
Received: 12/20/19

1. Sample No.	Description	Source of Material
M-31195	Sand	MARDUX_01_DU_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	100	
12.5 mm	1/2"	100	
9.5 mm	3/8"	100	
4.75 mm	#4	100	
2.38 mm	#8	100	
1.190 mm	#16	100	
0.595 mm	#30	95	
0.297 mm	#50	36	
0.150 mm	#100	1	
0.075 mm	#200	0.2	

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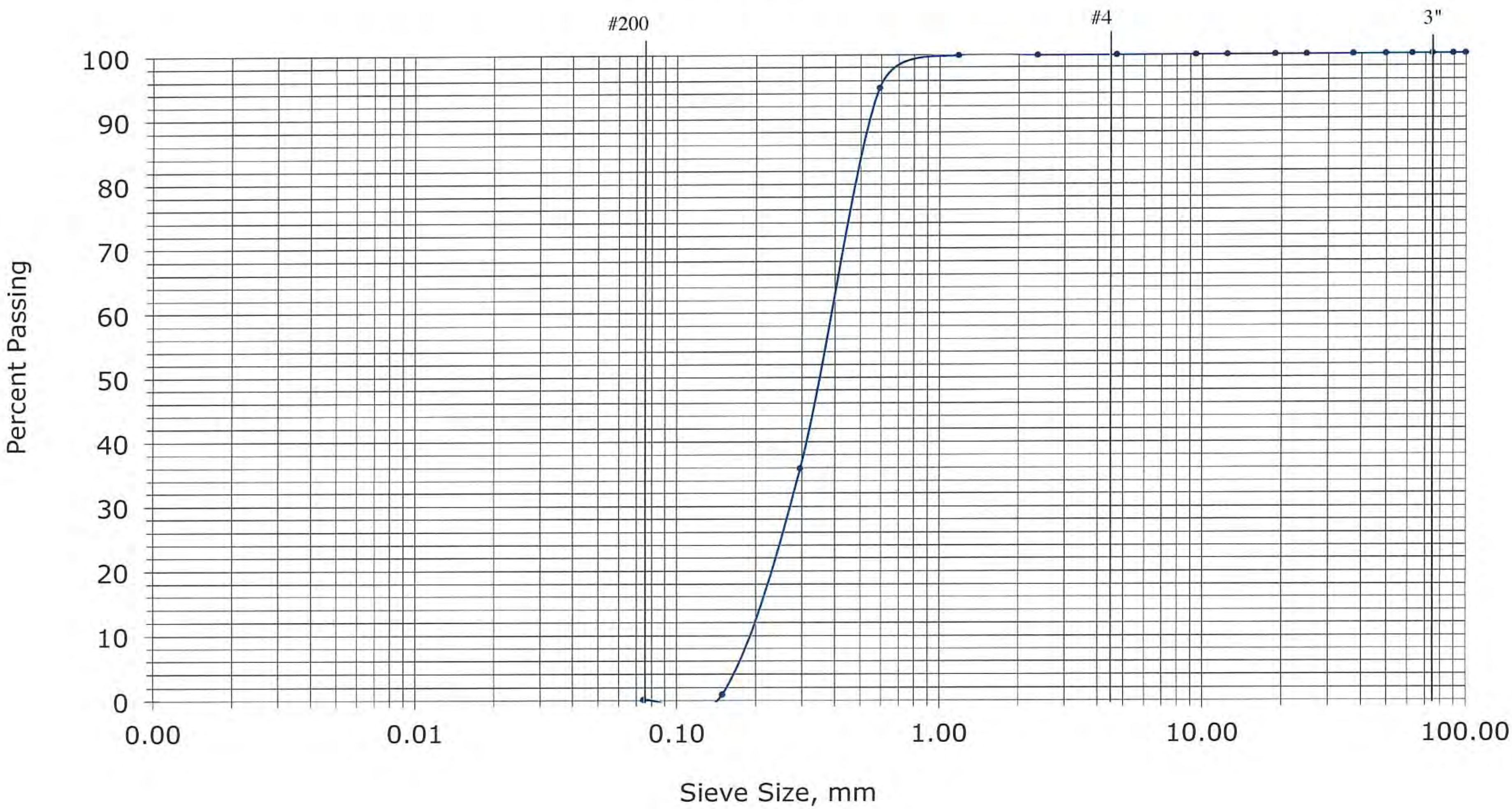
Briggs Engineering & Testing
A Division of PK Associates, Inc.

Project:	Marshfield/Duxbury Beaches
Date Tested:	12/31/19
Lab Ref. No.:	M-31195

Sieve Analysis



Briggs Engineering & Testing
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Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 12/31/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31196	Sand & Gravel	MARDUX_02_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	97	
19 mm	3/4"	96	
12.5 mm	1/2"	81	
9.5 mm	3/8"	54	
4.75 mm	#4	25	
2.38 mm	#8	17	
1.190 mm	#16	12	
0.595 mm	#30	8	
0.297 mm	#50	1	
0.150 mm	#100	1	
0.075 mm	#200	0.1	

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Briggs Engineering & Testing
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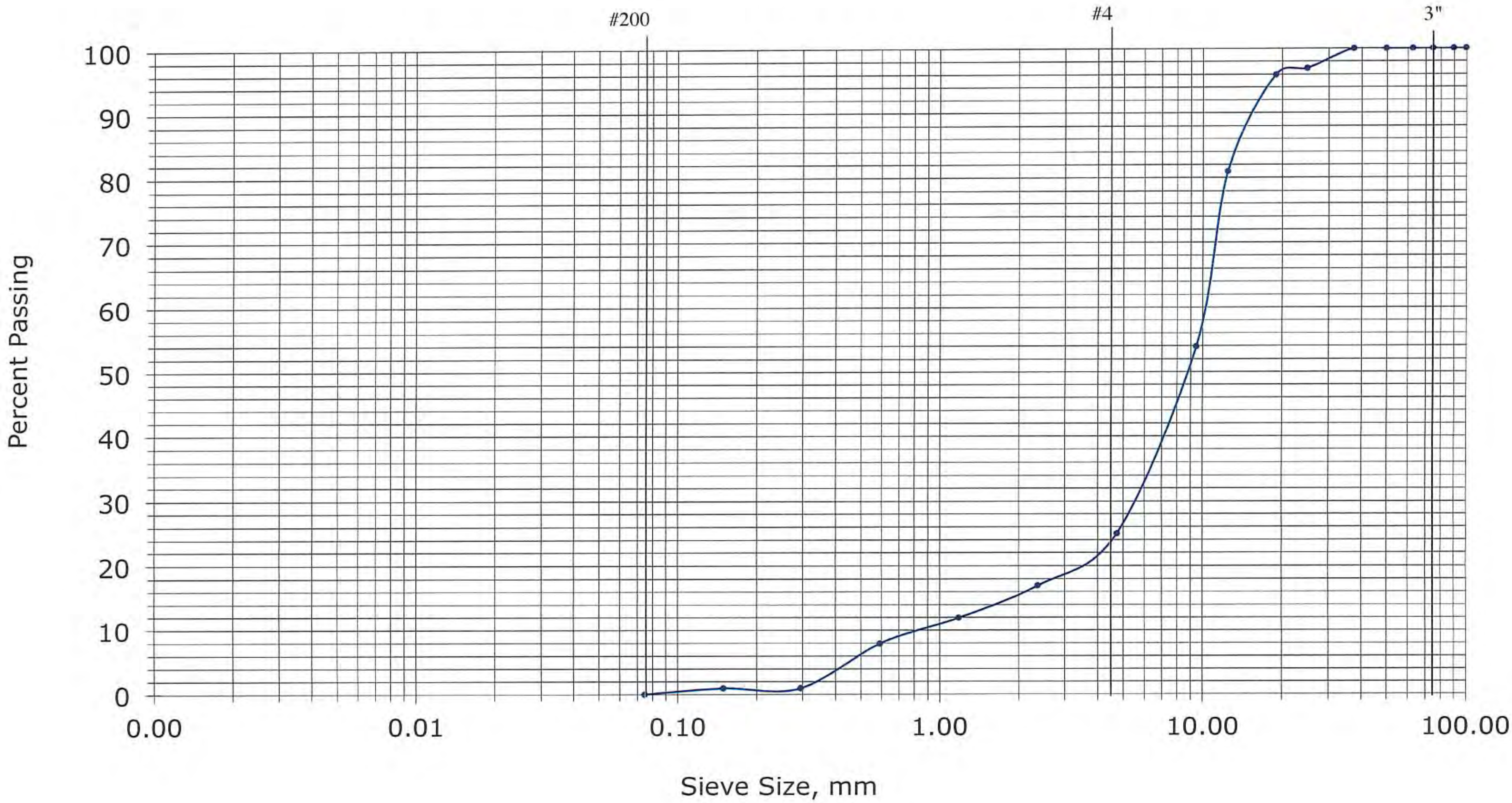
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/31/19
Lab Ref. No.:	M-31196

Sieve Analysis



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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 1/9/20
Received: 12/20/19

1. Sample No.	Description	Source of Material
M-31197	Sand & Cobble	MARDUX_02_MTL_COB

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	98	
63 mm	2-1/2"	96	
50 mm	2"	90	
37.5 mm	1-1/2"	82	
25 mm	1"	68	
19 mm	3/4"	59	
12.5 mm	1/2"	46	
9.5 mm	3/8"	33	
4.75 mm	#4	7	
2.38 mm	#8	3	
1.190 mm	#16	2	
0.595 mm	#30	2	
0.297 mm	#50	0	
0.150 mm	#100	0	
0.075 mm	#200	0.0	

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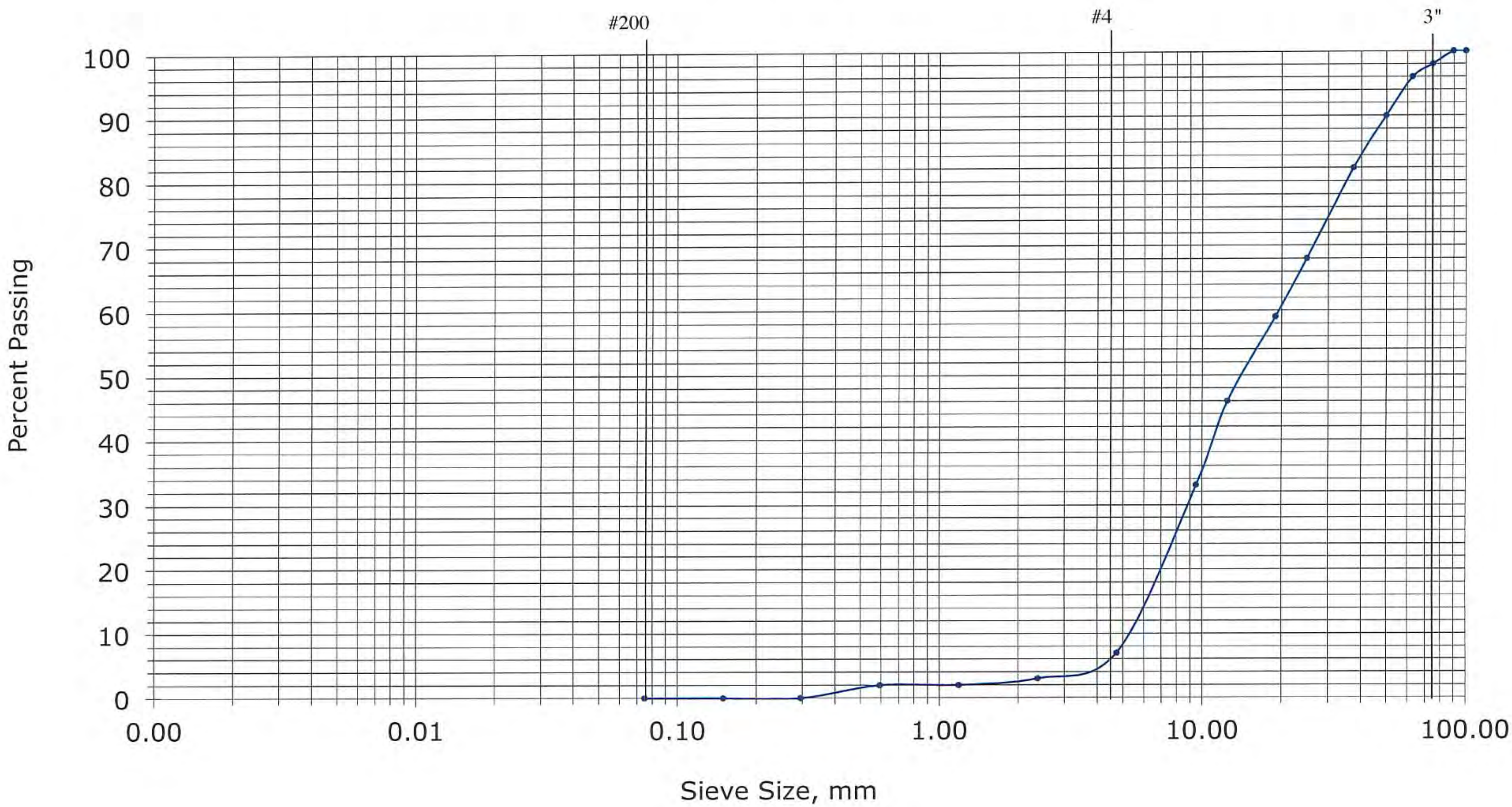
Project:	Marshfield/Duxbury Beaches
Date Tested:	1/9/20
Lab Ref. No.:	M-31197

Sieve Analysis



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Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 12/31/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31198	Sand	MARDUX_03_MHW_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	100	
12.5 mm	1/2"	100	
9.5 mm	3/8"	100	
4.75 mm	#4	100	
2.38 mm	#8	99	
1.190 mm	#16	97	
0.595 mm	#30	58	
0.297 mm	#50	2	
0.150 mm	#100	1	
0.075 mm	#200	0.1	

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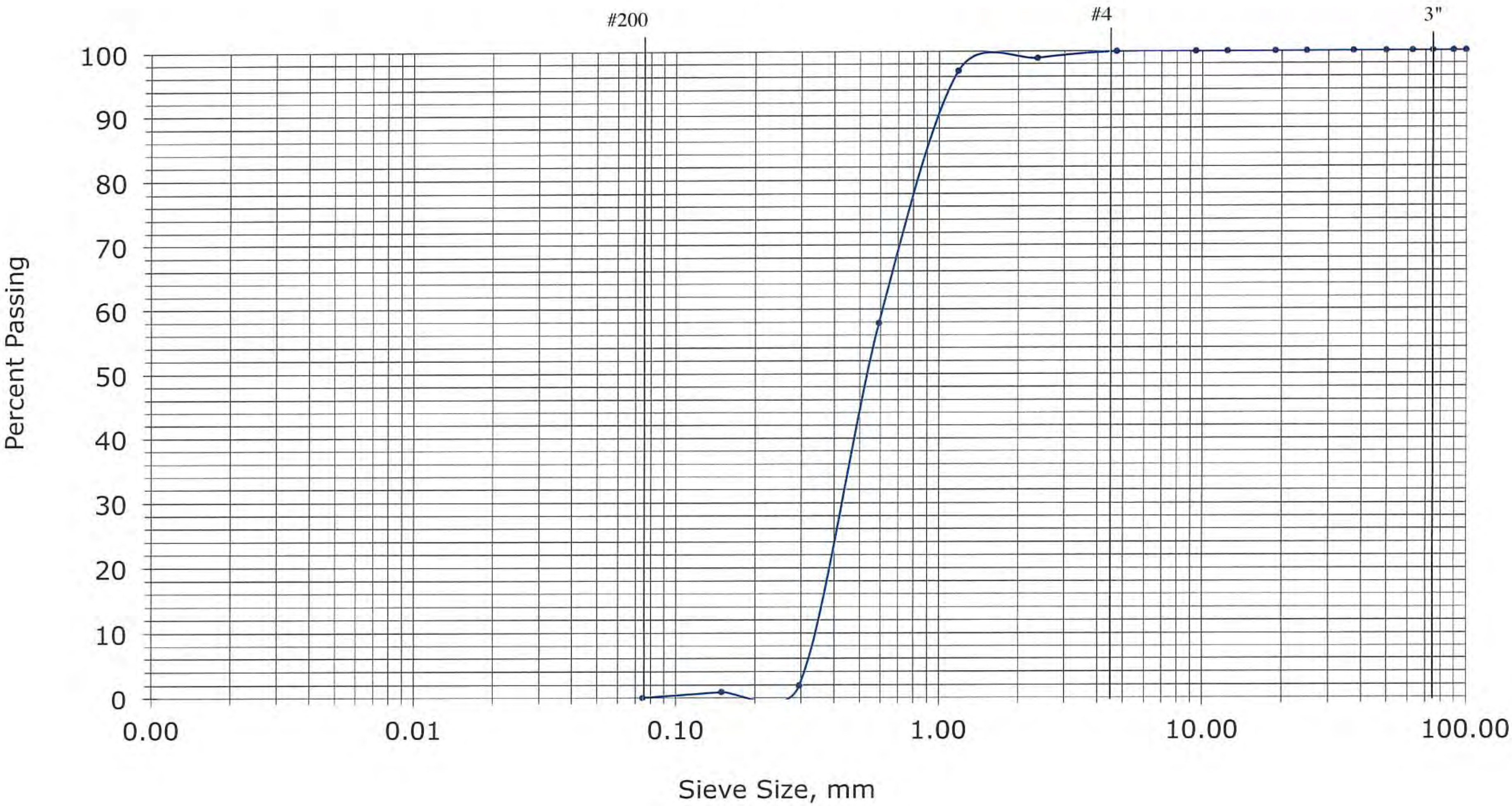
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/31/19
Lab Ref. No.:	M-31198

Sieve Analysis



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Woods Hole Group
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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 12/31/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31199	Sand & Gravel	MARDUX_04_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	93	
19 mm	3/4"	85	
12.5 mm	1/2"	71	
9.5 mm	3/8"	57	
4.75 mm	#4	37	
2.38 mm	#8	29	
1.190 mm	#16	24	
0.595 mm	#30	19	
0.297 mm	#50	6	
0.150 mm	#100	1	
0.075 mm	#200	0.1	

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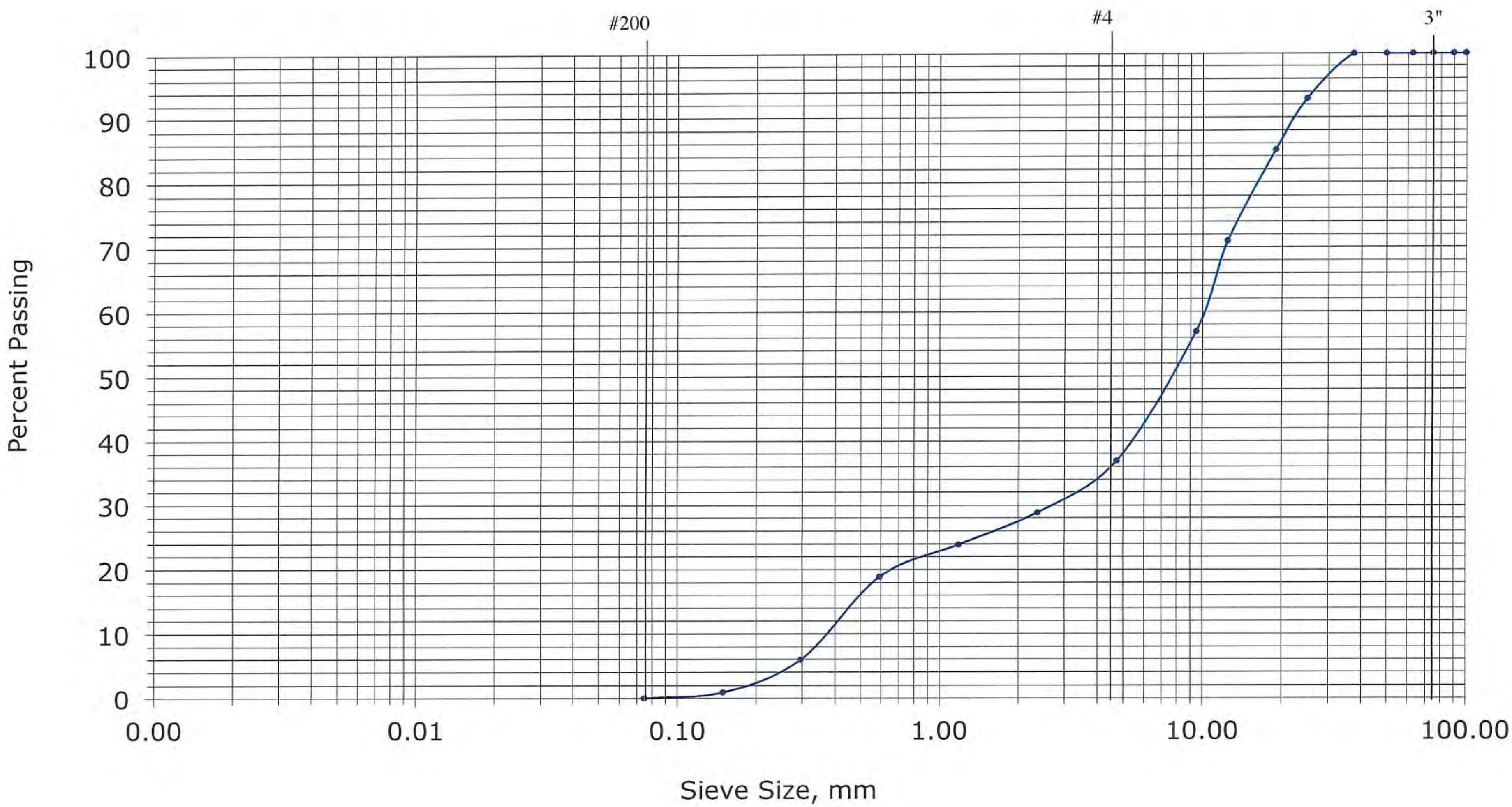
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/31/19
Lab Ref. No.:	M-31199

Sieve Analysis



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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 12/23/19
Received: 12/20/19

1. Sample No.	Description	Source of Material
M-31200	Sand	MARDUX_05_MHW_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	96	
12.5 mm	1/2"	87	
9.5 mm	3/8"	84	
4.75 mm	#4	82	
2.38 mm	#8	80	
1.190 mm	#16	76	
0.595 mm	#30	63	
0.297 mm	#50	15	
0.150 mm	#100	1	
0.075 mm	#200	0.1	

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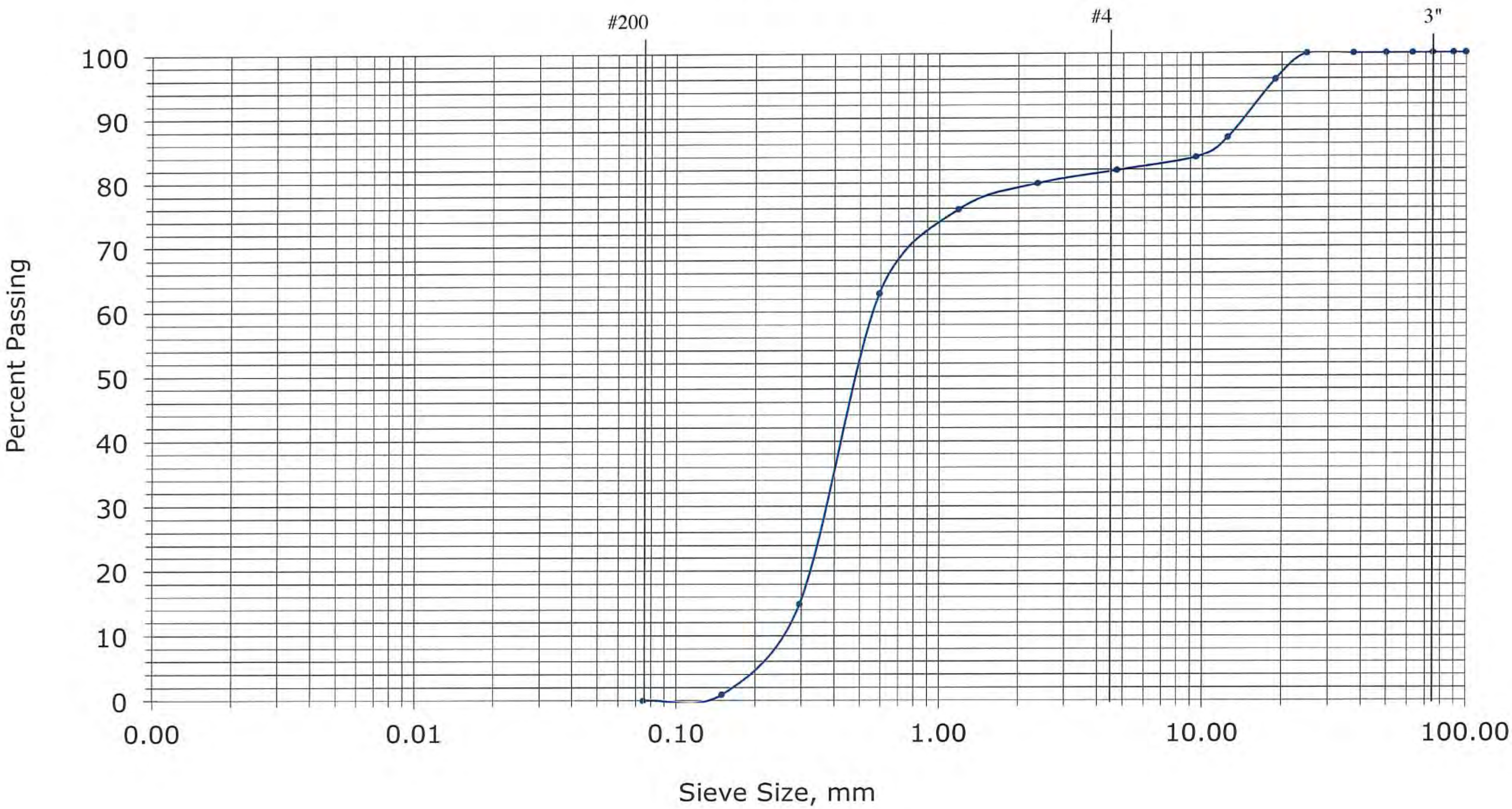
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/23/19
Lab Ref. No.:	M-31200

Sieve Analysis



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Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 12/23/19
Received: 12/20/19

1. Sample No.	Description	Source of Material
M-31201	Sand & Gravel	MARDUX_06_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	92	
19 mm	3/4"	79	
12.5 mm	1/2"	64	
9.5 mm	3/8"	63	
4.75 mm	#4	63	
2.38 mm	#8	63	
1.190 mm	#16	62	
0.595 mm	#30	58	
0.297 mm	#50	12	
0.150 mm	#100	1	
0.075 mm	#200	0.4	

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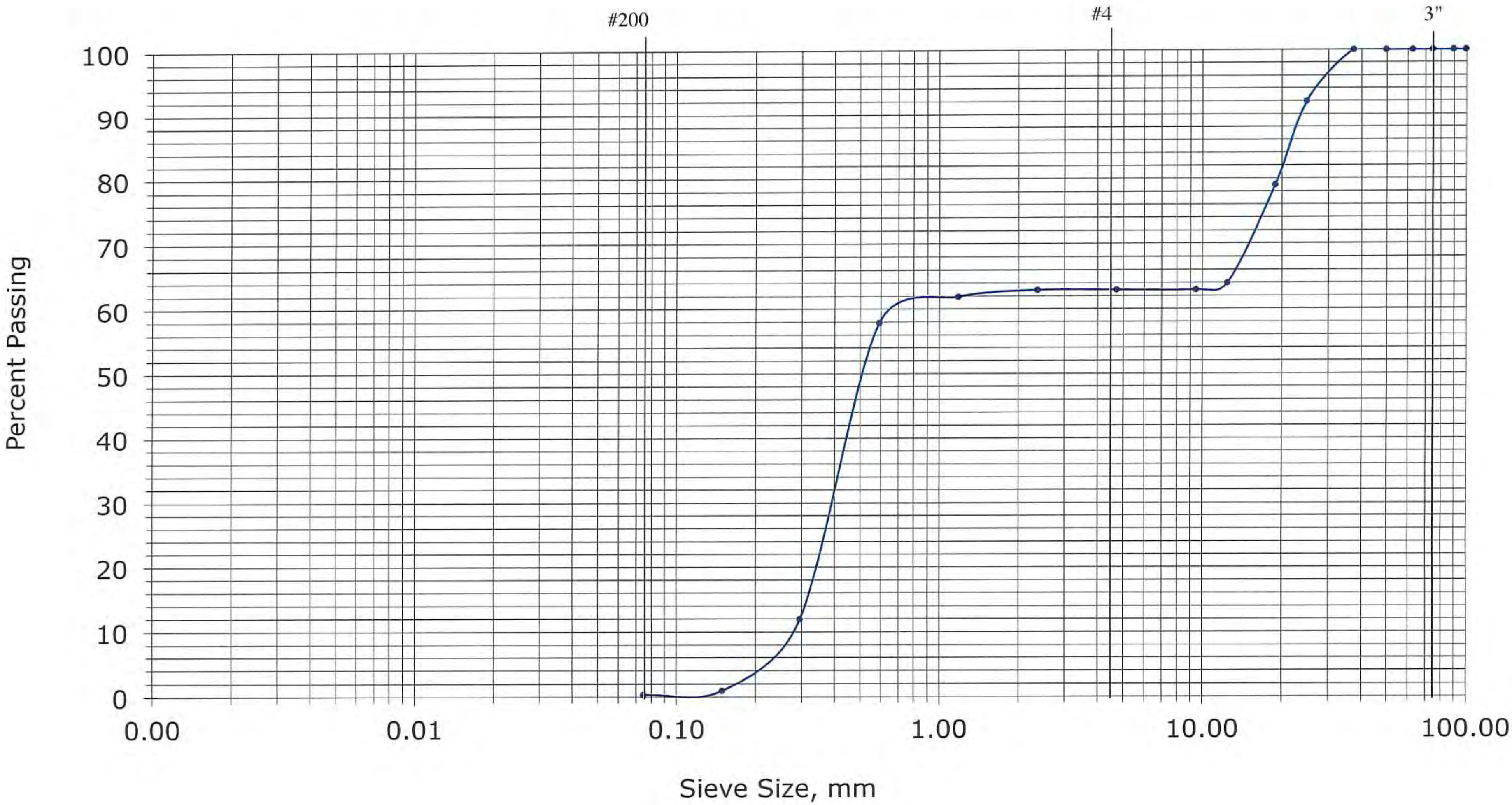
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/31/19
Lab Ref. No.:	M-31201

Sieve Analysis



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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 12/23/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31202	Sand	MARDUX_07_DU_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	100	
12.5 mm	1/2"	100	
9.5 mm	3/8"	100	
4.75 mm	#4	100	
2.38 mm	#8	100	
1.190 mm	#16	100	
0.595 mm	#30	99	
0.297 mm	#50	49	
0.150 mm	#100	1	
0.075 mm	#200	0.1	

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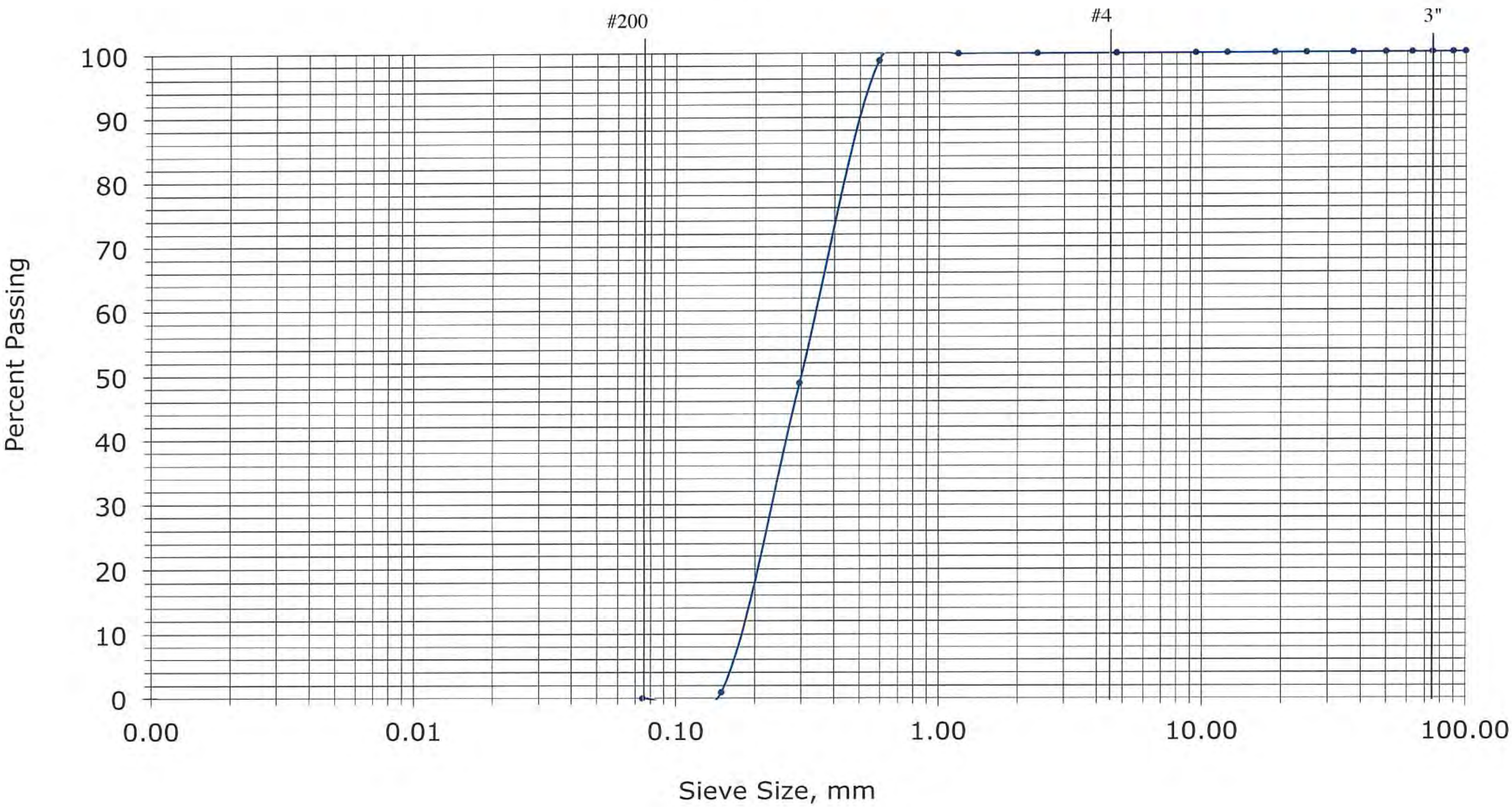
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/23/19
Lab Ref. No.:	M-31202

Sieve Analysis



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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 12/23/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31203	Sand & Gravel	MARDUX_08_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	87	
12.5 mm	1/2"	76	
9.5 mm	3/8"	63	
4.75 mm	#4	36	
2.38 mm	#8	23	
1.190 mm	#16	18	
0.595 mm	#30	14	
0.297 mm	#50	4	
0.150 mm	#100	1	
0.075 mm	#200	0.1	

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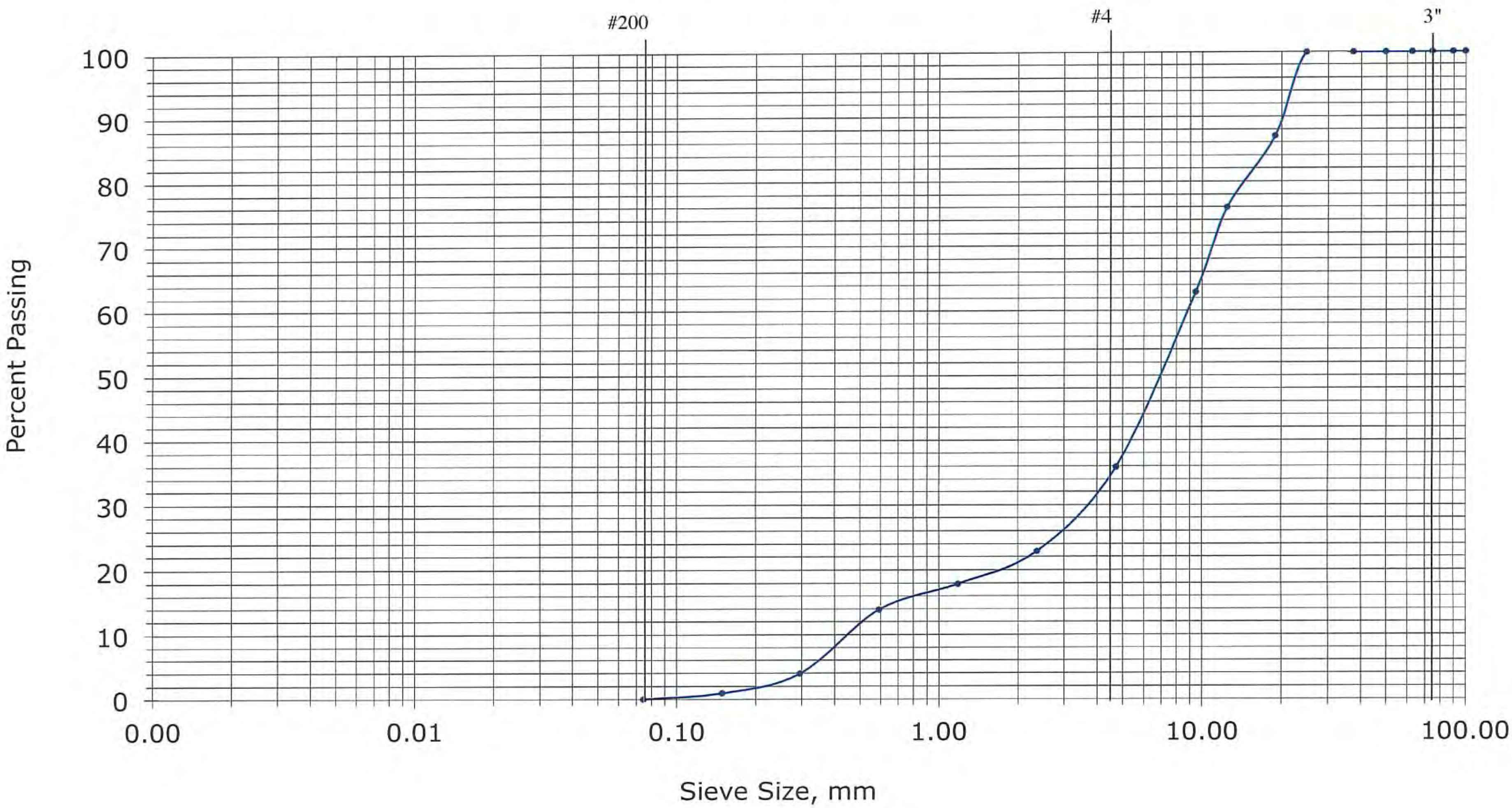
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/23/19
Lab Ref. No.:	M-31203

Sieve Analysis



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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 1/7/20
Received: 12/20/19

1. Sample No.	Description	Source of Material
M-31204	Sand & Cobble	MARDUX_08_MTL_COB

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	99	
63 mm	2-1/2"	96	
50 mm	2"	91	
37.5 mm	1-1/2"	80	
25 mm	1"	64	
19 mm	3/4"	51	
12.5 mm	1/2"	33	
9.5 mm	3/8"	23	
4.75 mm	#4	9	
2.38 mm	#8	6	
1.190 mm	#16	5	
0.595 mm	#30	4	
0.297 mm	#50	2	
0.150 mm	#100	0	
0.075 mm	#200	0.0	

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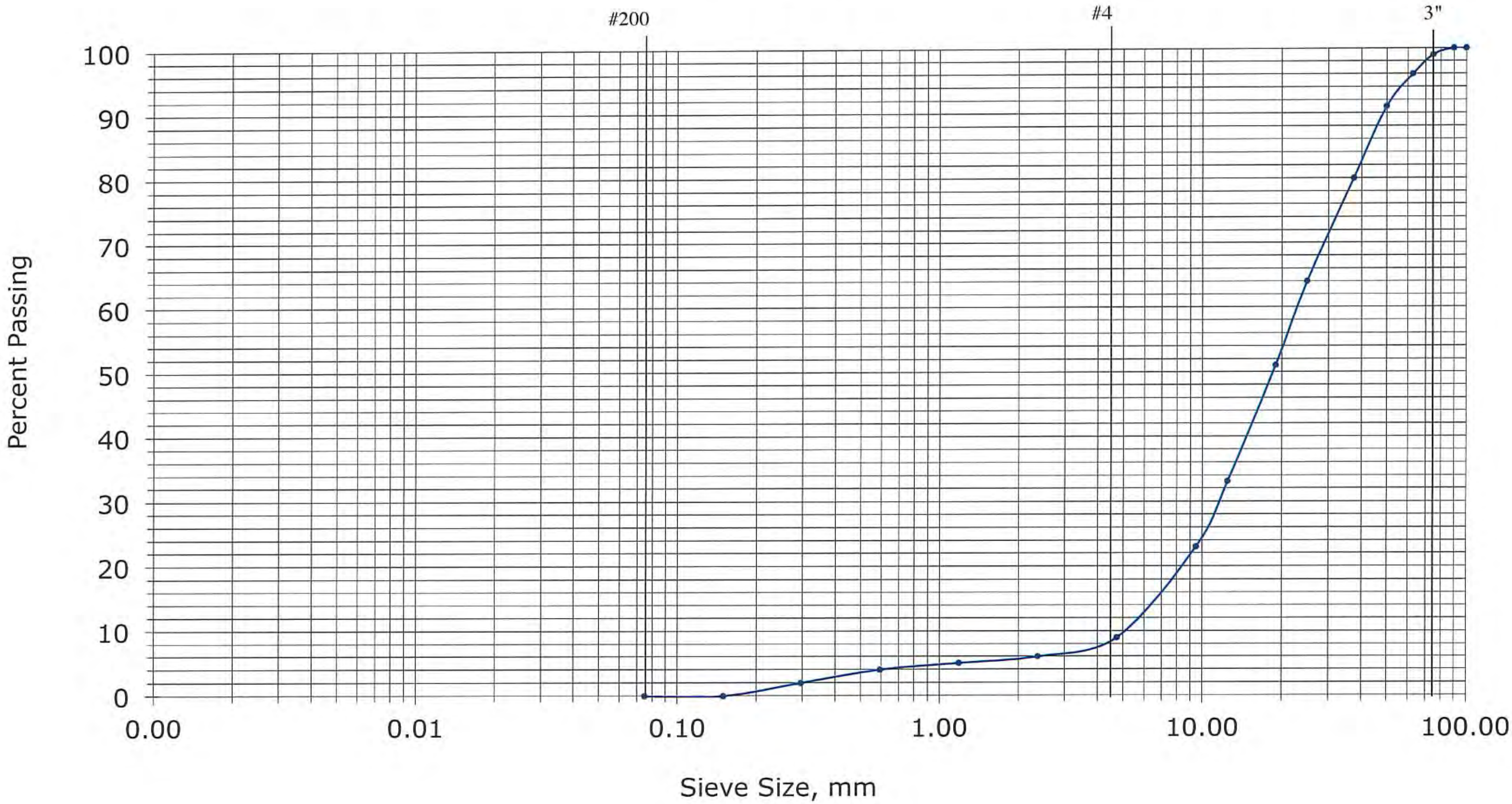
Project:	Marshfield/Duxbury Beaches
Date Tested:	1/7/20
Lab Ref. No.:	M-31204

Sieve Analysis



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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 12/23/19
Received: 12/20/19

1. Sample No.	Description	Source of Material
M-31205	Sand & Gravel	MARDUX_09_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	98	
12.5 mm	1/2"	91	
9.5 mm	3/8"	85	
4.75 mm	#4	69	
2.38 mm	#8	59	
1.190 mm	#16	51	
0.595 mm	#30	40	
0.297 mm	#50	16	
0.150 mm	#100	1	
0.075 mm	#200	0.2	

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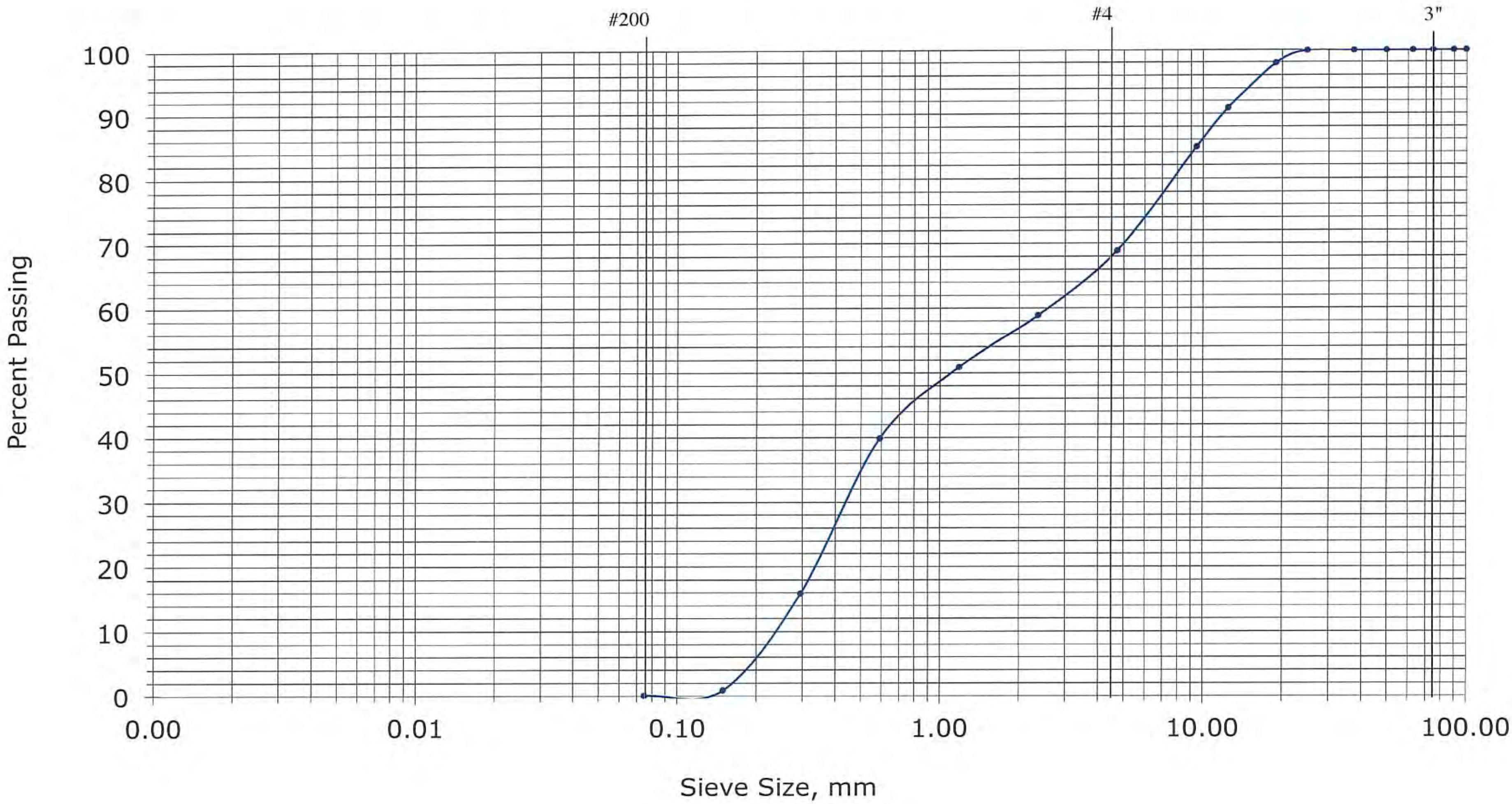
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/23/19
Lab Ref. No.:	M-31205

Sieve Analysis



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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 12/23/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31206	Sand & Gravel	MARDUX_10_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	97	
12.5 mm	1/2"	92	
9.5 mm	3/8"	86	
4.75 mm	#4	57	
2.38 mm	#8	30	
1.190 mm	#16	29	
0.595 mm	#30	29	
0.297 mm	#50	17	
0.150 mm	#100	1	
0.075 mm	#200	0.2	

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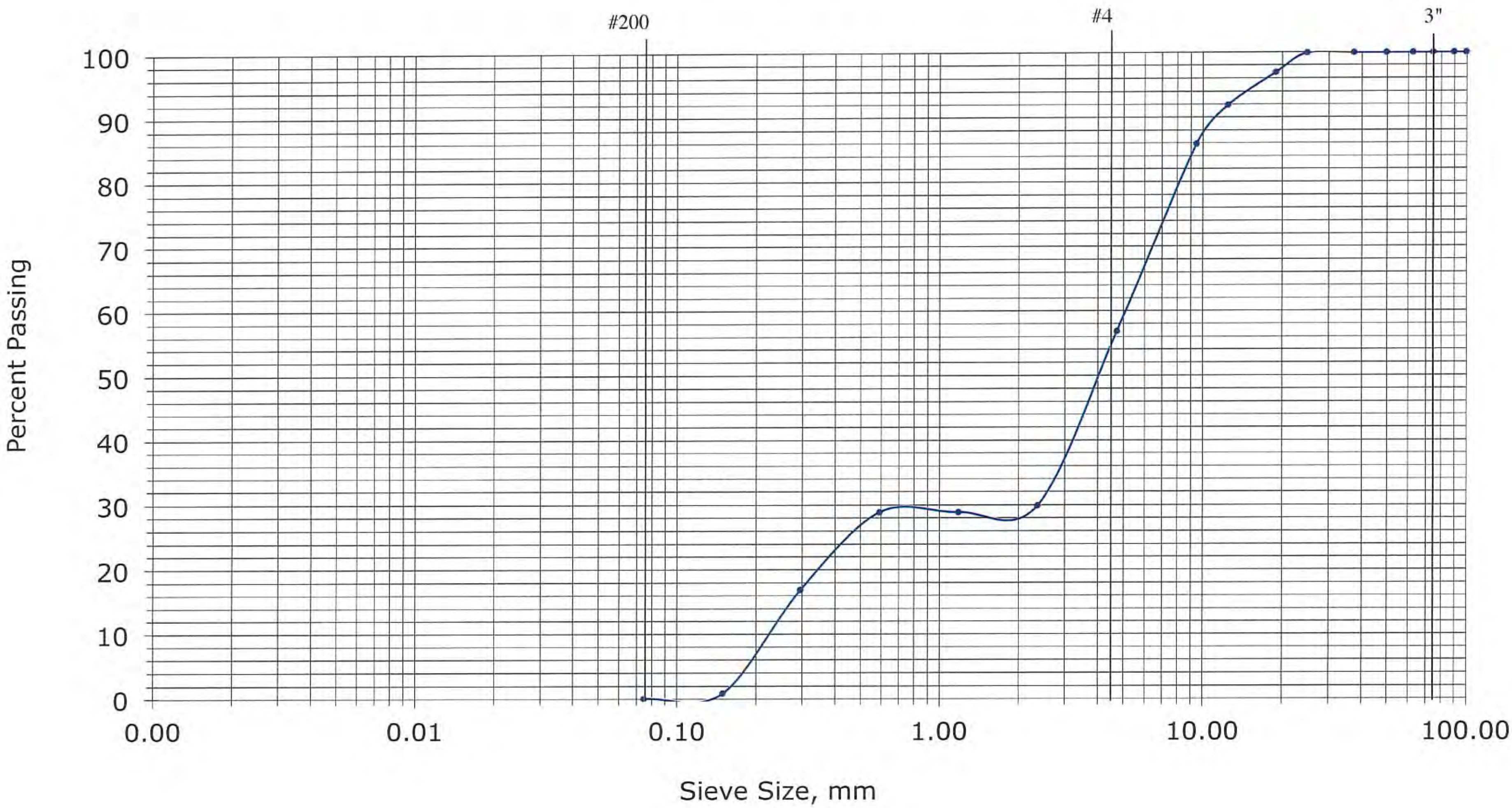
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/23/19
Lab Ref. No.:	M-31206

Sieve Analysis



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Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 1/9/20
Received: 12/20/19

1. Sample No.	Description	Source of Material
M-31207	Sand & Cobble	MARDUX_10_MTL_COB

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
127 mm	5"	100	
100 mm	4"	97	
75 mm	3"	91	
63 mm	2-1/2"	89	
50 mm	2"	86	
37.5 mm	1-1/2"	82	
25 mm	1"	75	
19 mm	3/4"	70	
12.5 mm	1/2"	55	
9.5 mm	3/8"	43	
4.75 mm	#4	15	
2.38 mm	#8	7	
1.190 mm	#16	6	
0.595 mm	#30	6	
0.297 mm	#50	2	
0.150 mm	#100	0	
0.075 mm	#200	0.0	

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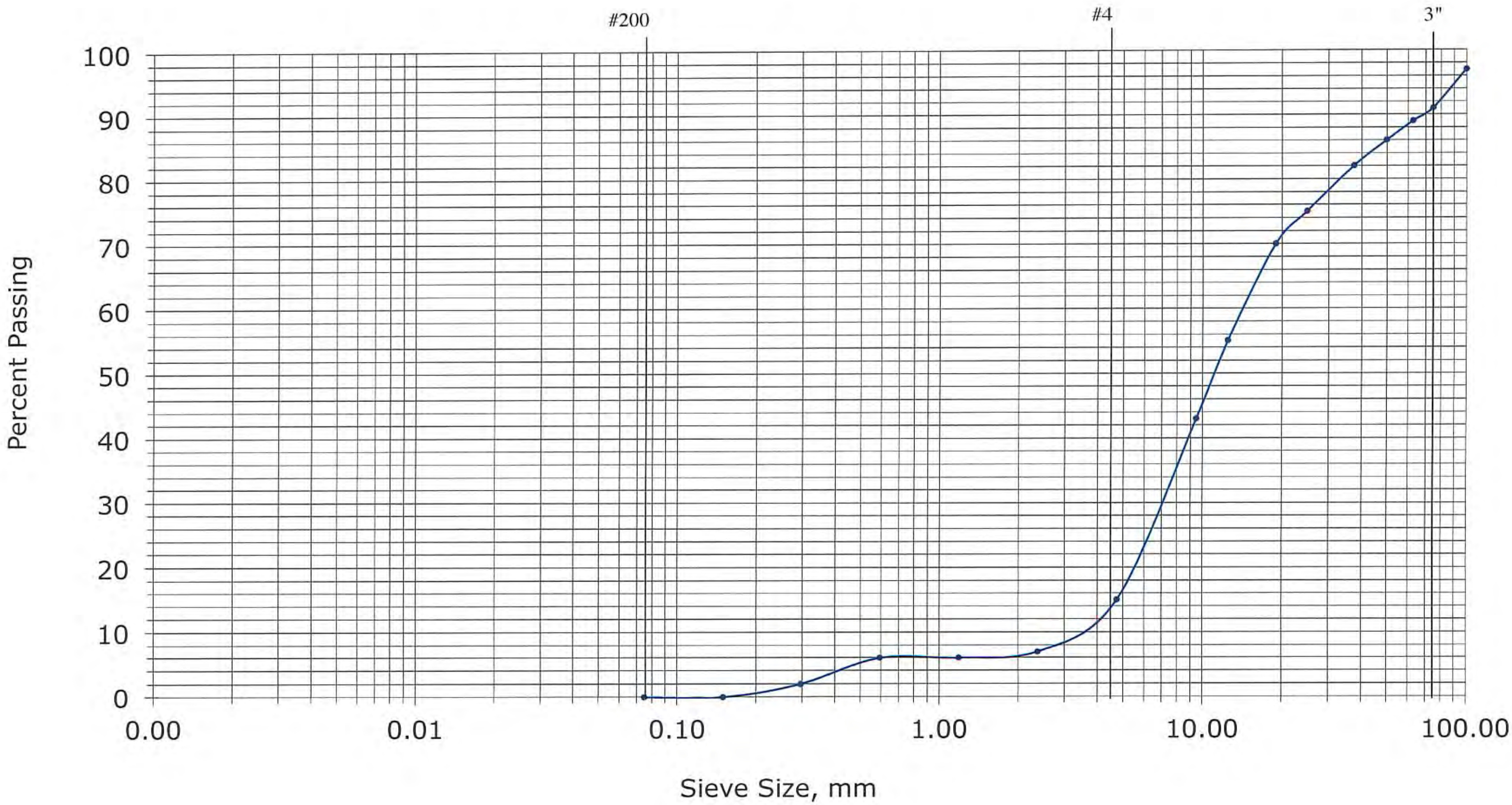
Project:	Marshfield/Duxbury Beaches
Date Tested:	1/9/20
Lab Ref. No.:	M-31207

Sieve Analysis



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Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 12/23/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31208	Sand & Gravel	MARDUX_11_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	86	
12.5 mm	1/2"	73	
9.5 mm	3/8"	65	
4.75 mm	#4	45	
2.38 mm	#8	35	
1.190 mm	#16	30	
0.595 mm	#30	24	
0.297 mm	#50	10	
0.150 mm	#100	1	
0.075 mm	#200	0.3	

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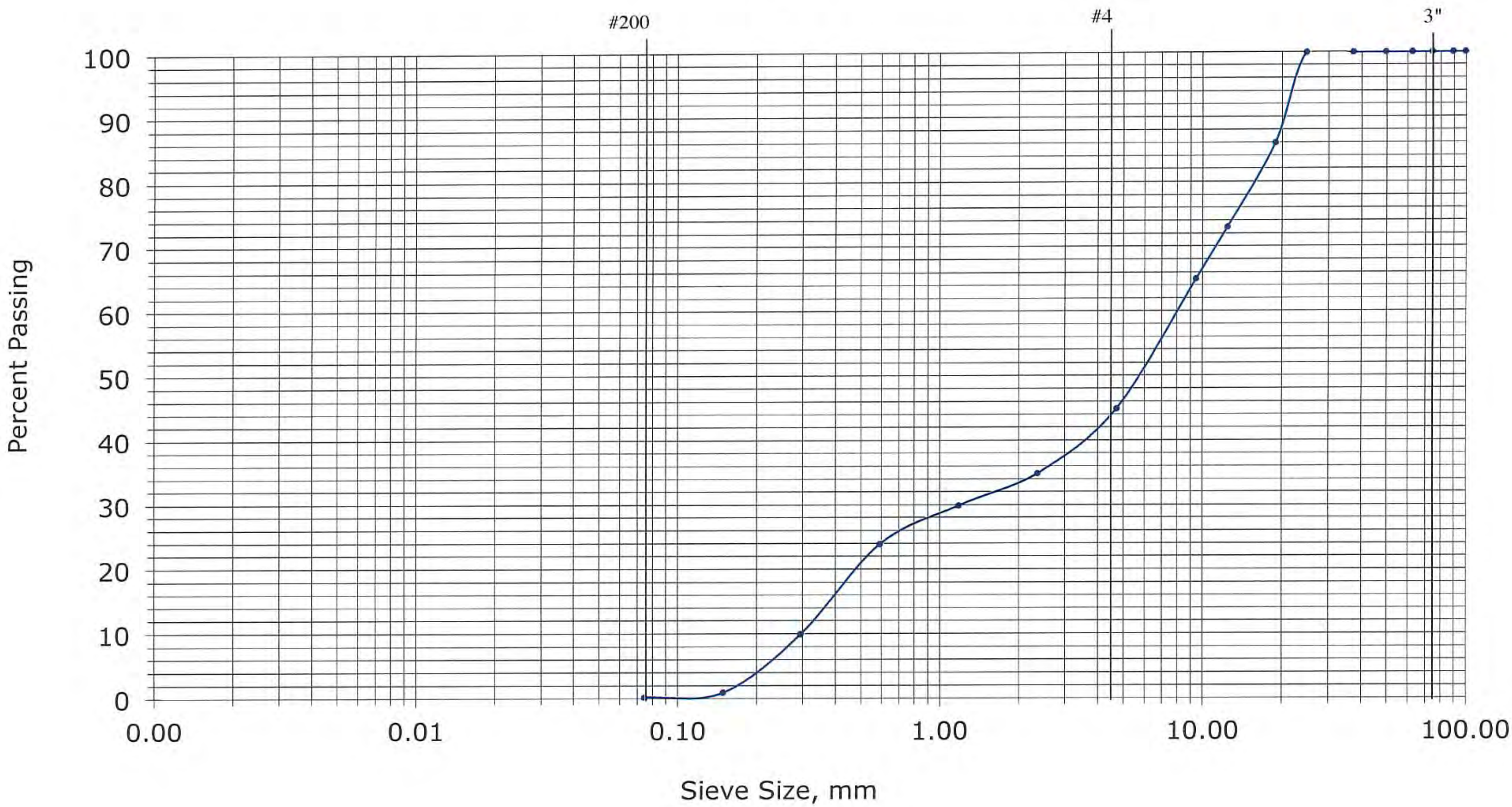
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/23/19
Lab Ref. No.:	M-31208

Sieve Analysis



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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 12/23/19
Received: 12/20/19

1.	Sample No.	Description	Source of Material
	M-31209	Sand	MARDUX_12_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	100	
12.5 mm	1/2"	100	
9.5 mm	3/8"	99	
4.75 mm	#4	99	
2.38 mm	#8	98	
1.190 mm	#16	98	
0.595 mm	#30	97	
0.297 mm	#50	66	
0.150 mm	#100	1	
0.075 mm	#200	0.7	

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Director of Testing Services
Construction Technology Division

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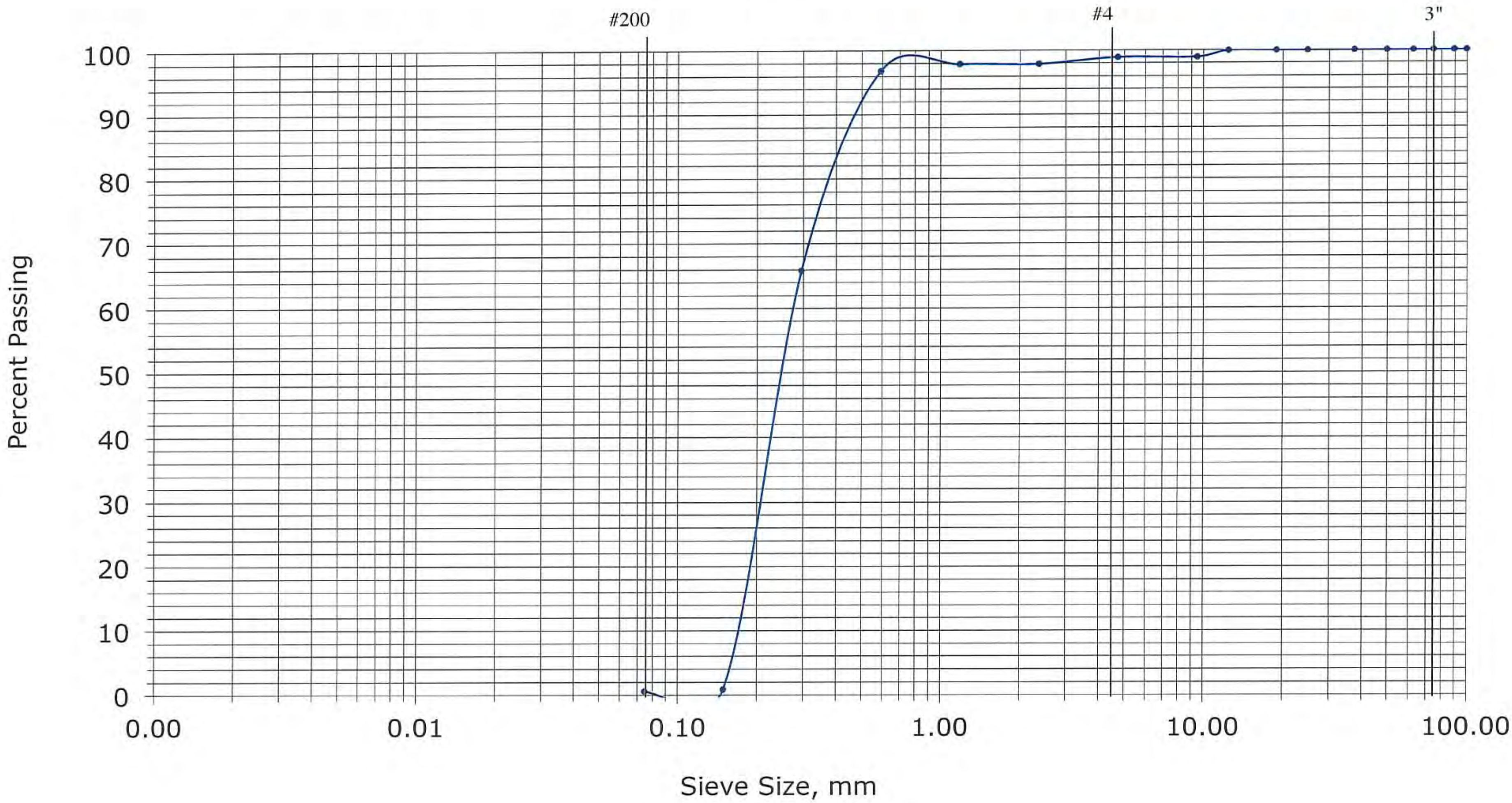
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/23/19
Lab Ref. No.:	M-31209

Sieve Analysis



Briggs Engineering & Testing
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Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Report Date: 1/10/20

Attn: Ms. Leslie Fields

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 1/9/20
Received: 12/20/19

1. Sample No.	Description	Source of Material
M-31210	Sand & Cobble	MARDUX_12_MTL_COB

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
127 mm	5"	100	
100 mm	4"	98	
75 mm	3"	78	
63 mm	2-1/2"	66	
50 mm	2"	60	
37.5 mm	1-1/2"	54	
25 mm	1"	44	
19 mm	3/4"	37	
12.5 mm	1/2"	29	
9.5 mm	3/8"	24	
4.75 mm	#4	15	
2.38 mm	#8	13	
1.190 mm	#16	11	
0.595 mm	#30	9	
0.297 mm	#50	3	
0.150 mm	#100	0	
0.075 mm	#200	0.0	

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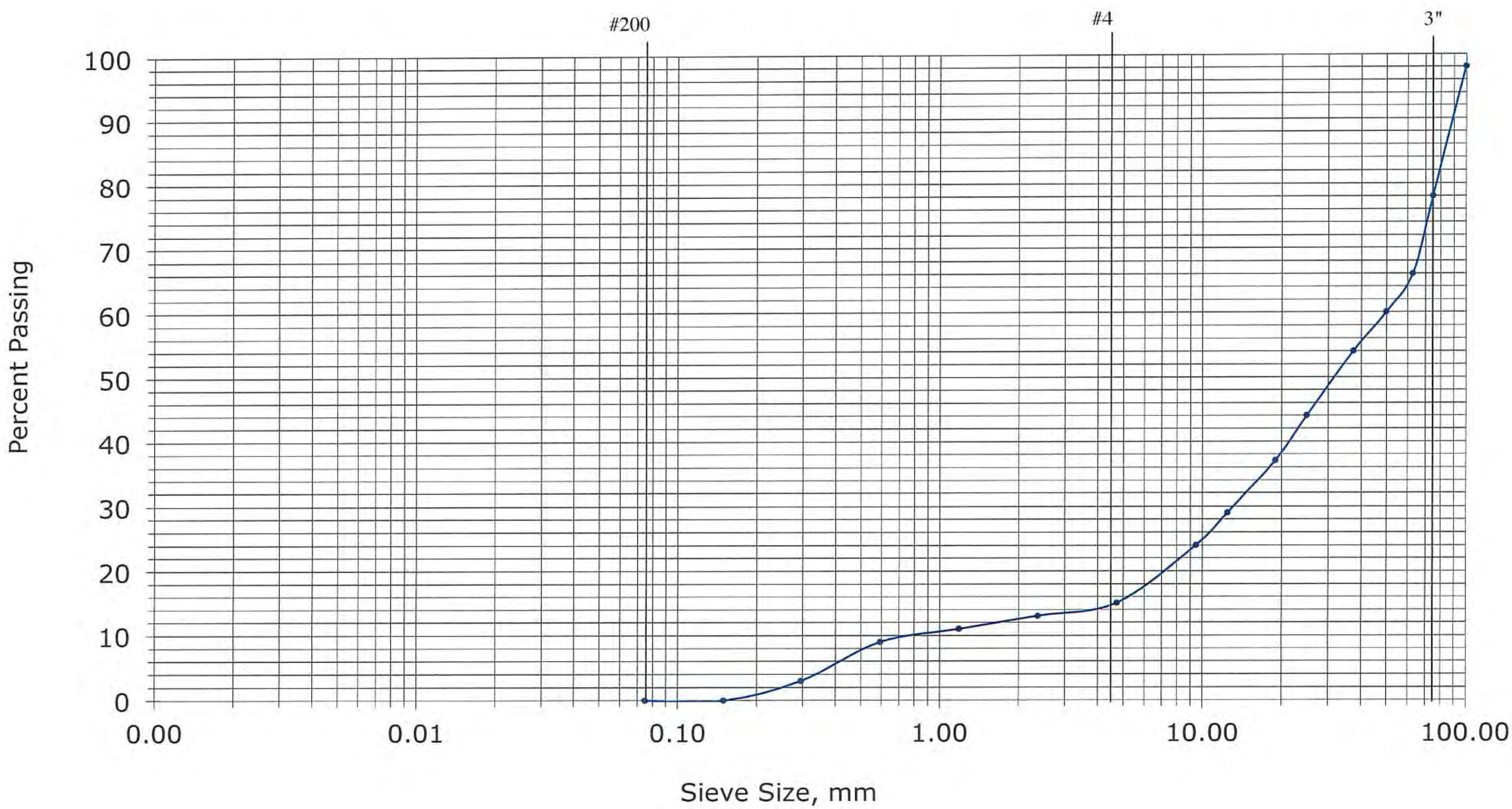
Project:	Marshfield/Duxbury Beaches
Date Tested:	1/9/20
Lab Ref. No.:	M-31210

Sieve Analysis



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Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 12/31/19
Received: 12/20/19

1. Sample No.	Description	Source of Material
M-31211	Sand	MARDUX_17_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	100	
19 mm	3/4"	100	
12.5 mm	1/2"	100	
9.5 mm	3/8"	100	
4.75 mm	#4	100	
2.38 mm	#8	100	
1.190 mm	#16	99	
0.595 mm	#30	98	
0.297 mm	#50	80	
0.150 mm	#100	4	
0.075 mm	#200	0.1	

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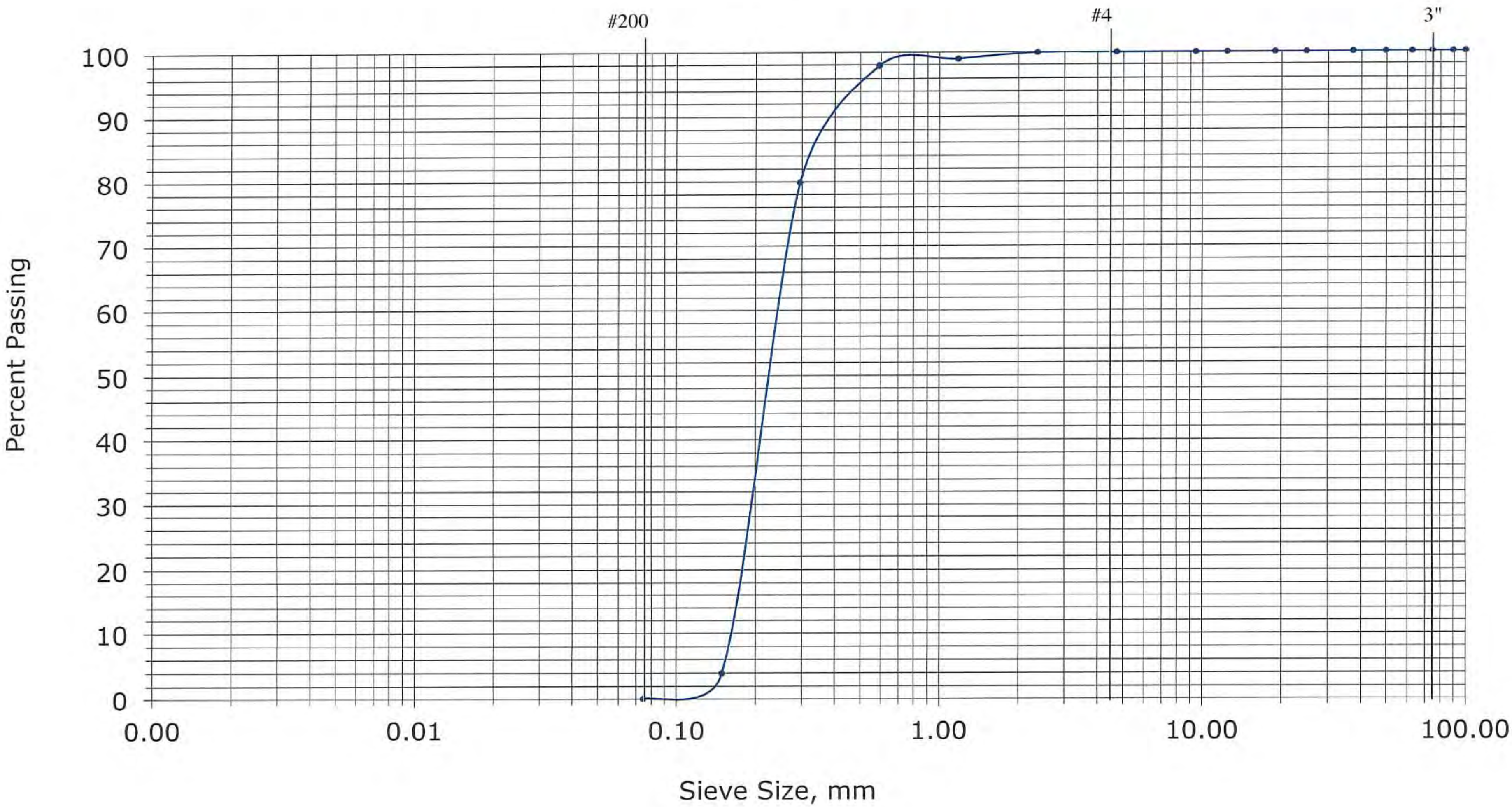
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/31/19
Lab Ref. No.:	M-31211

Sieve Analysis



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Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 1/2/20
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31212	Sand	MARDUX_16_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	97	
19 mm	3/4"	97	
12.5 mm	1/2"	94	
9.5 mm	3/8"	92	
4.75 mm	#4	79	
2.38 mm	#8	60	
1.190 mm	#16	38	
0.595 mm	#30	9	
0.297 mm	#50	1	
0.150 mm	#100	1	
0.075 mm	#200	0.1	

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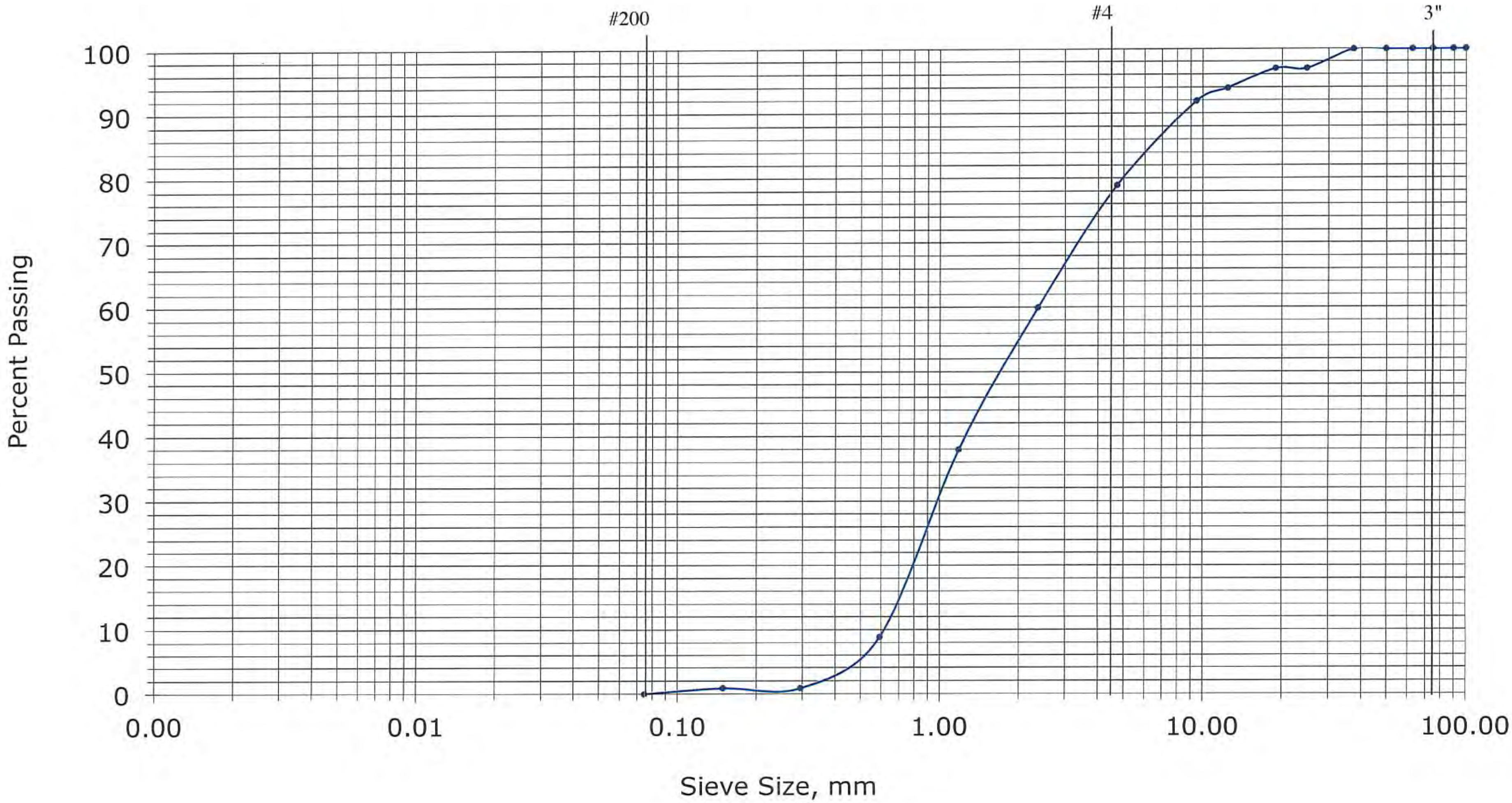
Project:	Marshfield/Duxbury Beaches
Date Tested:	1/2/20
Lab Ref. No.:	M-31212

Sieve Analysis



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Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 1/9/20
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31213	Sand & Cobble	MARDUX_16_MTL_COB

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	99	
63 mm	2-1/2"	90	
50 mm	2"	83	
37.5 mm	1-1/2"	77	
25 mm	1"	67	
19 mm	3/4"	62	
12.5 mm	1/2"	49	
9.5 mm	3/8"	37	
4.75 mm	#4	7	
2.38 mm	#8	1	
1.190 mm	#16	0	
0.595 mm	#30	0	
0.297 mm	#50	0	
0.150 mm	#100	0	
0.075 mm	#200	0.0	

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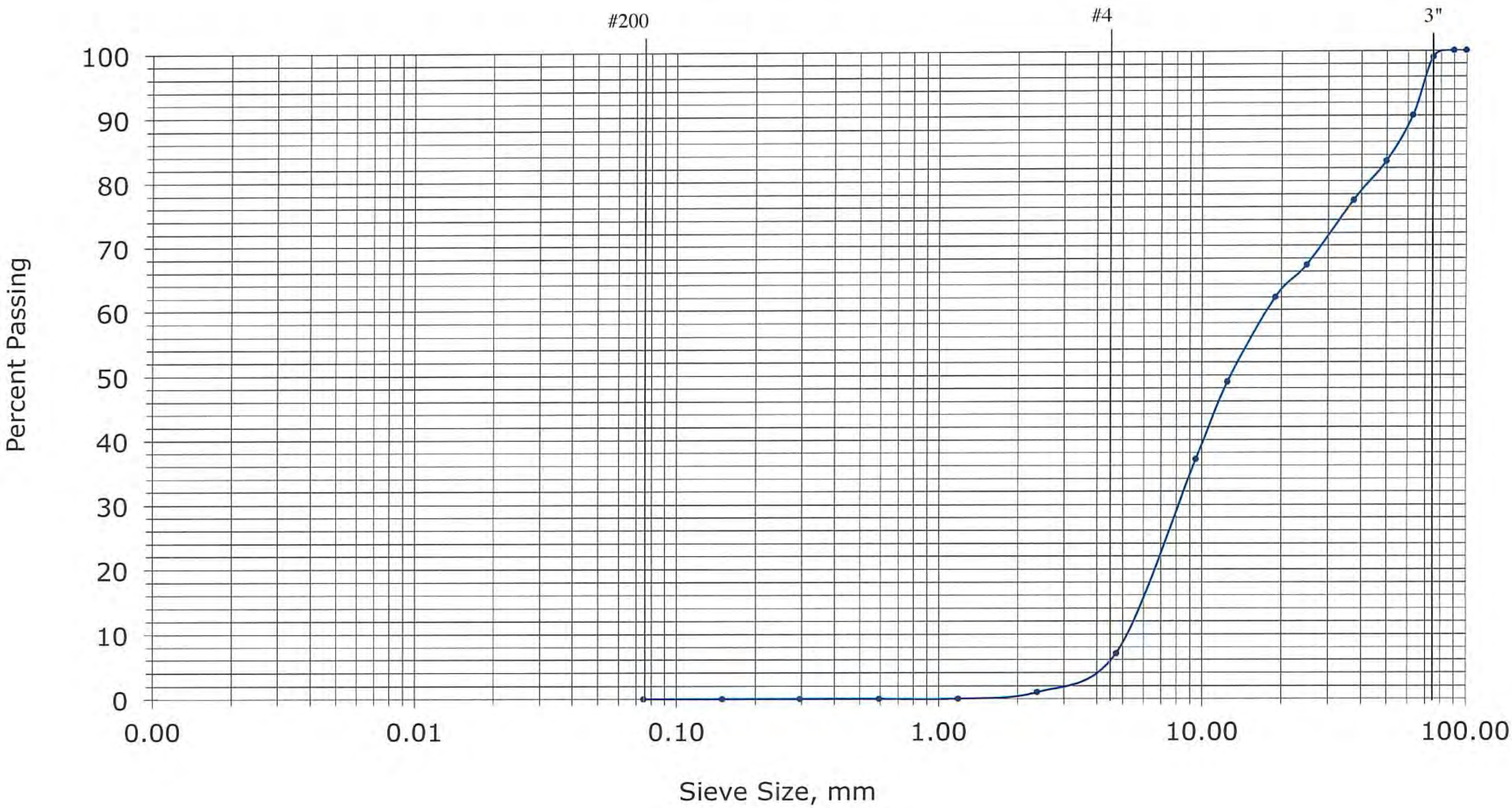
Project:	Marshfield/Duxbury Beaches
Date Tested:	1/9/20
Lab Ref. No.:	M-31213

Sieve Analysis



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Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: **Marshfield/Duxbury Beaches**
Briggs #: 31067

Tested: 12/31/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31214	Sand	MARDUX_15_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	**No Spec**
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	97	
19 mm	3/4"	97	
12.5 mm	1/2"	93	
9.5 mm	3/8"	88	
4.75 mm	#4	73	
2.38 mm	#8	64	
1.190 mm	#16	31	
0.595 mm	#30	15	
0.297 mm	#50	13	
0.150 mm	#100	1	
0.075 mm	#200	0.1	

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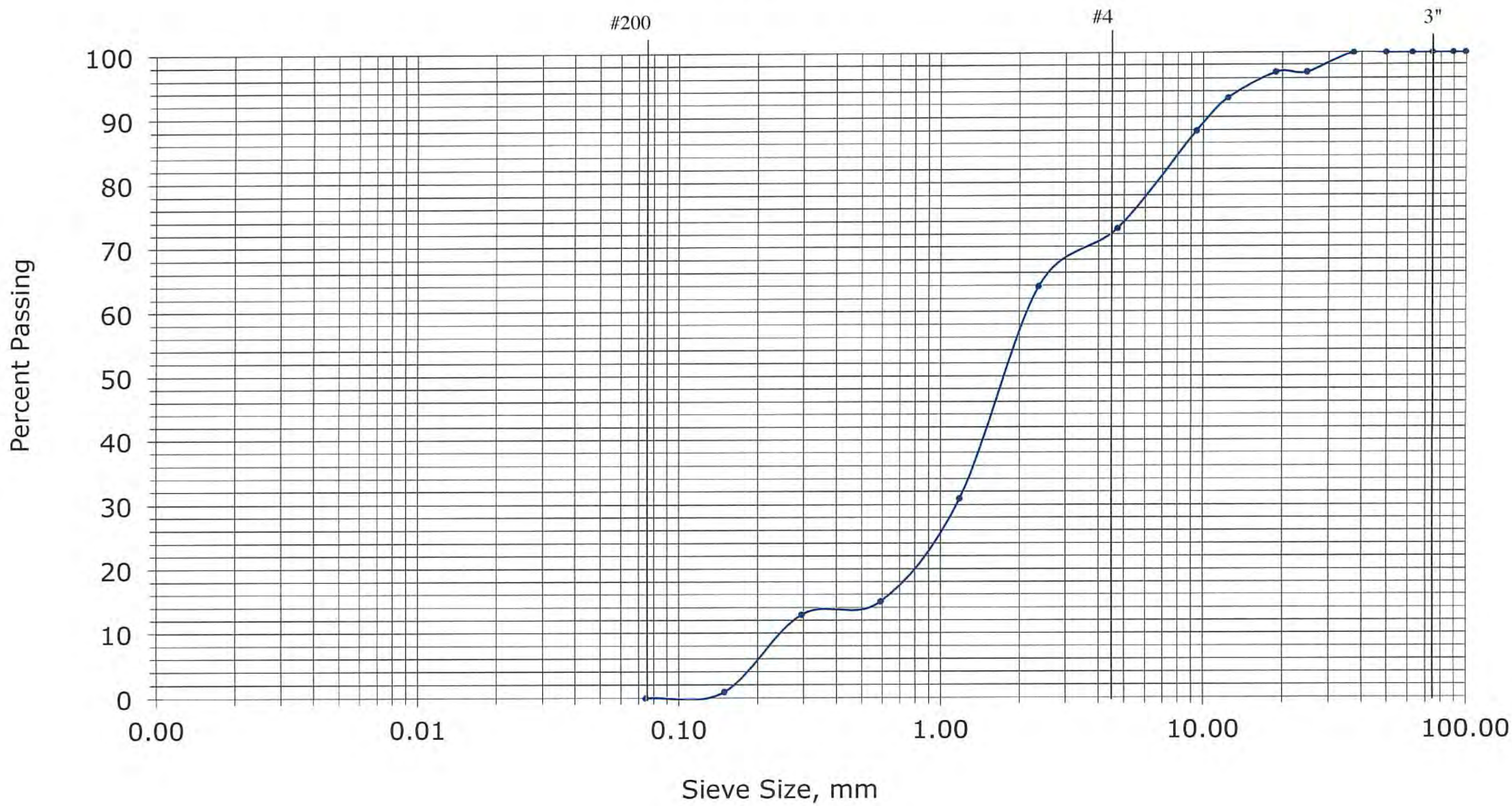
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/31/19
Lab Ref. No.:	M-31214

Sieve Analysis



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Woods Hole Group
107 Waterhouse Road
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Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 12/31/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31215	Sand	MARDUX_14_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	95	
19 mm	3/4"	92	
12.5 mm	1/2"	88	
9.5 mm	3/8"	87	
4.75 mm	#4	82	
2.38 mm	#8	78	
1.190 mm	#16	73	
0.595 mm	#30	66	
0.297 mm	#50	47	
0.150 mm	#100	2	
0.075 mm	#200	0.1	

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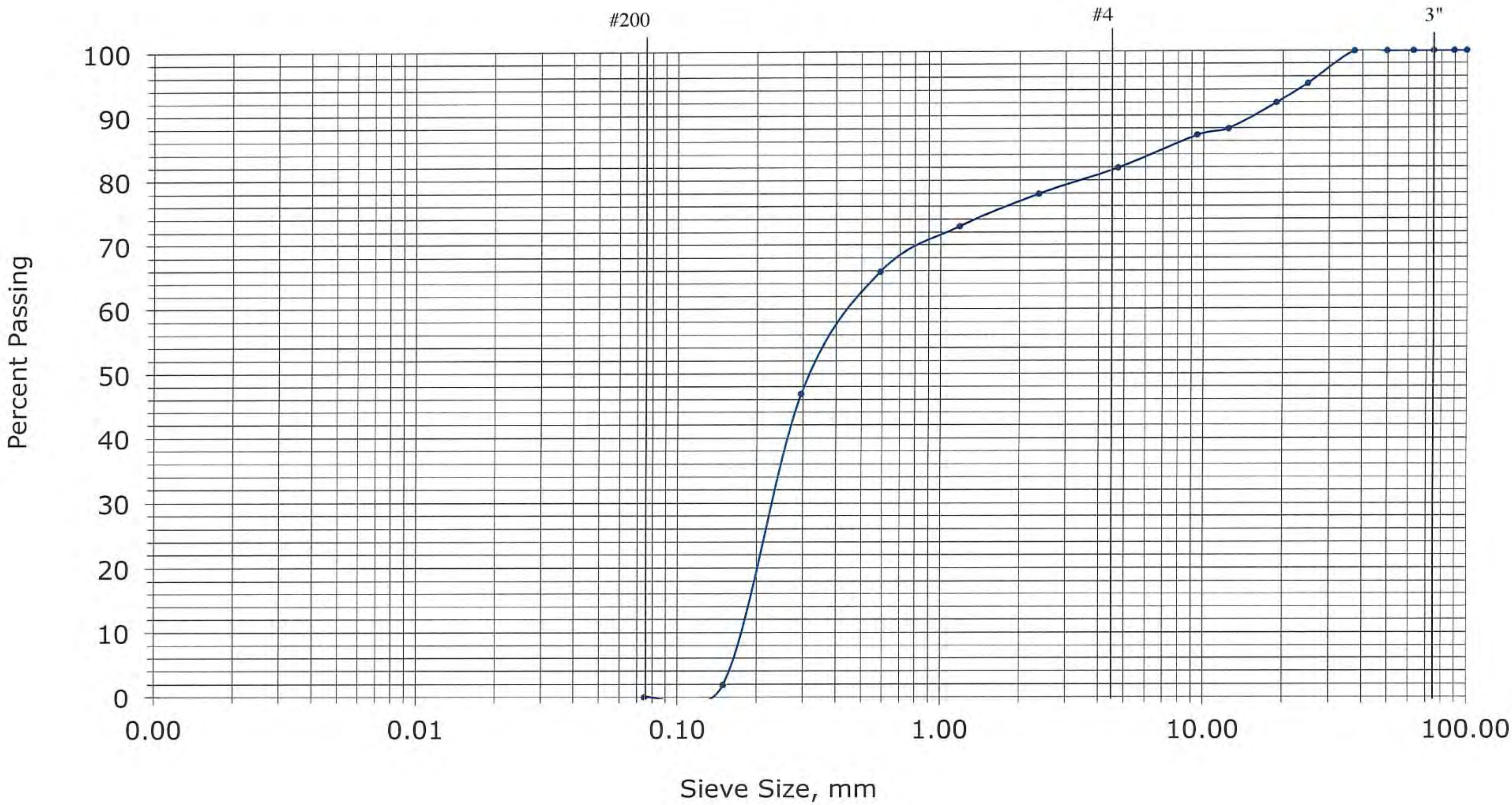
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/31/19
Lab Ref. No.:	M-31215

Sieve Analysis



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Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 1/9/20
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31216	Sand & Cobble	MARDUX_14_MTL_COB

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	96	
50 mm	2"	89	
37.5 mm	1-1/2"	81	
25 mm	1"	64	
19 mm	3/4"	58	
12.5 mm	1/2"	49	
9.5 mm	3/8"	44	
4.75 mm	#4	35	
2.38 mm	#8	28	
1.190 mm	#16	23	
0.595 mm	#30	19	
0.297 mm	#50	11	
0.150 mm	#100	1	
0.075 mm	#200	0.0	

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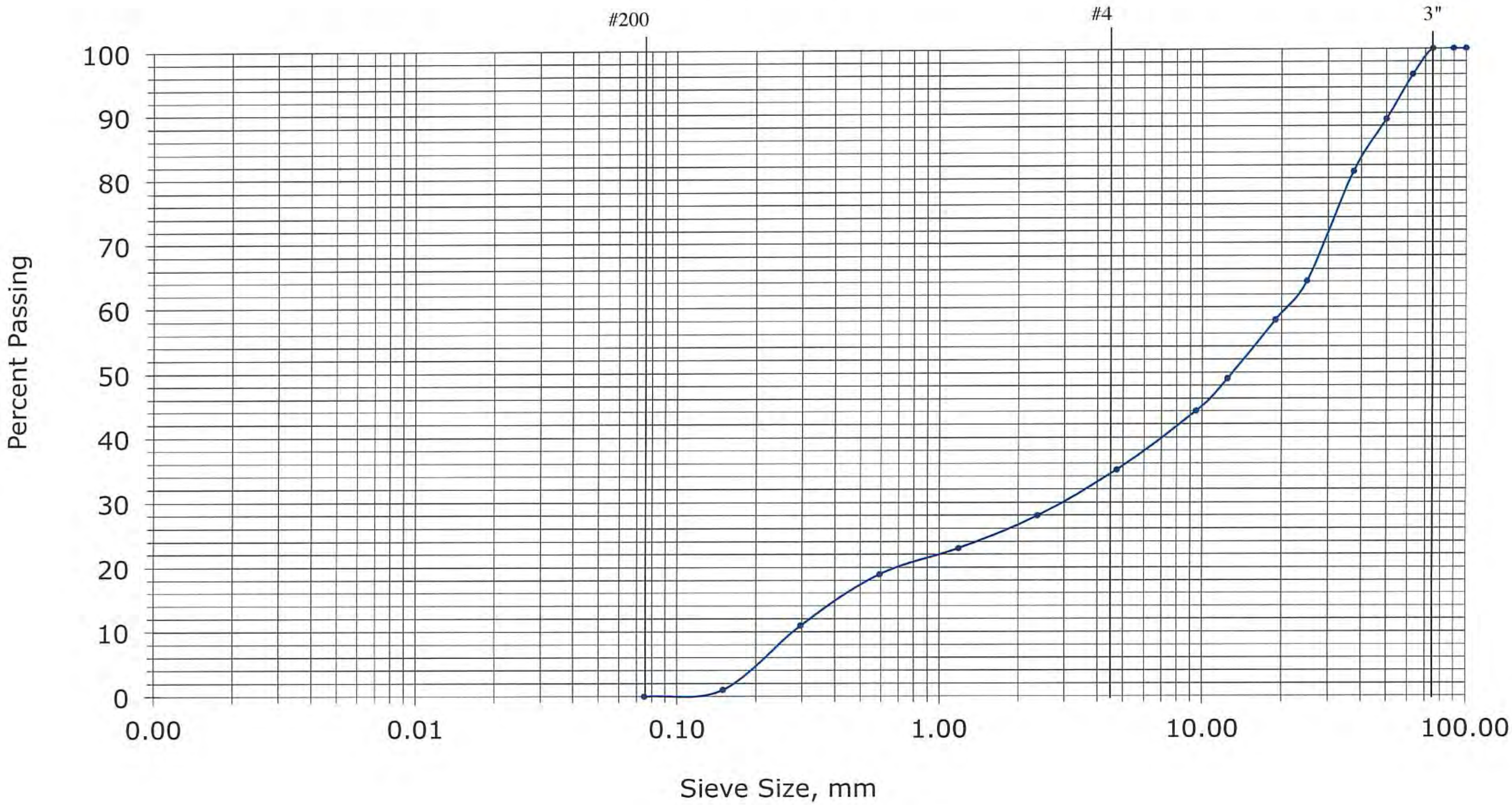
Project:	Marshfield/Duxbury Beaches
Date Tested:	1/9/20
Lab Ref. No.:	M-31216

Sieve Analysis



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Woods Hole Group
107 Waterhouse Road
Bourne, MA 02532

Attn: Ms. Leslie Fields

Report Date: 1/10/20

Project: Marshfield/Duxbury Beaches
Briggs #: 31067

Tested: 12/31/19
Received: 12/20/19

1.

Sample No.	Description	Source of Material
M-31217	Sand & Gravel	MARDUX_13_MTL_SAN

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

Sieve Size		Results	Specifications
Standard	Alternate	{% Passing by Wt.}	No Spec
100 mm	4"	100	
90 mm	3-1/2"	100	
75 mm	3"	100	
63 mm	2-1/2"	100	
50 mm	2"	100	
37.5 mm	1-1/2"	100	
25 mm	1"	93	
19 mm	3/4"	89	
12.5 mm	1/2"	77	
9.5 mm	3/8"	66	
4.75 mm	#4	43	
2.38 mm	#8	22	
1.190 mm	#16	11	
0.595 mm	#30	5	
0.297 mm	#50	1	
0.150 mm	#100	1	
0.075 mm	#200	0.1	

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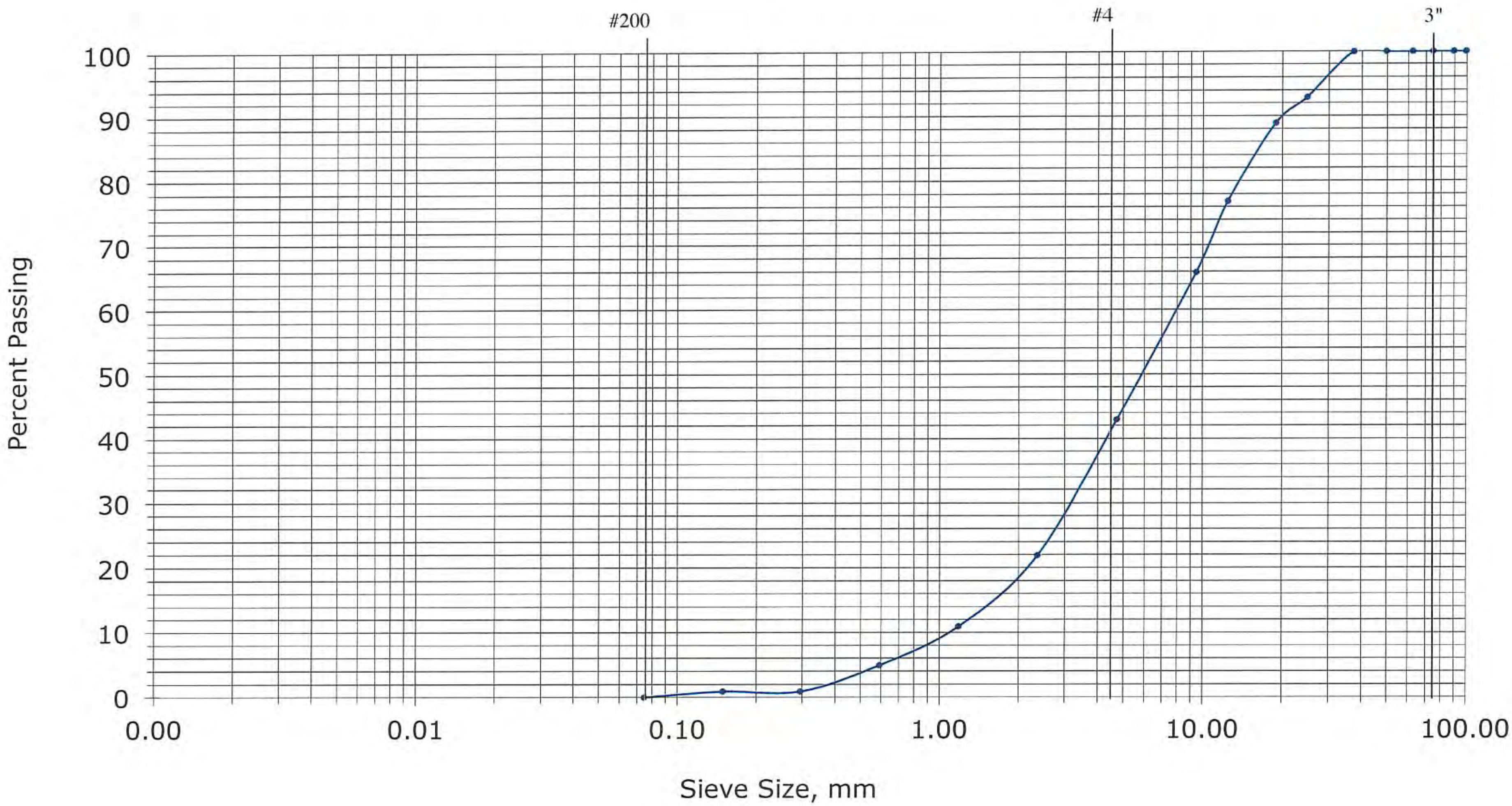
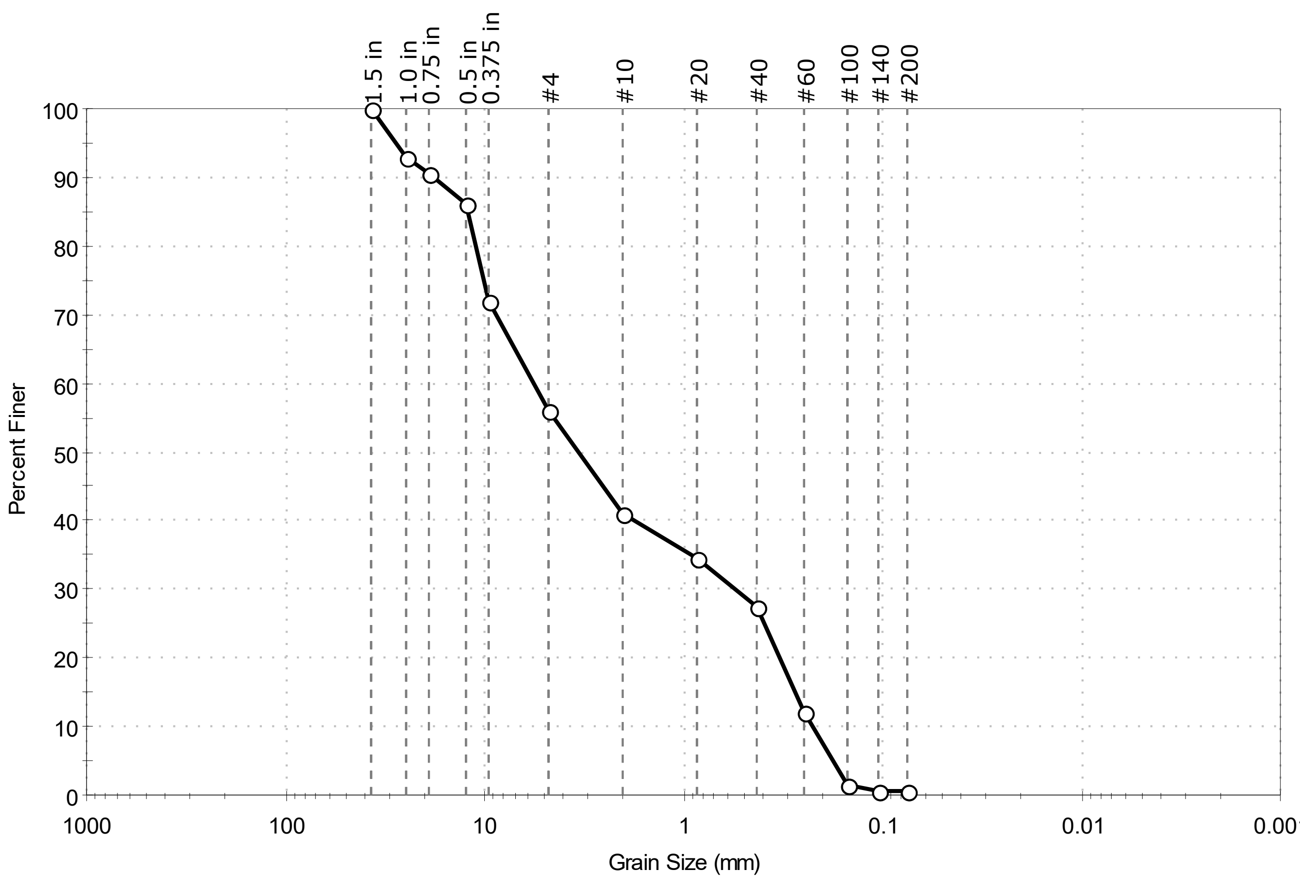
Project:	Marshfield/Duxbury Beaches
Date Tested:	12/31/19
Lab Ref. No.:	M-31217

Sieve Analysis



Client: Woods Hole Group			
Project: Marshfield 2017			
Location: Marshfield, MA		Project No: GTX-308233	
Boring ID: ---	Sample Type: bag	Tested By: GA	
Sample ID: 9th Street	Test Date: 06/08/18	Checked By: emm	
Depth : surface	Test Id: 457343		
Test Comment: ---			
Visual Description: Moist, light gray sand with gravel			
Sample Comment: ---			

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	44.0	55.4	0.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1.0 in	25.00	93		
0.75 in	19.00	91		
0.5 in	12.50	86		
0.375 in	9.50	72		
#4	4.75	56		
#10	2.00	41		
#20	0.85	34		
#40	0.42	28		
#60	0.25	12		
#100	0.15	1		
#140	0.11	1		
#200	0.075	0.6		

Coefficients

D_{85} =12.2472 mm D_{30} =0.5447 mm

D_{60} =5.6539 mm D_{15} =0.2759 mm

D_{50} =3.3659 mm D_{10} =0.2260 mm

C_u =25.017 C_c =0.232

Classification

ASTM Poorly graded SAND with Gravel (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-a (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

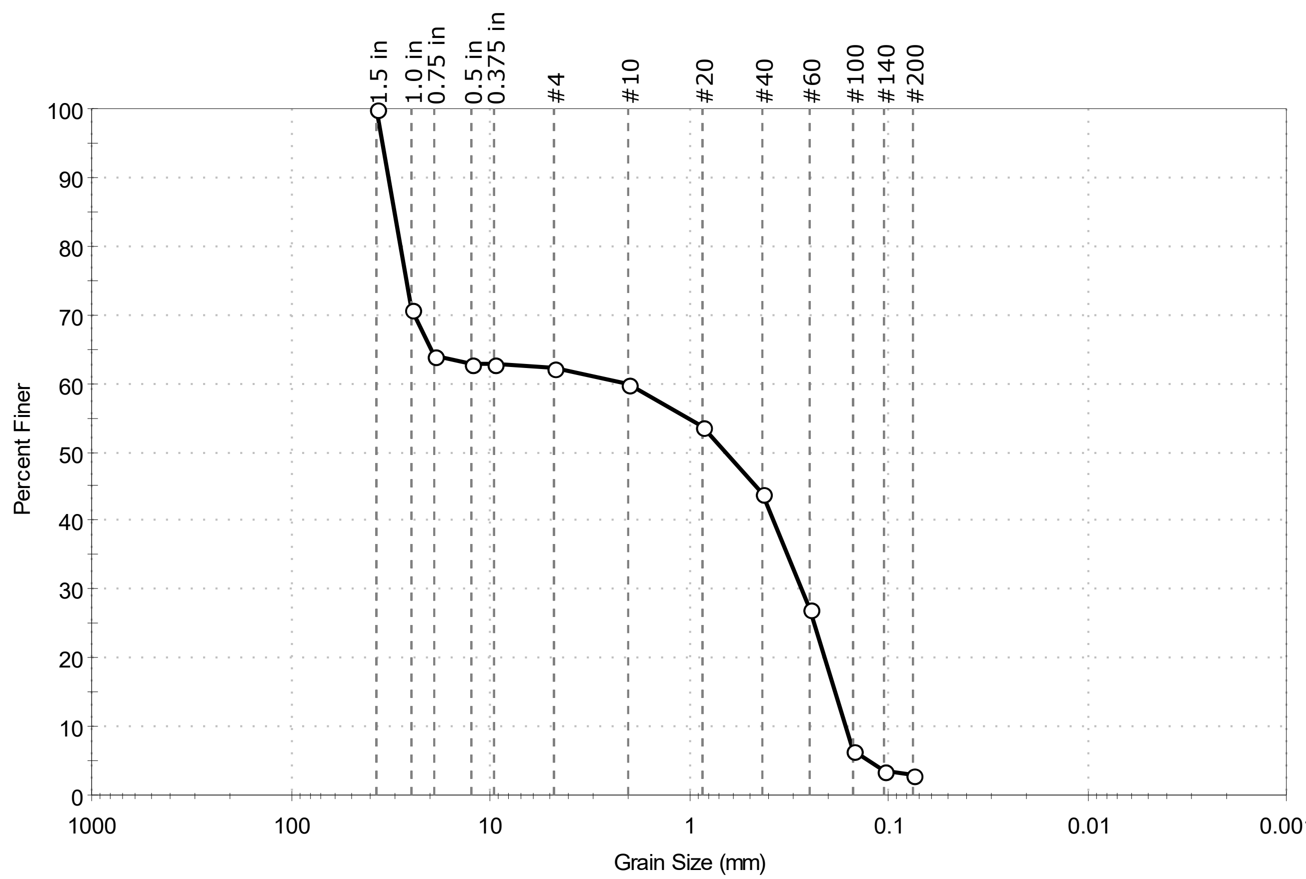
Sand/Gravel Hardness : HARD

printed 6/8/2018 8:29:33 AM

Client:	Woods Hole Group		
Project:	Marshfield 2017		
Location:	Marshfield, MA	Project No:	GTX-308233
Boring ID: ---	Sample Type: bag	Tested By:	GA
Sample ID: GH Nav Channel	Test Date: 06/08/18	Checked By:	emm
Depth : surface	Test Id: 457345		

Test Comment: ---
Visual Description: Moist, greenish gray sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	37.7	59.5	2.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1.0 in	25.00	71		
0.75 in	19.00	64		
0.5 in	12.50	63		
0.375 in	9.50	63		
#4	4.75	62		
#10	2.00	60		
#20	0.85	54		
#40	0.42	44		
#60	0.25	27		
#100	0.15	6		
#140	0.11	4		
#200	0.075	2.8		

Coefficients

D_{85} =30.4235 mm D_{30} =0.2733 mm
D_{60} =2.1548 mm D_{15} =0.1853 mm
D_{50} =0.6566 mm D_{10} =0.1639 mm
C_u =13.147 C_c =0.211

Classification

ASTM Poorly graded SAND with Gravel (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

printed 6/8/2018 8:29:34 AM

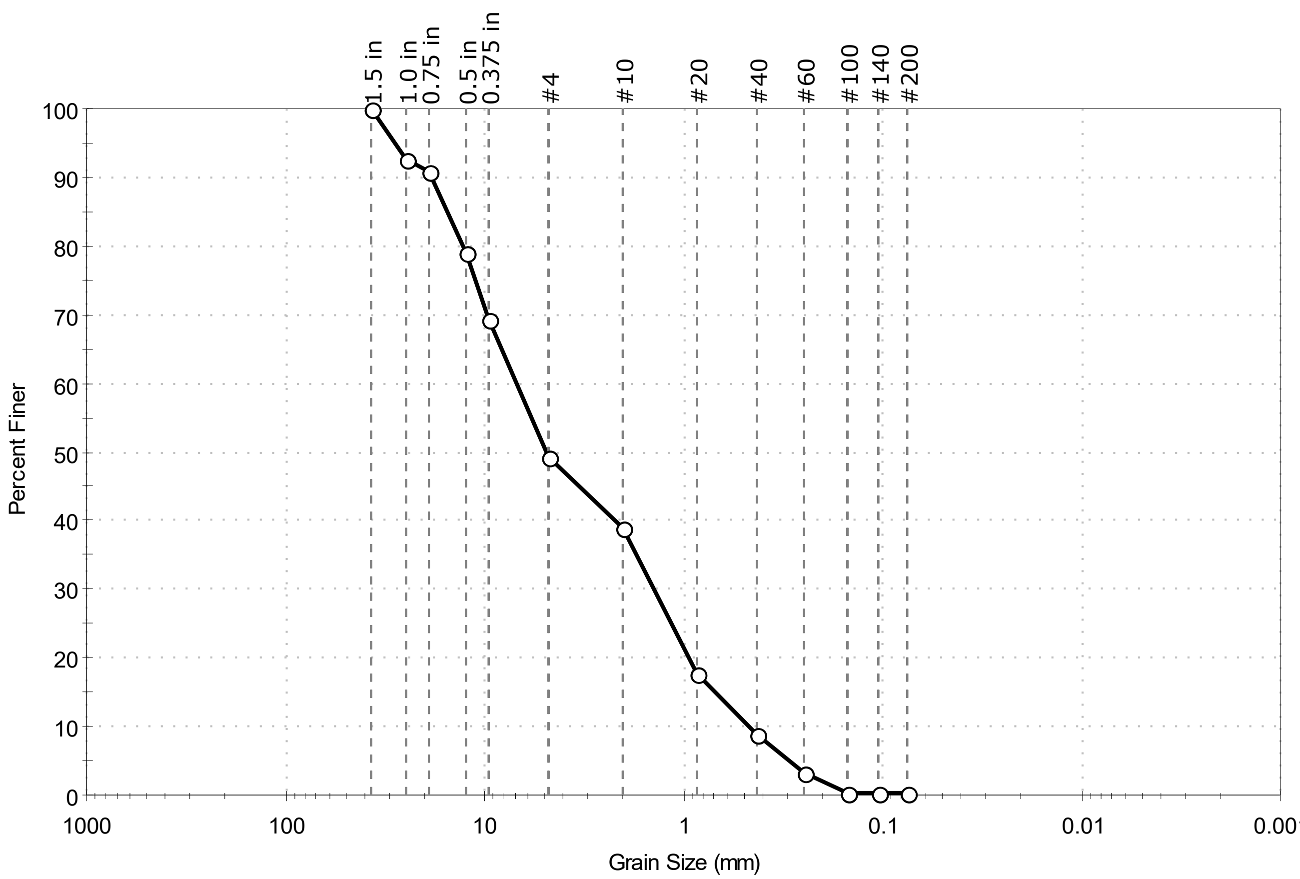
Client:	Woods Hole Group		
Project:	Marshfield 2017		
Location:	Marshfield, MA	Project No:	GTX-308233
Boring ID: ---	Sample Type: bag	Tested By:	GA
Sample ID: Pearl Street	Test Date: 06/08/18	Checked By:	emm
Depth : surface	Test Id: 457344		

Test Comment: ---

Visual Description: Moist, light gray gravel with sand

Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	50.8	48.9	0.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1.0 in	25.00	93		
0.75 in	19.00	91		
0.5 in	12.50	79		
0.375 in	9.50	69		
#4	4.75	49		
#10	2.00	39		
#20	0.85	18		
#40	0.42	9		
#60	0.25	3		
#100	0.15	0		
#140	0.11	0		
#200	0.075	0.3		

Coefficients

D_{85} =15.4352 mm — D_{30} =1.3917 mm

D_{60} =6.8767 mm — D_{15} =0.6869 mm

D_{50} =4.8762 mm — D_{10} =0.4648 mm

C_u =14.795 — C_c =0.606

Classification

ASTM: Poorly graded GRAVEL with Sand (GP)

AASHTO: Stone Fragments, Gravel and Sand (A-1-a (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

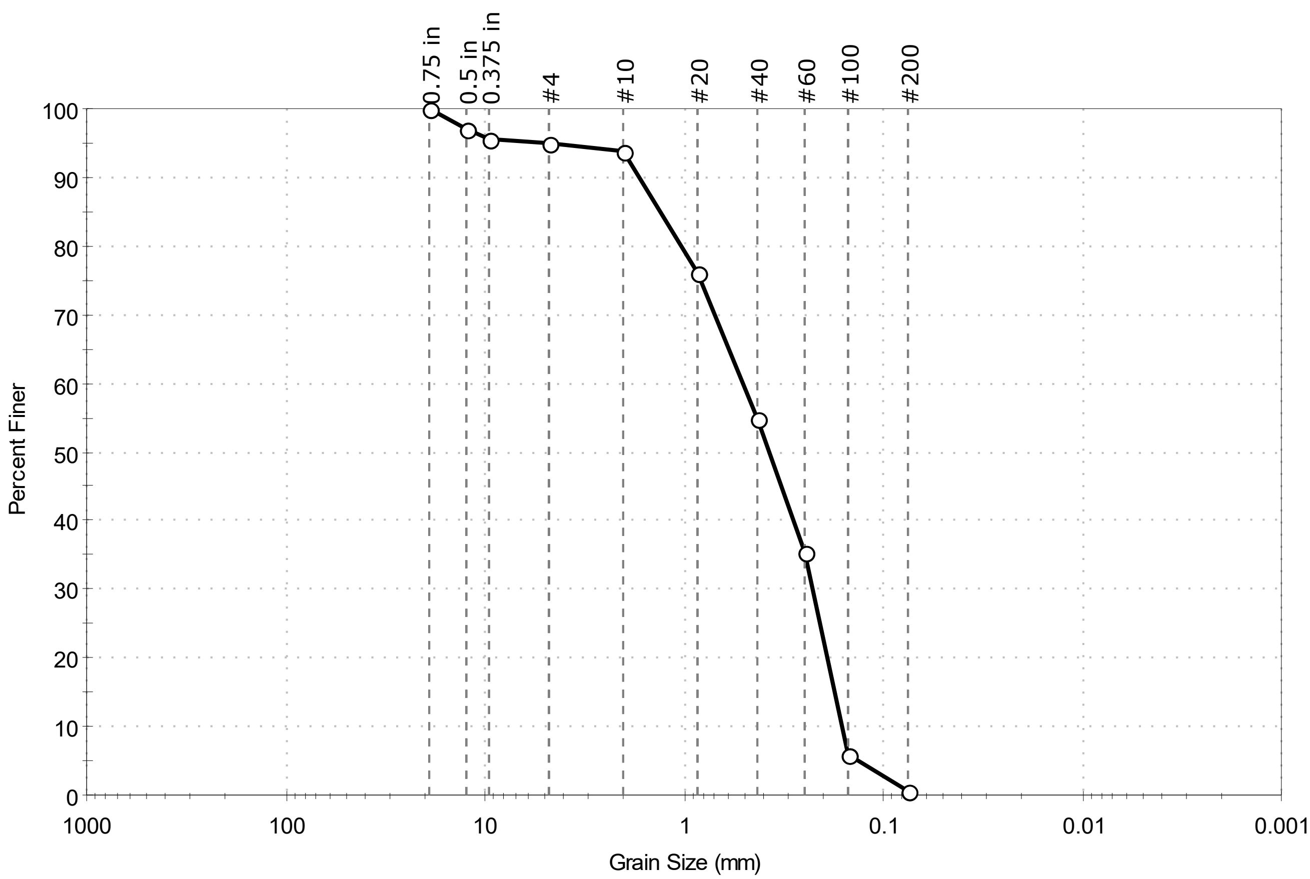
Sand/Gravel Hardness : HARD

GeoTesting EXPRESS

Client: Woods Hole Group			
Project: Marshfield BMP			
Location: Marshfield, MA		Project No:	GTX-306822
Boring ID: ---	Sample Type: bag	Tested By:	GA
Sample ID: Green Harbor	Test Date: 08/14/17	Checked By:	jdt
Depth : ---	Test Id: 419588		

Test Comment: ---
Visual Description: Moist, light gray sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	5.1	94.2	0.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	97		
0.375 in	9.50	96		
#4	4.75	95		
#10	2.00	94		
#20	0.85	76		
#40	0.42	55		
#60	0.25	35		
#100	0.15	6		
#200	0.075	0.7		

Coefficients

D_{85} =1.3039 mm | D_{30} =0.2279 mm
D_{60} =0.5037 mm | D_{15} =0.1758 mm
D_{50} =0.3729 mm | D_{10} =0.1613 mm
C_u =3.123 | C_c =0.639

Classification

ASTM Poorly graded sand (SP)

AASHTO Fine Sand (A-3 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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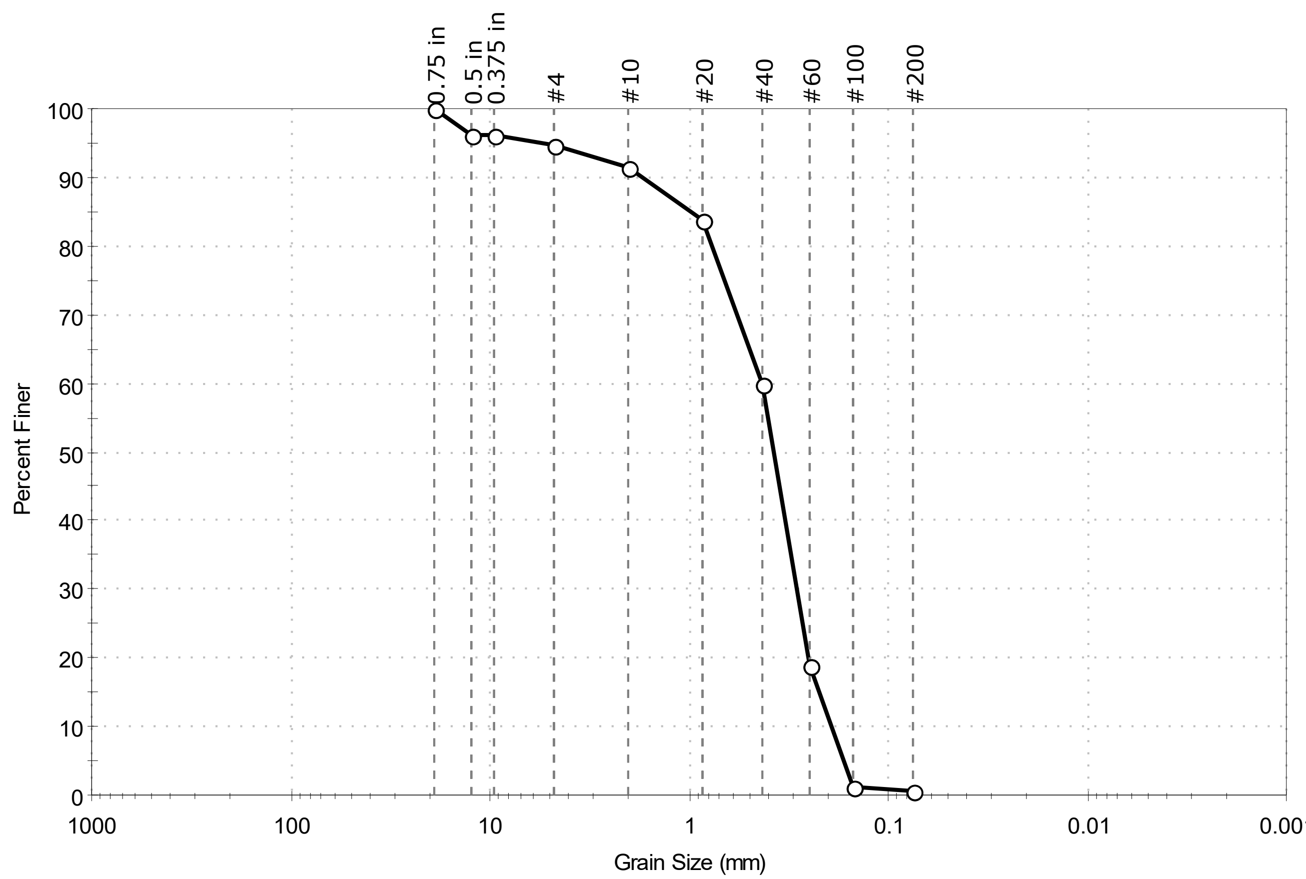
Client: Woods Hole Group			
Project: Marshfield BMP			
Location: Marshfield, MA		Project No:	GTX-306822
Boring ID: ---	Sample Type: bag	Tested By:	GA
Sample ID: Fieldston/Sunrise	Test Date: 08/14/17	Checked By:	jdt
Depth : ---	Test Id: 419589		
Test Comment: ---			
Visual Description: Moist, light gray sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	5.4	93.9	0.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	96		
0.375 in	9.50	96		
#4	4.75	95		
#10	2.00	92		
#20	0.85	84		
#40	0.42	60		
#60	0.25	19		
#100	0.15	1		
#200	0.075	0.7		

Coefficients

D_{85} =0.9687 mm | D_{30} =0.2889 mm

D_{60} =0.4250 mm | D_{15} =0.2243 mm

D_{50} =0.3737 mm | D_{10} =0.1942 mm

C_u =2.188 | C_c =1.011

Classification

ASTM Poorly graded sand (SP)

AASHTO Fine Sand (A-3 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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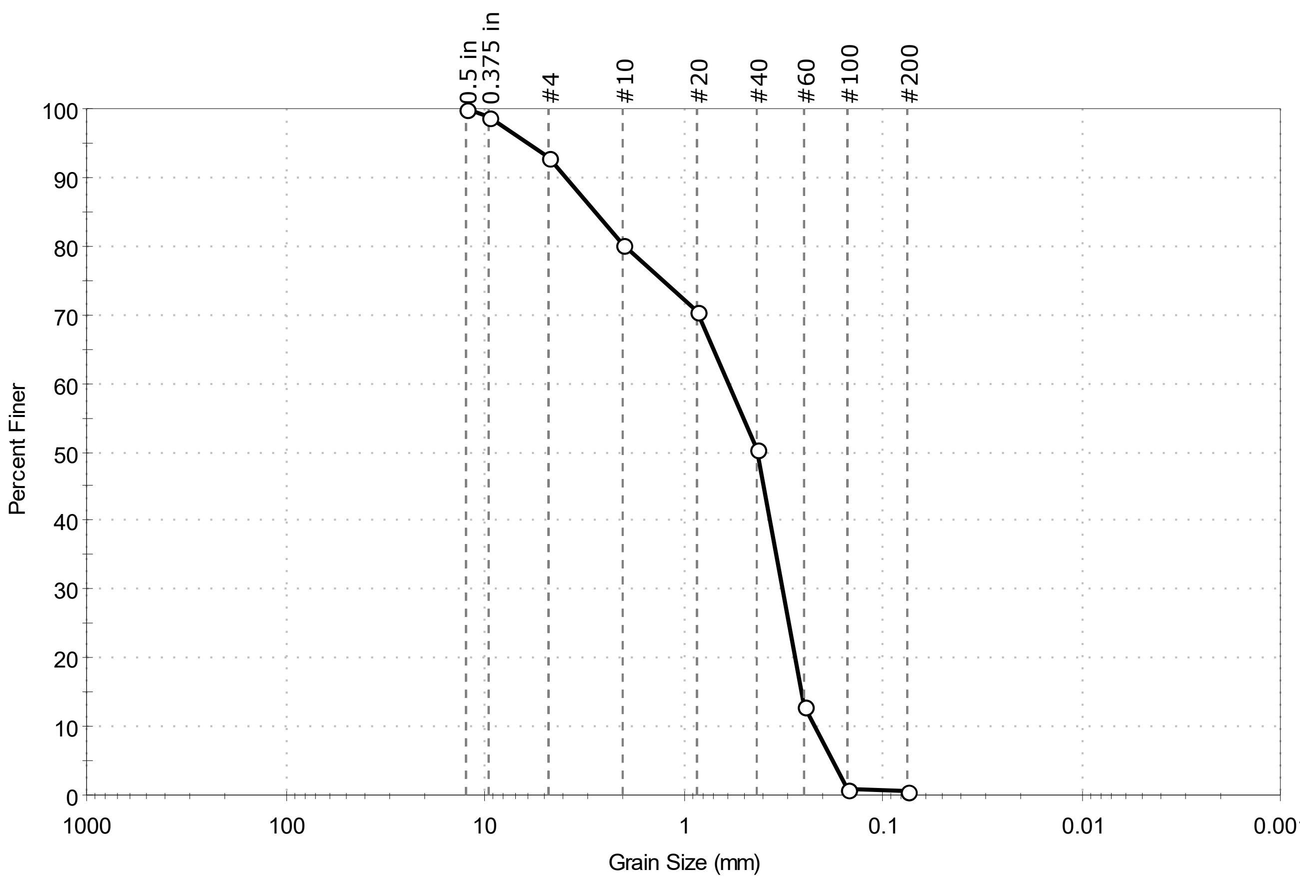
Client:	Woods Hole Group				
Project:	Marshfield BMP				
Location:	Marshfield, MA			Project No:	GTX-306822
Boring ID:	---	Sample Type:	bag	Tested By:	GA
Sample ID:	Brant Rock	Test Date:	08/14/17	Checked By:	jdt
Depth :	---	Test Id:	419590		
Test Comment:	---				
Visual Description:	Moist, light gray sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	7.0	92.5	0.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	99		
#4	4.75	93		
#10	2.00	80		
#20	0.85	71		
#40	0.42	50		
#60	0.25	13		
#100	0.15	1		
#200	0.075	0.5		

Coefficients

D_{85} =2.7702 mm　D_{30} =0.3184 mm

D_{60} =0.5904 mm　D_{15} =0.2576 mm

D_{50} =0.4224 mm　D_{10} =0.2208 mm

C_u =2.674　C_c =0.778

Classification

ASTM　Poorly graded sand (SP)

AASHTO　Fine Sand (A-3 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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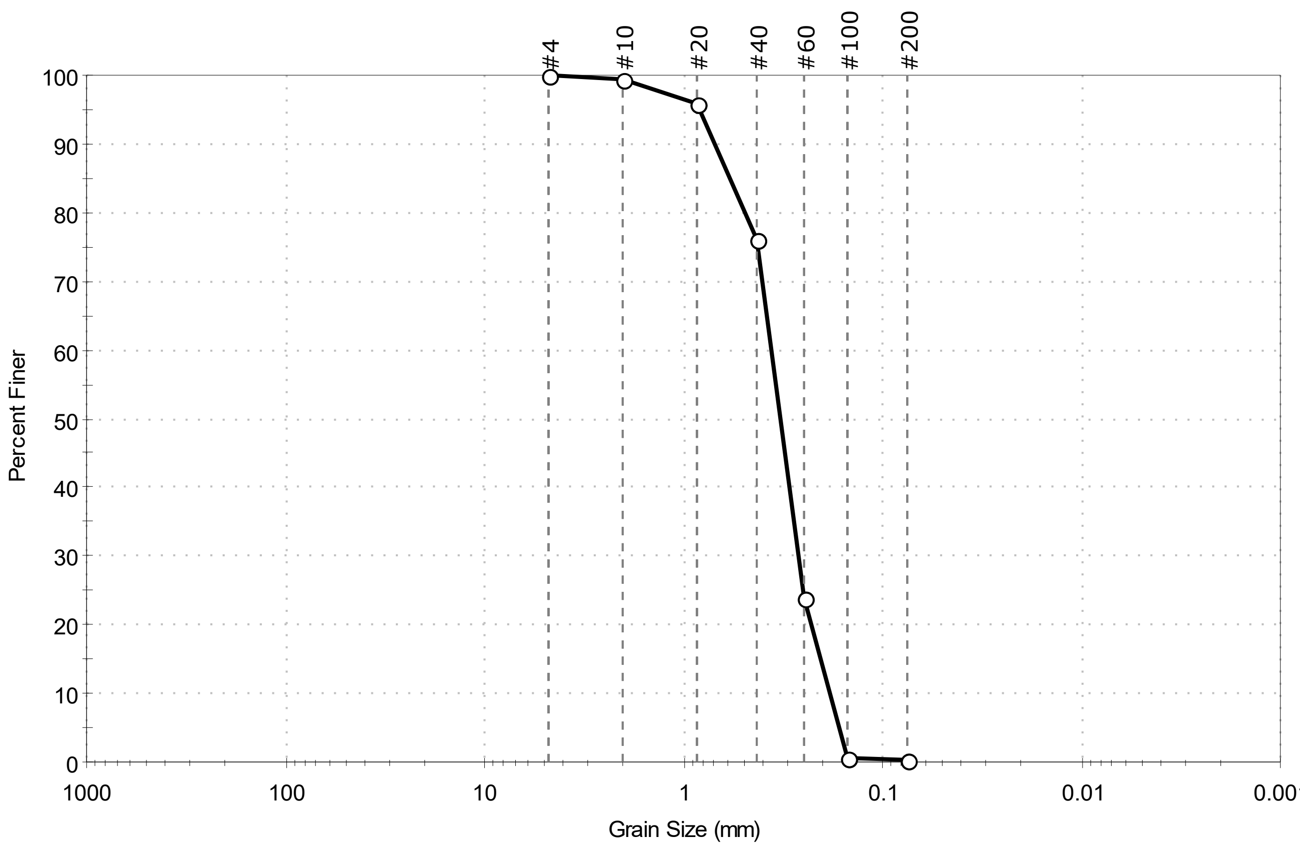
GeoTesting EXPRESS

Client: Woods Hole Group			
Project: Marshfield BMP			
Location: Marshfield, MA		Project No:	GTX-306822
Boring ID: ---	Sample Type: bag	Tested By:	GA
Sample ID: Rexhame	Test Date: 08/14/17	Checked By:	jdt
Depth : ---	Test Id: 419591		
Test Comment: ---			
Visual Description: Moist, light gray sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	99.8	0.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.85	96		
#40	0.42	76		
#60	0.25	24		
#100	0.15	1		
#200	0.075	0.2		

Coefficients

D_{85} =0.5832 mm D_{30} =0.2664 mm
D_{60} =0.3613 mm D_{15} =0.2060 mm
D_{50} =0.3264 mm D_{10} =0.1844 mm
C_u =1.959 C_c =1.065

Classification

ASTM Poorly graded sand (SP)

AASHTO Fine Sand (A-3 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

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Section L

Accompanying Documents

MASSWILDLIFE

DIVISION OF
FISHERIES & WILDLIFE

1 Rabbit Hill Road, Westborough, MA 01581
p: (508) 389-6300 | f: (508) 389-7890
MASS.GOV/MASSWILDLIFE

January 30, 2020

Greg Guimond
Town of Marshfield
870 Moraine Street
Marshfield MA 02050

RE: Project Location: Marshfield & Northern Duxbury Beaches
Town: MARSHFIELD, DUXBURY
NHESP Tracking No.: 20-39123

To Whom It May Concern:

Thank you for contacting the Natural Heritage and Endangered Species Program of the MA Division of Fisheries & Wildlife (the "Division") for information regarding state-listed rare species in the vicinity of the above referenced site. Based on the information provided, this project site, or a portion thereof, is located **within** *Priority Habitat* and *Estimated Habitat* as indicated in the *Massachusetts Natural Heritage Atlas* (14th Edition) for the following state-listed rare species:

Priority Habitat 942 (PH 942) and *Estimated Habitat 754* (EH 754)

Scientific name	Common Name	Taxonomic Group	State Status
Charadrius melodus	Piping Plover	Bird	Threatened
Aristida tuberculosa	Seabeach Needlegrass	Plant	Threatened

Priority Habitat 842 (PH 842) and *Estimated Habitat 682* (EH 682)

Scientific name	Common Name	Taxonomic Group	State Status
Charadrius melodus	Piping Plover	Bird	Threatened
Sternula antillarum	Least Tern	Bird	Special Concern

The species listed above are protected under the Massachusetts Endangered Species Act (MESA) (M.G.L. c. 131A) and its implementing regulations (321 CMR 10.00). State-listed wildlife are also protected under the state's Wetlands Protection Act (WPA) (M.G.L. c. 131, s. 40) and its implementing regulations (310 CMR 10.00). Fact sheets for most state-listed rare species can be found on our website (www.mass.gov/nhesp).

Please note that projects and activities located within Priority and/or Estimated Habitat **must** be reviewed by the Division for compliance with the state-listed rare species protection provisions of MESA (321 CMR 10.00) and/or the WPA (310 CMR 10.00).

Wetlands Protection Act (WPA)

If the project site is within Estimated Habitat and a Notice of Intent (NOI) is required, then a copy of the NOI must be submitted to the Division so that it is received at the same time as the local conservation commission. If the Division determines that the proposed project will adversely affect the actual

Resource Area habitat of state-protected wildlife, then the proposed project may not be permitted (310 CMR 10.37, 10.58(4)(b) & 10.59). In such a case, the project proponent may request a consultation with the Division to discuss potential project design modifications that would avoid adverse effects to rare wildlife habitat.

A streamlined joint MESA/WPA review process is available. When filing a Notice of Intent (NOI), the applicant may file concurrently under the MESA on the same NOI form and qualify for a 30-day streamlined joint review. For a copy of the NOI form, please visit the MA Department of Environmental Protection's website: https://www.mass.gov/how-to/wpa-form-3-wetlands-notice-of-intent.

MA Endangered Species Act (MESA)

If the proposed project is located within Priority Habitat and is not exempt from review (see 321 CMR 10.14), then project plans, a fee, and other required materials must be sent to Natural Heritage Regulatory Review to determine whether a probable Take under the MA Endangered Species Act would occur (321 CMR 10.18). Please note that all proposed and anticipated development must be disclosed, as MESA does not allow project segmentation (321 CMR 10.16). For a MESA filing checklist and additional information please see our website: https://www.mass.gov/regulatory-review.

We recommend that rare species habitat concerns be addressed during the project design phase prior to submission of a formal MESA filing, as avoidance and minimization of impacts to rare species and their habitats is likely to expedite endangered species regulatory review.

This evaluation is based on the most recent information available in the Natural Heritage database, which is constantly being expanded and updated through ongoing research and inventory. If the purpose of your inquiry is to generate a species list to fulfill the federal Endangered Species Act (16 U.S.C. 1531 et seq.) information requirements for a permit, proposal, or authorization of any kind from a federal agency, we recommend that you contact the National Marine Fisheries Service at (978)281-9328 and use the U.S. Fish and Wildlife Service's Information for Planning and Conservation website (https://ecos.fws.gov/ipac). If you have any questions regarding this letter please contact Emily Holt, Endangered Species Review Assistant, at (508) 389-6385.

Sincerely,

Everose Schlüter

Everose Schlüter, Ph.D.
Assistant Director

Marshfield Planning Department

Town Hall
870 Moraine Street
Marshfield, Massachusetts 02050-3498

Greg Guimond
Town Planner

Tel: 781-834-5554
Fax: 781-837-7163

September 10, 2020

Kathleen A. Theoharides
Secretary Executive Office of Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114

RE: Marshfield and Duxbury EENF – Beach Nourishment

Dear Secretary Theoharides,

The Towns of Marshfield and Duxbury have cooperated to study their coastline through the support of the Commonwealth awarding a grant from the CZM Coastal Resiliency Program to carefully study, evaluate and recommend best practices to support nourishment and other alternatives to strengthen our local response to reduce the impacts of storm damage along the ocean-facing shorelines in our communities.

Public outreach, and scientific study, have informed our lead consultant, the Woods Hole Group, in preparing this submittal, and guidance from the Coastal Zone Management Program and other agencies in preparing this document were carefully considered.

I fully support the proposed work in order to endeavor to reduce impacts, and the costs associated with them, to our local infrastructure, which has been built with the support of public funds these many years, and which will additionally provide improved safety for private property owners in the these sensitive regions of our towns.

Sincerely,

Greg Guimond

Greg Guimond

Cc: Marshfield Board of Selectmen, Marshfield Planning Board, Marshfield Conservation Commission Marshfield Board of Public Works

DUXBURY
BEACH
RESERVATION, INC.
P.O . Box 2593
Duxbury, MA 02331

September 9, 2020

Kathleen A. Theoharides
Secretary Executive Office of Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114

RE: Marshfield and Duxbury EENF – Beach Nourishment

Dear Secretary Theoharides,

The Towns of Marshfield and Duxbury have cooperated to study their coastline through the support of the Commonwealth awarding a grant from the CZM Coastal Resiliency Program to carefully study, evaluate and recommend best practices to support nourishment and other alternatives to strengthen our local response to reduce the impacts of storm damage along the ocean-facing shorelines in our communities.

The Duxbury Beach Reservation is responsible for the management and operation of Duxbury Beach, a 4.5 mile barrier beach which is an abutter to the EENF- beach nourishment study area. Duxbury Beach protects the Town of Duxbury, Kingston and parts of Plymouth from storm surges by maintaining the barrier beach. It is also the only land access to the Plymouth communities of Gurnet and Saquish.

The Reservation is committed to nature-based solutions for coastal resiliency projects and fully supports the Towns of Duxbury and Marshfield in their efforts to introduce sand into a sediment starved area due, in part, to hard infrastructure projects of the past. Duxbury Beach wholly endorses beach nourishment in the project area that will benefit the immediate properties westward of the project area as well as areas to the south along the sediment transport system.

Best regards,

Cris Luttazi
Executive Director

Cc: René Read, Valerie Massard, Peter Butkus

Section M

List of Property Owners

M. LIST OF PROPERTY OWNERS

OWNER LIST FOR MARSHFIELD PARCELS

SITE_ADDRESS	CITY	MAP_PAR_ID	OWNER	OWNER_ADDRESS	OWNER_CITY	OWNER_STATE	OWNER_ZIP
158 FOSTER AVENUE	MARSHFIELD	L09-23-01A	KNIGHT ROBERT L JR	112 RIVER RD	HANOVER	MA	2339
148 FOSTER AVENUE	MARSHFIELD	L09-23-02	MONIZ JOHN III	148 FOSTER AVENUE	MARSHFIELD	MA	2050
0 FOSTER AVENUE	MARSHFIELD	L09-23-03	TOWN OF MARSHFIELD CON COMM	870 MORAINE STREET	MARSHFIELD	MA	2050
325 STANDISH STREET	MARSHFIELD	J13-02-31	TOWN OF MARSHFIELD BEACH LOT	870 MORAINE STREET	MARSHFIELD	MA	2050
260 FOSTER AVENUE	MARSHFIELD	L10-23-05	SAVINI JOHN N JR & MARY K TRS	260 FOSTER AVENUE	MARSHFIELD	MA	02050-0000
254 FOSTER AVENUE	MARSHFIELD	L10-23-04	WALDRON WALTER J JR	10 MAGAZINE ST	ROXBURY	MA	2119
246 FOSTER AVENUE	MARSHFIELD	L10-23-03	HANLON TARA M TR	26 ABERDEEN ROAD	WELLESLEY	MA	2482
242 FOSTER AVENUE	MARSHFIELD	L10-23-02A	KETTENDORF NOMINEE TRUST	5636 INVERCHAPEL ROAD	SPRINGFIELD	VA	22151-0000
0 FOSTER AVENUE	MARSHFIELD	L10-23-06	BRENNAN LUKE F III &	3719 GROVE AVE	PALO ALTO	CA	94303-0000
0 FOSTER AVENUE	MARSHFIELD	L10-23-01	NIELSEN KAROLE TR	5636 INVERCHAPEL ROAD	SPRINGFIELD	VA	22151
226 FOSTER AVENUE	MARSHFIELD	L10-24-09	CODY MICHAEL T TRUSTEE	276 ASHMONT STREET	DORCHESTER	MA	2124
222 FOSTER AVENUE	MARSHFIELD	L10-24-08	MARTEL ARTHUR & MOLLISON ELIZ	PO BOX 424	WORTHINGTON	MA	01098-0424
218 FOSTER AVENUE	MARSHFIELD	L10-24-07	STANTON MATTHEW MEACOM &	218 FOSTER AVE	MARSHFIELD	MA	2050
216 FOSTER AVENUE	MARSHFIELD	L10-24-06	ROTH JOHN E ET AL	72 SUMMIT STREET	HYDE PARK	MA	2136
212 FOSTER AVENUE	MARSHFIELD	L10-24-05	RYAN MARY ANDREA ETAL	92 NORTH ROAD	NORTH ADAMS	MA	1247
208 FOSTER AVENUE	MARSHFIELD	L10-24-04	ZABLOCKI JOHN M & MARIA C	9 CREST AVENUE	MELROSE	MA	2176
206 FOSTER AVENUE	MARSHFIELD	L10-24-03	GRIFFIN MARY G	P O BOX 2235	OCEAN BLUFF	MA	2065
204 FOSTER AVENUE	MARSHFIELD	L10-24-02	DION PETER M & ANN S	11 PLEASANT ST	W NEWTON	MA	02465-0000
200 FOSTER AVENUE	MARSHFIELD	L10-24-01	BERRY CECILE H	29 FULLERS LANE	MILTON	MA	2186
194 FOSTER AVENUE	MARSHFIELD	L10-25-08	DONOVAN SEAN M	15 BAZIN LANE	CANTON	MA	2021
190 FOSTER AVENUE	MARSHFIELD	L10-25-07	ETHIER RAYMOND L & DEBORAH	211 CHURCH ST	NEWTON	MA	2458
166 FOSTER AVENUE	MARSHFIELD	L10-25-01	GILLIS THOMAS M & KERRI K	69 PINEWOOD ROAD	NEEDHAM	MA	2492
174 FOSTER AVENUE	MARSHFIELD	L10-25-02	MILLER LOUISE DANIELS	PO BOX 2222	OCEAN BLUFF	MA	02065-2222
176 FOSTER AVENUE	MARSHFIELD	L10-25-03	LILLIS JACQUELINE A	176 FOSTER AVENUE	MARSHFIELD	MA	02050-0000
178 FOSTER AVENUE	MARSHFIELD	L10-25-04	POWELL FRANK T & JANITA V	11 MEADOWLARK FARM LANE	MIDDLETON	MA	1949
184 FOSTER AVENUE	MARSHFIELD	L10-25-05	DRISCOLL JOHN E JR & MAJORIE	P O BOX 590	BRANT ROCK	MA	02020-0590
186 FOSTER AVENUE	MARSHFIELD	L10-25-06	OREILLY ELIZABETH	186 FOSTER AVE	MARSHFIELD	MA	02050-0000
20 REXHAME ROAD	MARSHFIELD	K11-26-02	TOWN 0F MARSHFIELD	870 MORAINE STREET	MARSHFIELD	MA	02050-0000
0 CIRCUIT AVENUE EAST	MARSHFIELD	K11-28-01	TOWN 0F MARSHFIELD	870 MORAINE STREET	MARSHFIELD	MA	02050-0000
0 CIRCUIT AVENUE	MARSHFIELD	K11-33-01	TOWN 0F MARSHFIELD	870 MORAINE STREET	MARSHFIELD	MA	02050-0000
0 CIRCUIT AVENUE EAST	MARSHFIELD	K11-33-02	TOWN 0F MARSHFIELD	870 MORAINE STREET	MARSHFIELD	MA	02050-0000
0 CIRCUIT AVENUE EAST	MARSHFIELD	K11-34-01	TOWN 0F MARSHFIELD	870 MORAINE STREET	MARSHFIELD	MA	02050-0000
0 CIRCUIT AVENUE EAST	MARSHFIELD	K11-35-01	TOWN 0F MARSHFIELD	870 MORAINE STREET	MARSHFIELD	MA	02050-0000
11 REXHAME ROAD	MARSHFIELD	L11-01-04	DONOVAN LEO J JR & NANCY M TRS	10914 BLUE ROAN ROAD	OAKTON	VA	22124
11 A REXHAME ROAD	MARSHFIELD	L11-01-03	DIBENEDETTO DAVID C TRUSTEE	71 PENNI LANE	NORTH ANDOVER	MA	1845
12 CONSTITUTION RD	MARSHFIELD	L11-01-02	DONAHUE CLARKE BARBARA A	55 ALBERT AVE	BELMONT	MA	2452
11 CONSTITUTION RD	MARSHFIELD	L11-02-05	PRIMO SANDRA M	P O BOX 898	MEDFORD	MA	02155-0000
0 CONSTELLATION RD	MARSHFIELD	L11-02-04	COLLEY SADIE A	P O BOX 898	MEDFORD	MA	2155
18 CONSTELLATION RD	MARSHFIELD	L11-02-02	STONE ROBERT J & KAREN A	18 CONSTELLATION ROAD	MARSHFIELD	MA	02050-0000

SITE_ADDRESS	CITY	MAP_PAR_ID	OWNER	OWNER_ADDRESS	OWNER_CITY	OWNER_STATE	OWNER_ZIP
11 CONSTELLATION RD	MARSHFIELD	L11-03-07	MACLELLAN ALLISON	10 FORBUSH AVENUE	QUINCY	MA	2169
16 MONITOR ROAD REAR	MARSHFIELD	L11-03-06	MACLELLAN TIMOTHY D & JANET M	16 R MONITOR RD	MARSHFIELD	MA	2050
12 MONITOR ROAD	MARSHFIELD	L11-03-05	MAHER STEPHEN M &	12 MONITOR RD	MARSHFIELD	MA	2050
13 MONITOR ROAD	MARSHFIELD	L11-04-09	LEROY LINDA J TR M HALL	800 BOYLSTON STREET	BOSTON	MA	02199-3600
12 FARRAGUT ROAD	MARSHFIELD	L11-04-08	GIARGIARGI HUGO E TRUSTEE	10 MAINSTONE ROAD	WAYLAND	MA	1778
11 FARRAGUT ROAD	MARSHFIELD	L11-05-07	ODONOVAN CONOR F & CASSANDRA	11 FARRAGUT RD	MARSHFIELD	MA	2050
12 A HARTFORD ROAD	MARSHFIELD	L11-05-06	SULLIVAN JOAN E TRUSTEE	11 BOYLSTON TERRACE APT 1	MEDFORD	MA	02155-0000
12 HARTFORD ROAD	MARSHFIELD	L11-05-05A	GRIFFIN JOHN H & JANICE M	12 HARTFORD RD	MARSHFIELD	MA	2050
128 FOSTER AVENUE	MARSHFIELD	L09-24-01	MORAN M ARY B & ROBERT J TRS	86 MINOT STREET	DORCHESTER	MA	2122
122 FOSTER AVENUE	MARSHFIELD	L09-24-02	BISCEGLIA PAUL M	126 WINTER STREET	WESTWOOD	MA	2090
118 FOSTER AVENUE	MARSHFIELD	L09-24-03	COSTELLO EDWARD J & MARY N	BRAINTREE HILL OFFICE PK #205	BRAINTREE	MA	02184-0000
108 FOSTER AVENUE	MARSHFIELD	L09-24-04	FLANNERY MARY F	900 WEST ROXBURY PARKWAY	CHESTNUT HILL	MA	2467
104 FOSTER AVENUE	MARSHFIELD	L09-24-05	GIORDANI RICHARD TR	178 PLEASANT ST	HANOVER	MA	2339
100 FOSTER AVENUE	MARSHFIELD	L09-24-06	MCLAUGHLIN SEAN	10471 HONEY BEAR LN	ANCHORAGE	AK	99516
96 FOSTER AVENUE	MARSHFIELD	L09-24-07	MAHONEY NANCY M	PO BOX 2232	OCEAN BLUFF	MA	02065-2232
92 FOSTER AVENUE	MARSHFIELD	L09-24-08	SOUSA MICHAEL A	92 FOSTER AVENUE	MARSHFIELD	MA	02050-0000
11 HARTFORD ROAD	MARSHFIELD	L10-04-10	CARLUCCI KATHLEEN	6 KETTLE VIEW	PLYMOUTH	MA	2360
14A KEARSARGE ROAD	MARSHFIELD	L10-04-09	WAINWRIGHT ERIKA H & BRENT & MARK	6 PHEASANT HILL STREET	WESTWOOD	MA	02090-0000
14 KEARSARGE ROAD	MARSHFIELD	L10-04-08	SHEEHAN RICHARD E	P O BOX 669	MARSHFIELD	MA	02050-0000
13 KEARSARGE ROAD	MARSHFIELD	L10-05-10	MOWBRAY CAROLYN P	13 KEARSARGE ROAD	MARSHFIELD	MA	2050
14 OLYMPIA ROAD	MARSHFIELD	L10-05-09	AFK ENTERPRISES LLC	461 BOSTON STREET U D-6	TOPSFIELD	MA	1983
14 OREGON ROAD	MARSHFIELD	L10-06-10	LOTTI PINO B	PO BOX 457	BRANT ROCK	MA	2020
21 OLYMPIA ROAD	MARSHFIELD	L10-06-13A	PIZZIFERRI JOSEPH M TR	1001 MARINA DRIVE # 701E	QUINCY	MA	2171
11 OREGON ROAD	MARSHFIELD	L10-07-04	LOTTI PINO B	PO BOX 457	BRANT ROCK	MA	2020
16 MAYFLOWER WAY	MARSHFIELD	L10-07-03	PATRICIA E OBRIEN LIVING TRUST	PO BOX 2638	OCEAN BLUFF	MA	02065-0263
44 OLD BEACH ROAD	MARSHFIELD	L10-07-08	GRANNIS KEITH W & KRISTEN E	44 OLD BEACH ROAD	MARSHFIELD	MA	02050-0000
4 THIRTEENTH ROAD	MARSHFIELD	L10-21-04	BENDER DANIEL S & DANIELLE E	4 THIRTEENTH ROAD	MARSHFIELD	MA	02050-0000
16 JOYCE STREET	MARSHFIELD	L10-21-05A	DADDARIO JAMES F & SUSAN	46 MARVIN AVENUE	FRANKLIN	MA	2038
292 FOSTER AVENUE	MARSHFIELD	L10-22-07	ADAMS GLENDA R	292 FOSTER AVENUE	MARSHFIELD	MA	02050-0000
284 FOSTER AVENUE	MARSHFIELD	L10-22-06	MULLEN VIRGINIA M & HUGH E	10 BRUCE STREET	DORCHESTER	MA	2124
280 FOSTER AVENUE	MARSHFIELD	L10-22-05	DIGIACOMO JOAN M TR	280 FOSTER AVENUE	MARSHFIELD	MA	2050
278 FOSTER AVENUE	MARSHFIELD	L10-22-04	BIRK TONI JO & PESCOSOLIDO P, PESCOSOLIDO PAUL TRS	112 POTUNK LANE	WESTHAMPTON BEACH	NY	11978 -221
274 FOSTER AVENUE	MARSHFIELD	L10-22-03	FOSTER AVENUE LLC	P O BOX 2674	OCEAN BLUFF	MA	2065
272 FOSTER AVENUE	MARSHFIELD	L10-22-02	MAJENSKI DOROTHY	62 EAST STREET	DORCHESTER	MA	2122
268 FOSTER AVENUE	MARSHFIELD	L10-22-01	GRINDLE LEE J & RAFFA JOANNE	1604 OCEAN STREET	MARSHFIELD	MA	2050
104 BAY AVENUE	MARSHFIELD	M05-06-01	DORSEY MICHAEL J & AMY M	114 MILTON STREET	DORCHESTER	MA	2124
114 BAY AVENUE	MARSHFIELD	M05-06-02	COLLINS SCOTT T TRUSTEE	113 WENDELL AVENUE	QUINCY	MA	02170-0000
0 CIRCUIT AVENUE EAST	MARSHFIELD	K11-36-01	TOWN 0F MARSHFIELD	870 MORAINE STREET	MARSHFIELD	MA	02050-0000
0 RIDGE ROAD OFF	MARSHFIELD	J14-03-01	SEA RIVERS TRUST	210 PILGRIM ROAD	MARSHFIELD	MA	2050
14 BAY AVENUE	MARSHFIELD	M04-23-02A	LALLY GREGORY ADAM & KATHRYN E	151 RIVERSIDE DRIVE	NORWELL	MA	2061

SITE_ADDRESS	CITY	MAP_PAR_ID	OWNER	OWNER_ADDRESS	OWNER_CITY	OWNER_STATE	OWNER_ZIP
50 BAY AVENUE	MARSHFIELD	M04-21-02	SUNSHINE REALTY TRUST	P O BOX 257	ACCORD	MA	2018
56 BAY AVENUE	MARSHFIELD	M04-21-03	OCONNOR FRANK C III & CAROL A	407 PERSIMMON DRIVE	SCHENECTADY	NY	12303
60 BAY AVENUE	MARSHFIELD	M04-21-04	DONNELLY JAMES C & MARY C	PO BOX 72	GREEN HARBOR	MA	02041-0072
64 BAY AVENUE	MARSHFIELD	M04-21-05	GRADY JOHN K	43 SLOUGH ROAD	HARVARD	MA	2138
46 BAY AVENUE	MARSHFIELD	M04-21-01	MCCARTHY RONALD C & SUSAN P TR	528 NICHOLS STREET	NORWOOD	MA	2062
72 BAY AVENUE	MARSHFIELD	M04-20-08	HANLAN DEBORAH P	7 HARRIS AVE	MILLBURY	MA	1527
76 BAY AVENUE	MARSHFIELD	M04-20-02A	MAURO JAMES & DANA	870 CHAMBERLAIN COURT	MILL VALLEY	CA	94941
80 BAY AVENUE	MARSHFIELD	M04-20-03	MCCORMACK MARTIN	PO BOX 131	GREEN HARBOR	MA	02041-0131
84 BAY AVENUE	MARSHFIELD	M04-20-04	ST OURS FREDERICK H & SINATRA MARY ELLEN TRS	315 RIVER STREET	NORWELL	MA	2061
90 BAY AVENUE	MARSHFIELD	M04-20-05	GROSSMAN MICHAEL S & MEAGAN S	7927 HADDON HALL WAY	BALDWINSVILLE	NY	13027
94 BAY AVENUE	MARSHFIELD	M04-20-06	GILL ROBERT E & RITA S	PO BOX 515	GREEN HARBOR	MA	02041-0515
98 BAY AVENUE	MARSHFIELD	M04-20-07	DOHERTY GEORGE F JR & MARY F	184 SANDERSON AVE	DEDHAM	MA	2026
70 BAY AVENUE	MARSHFIELD	M04-20-01	FLAVIN JANE E	235 CHANNING RD	BELMONT	MA	2478
20 BAY AVENUE	MARSHFIELD	M04-22-01	DEININGER ROBERT J & ELINOR C TRUST	15539 MONTEROSSO LN #101	NAPLES	FL	34110
30 BAY AVENUE	MARSHFIELD	M04-22-03	KEFAUVER DAVID & JOANNE	30 BAY AVENUE	MARSHFIELD	MA	02050-0000
34 BAY AVENUE	MARSHFIELD	M04-22-04	PACKER DAMIAN T &	17 VALLEYWOOD ROAD	HOPKINTON	MA	01748-0000
40 BAY AVENUE	MARSHFIELD	M04-22-05	EDER KONRAD	P O BOX 501	GREEN HARBOR	MA	2041
24 BAY AVENUE	MARSHFIELD	M04-22-02	HACKETT JOSEPH P & ELLIE	24 BAY AVENUE	MARSHFIELD	MA	02050-0000

OWNER LIST FOR DUXBURY PARCELS

SITE_ADDRESS	CITY	MAP_PAR_ID	OWNER	OWNER_ADDRESS	OWNER_CITY	OWNER_STATE	OWNER_ZIP
15 OCEAN RD S	DUXBURY	821390093901250	PALMIERI JOHN R	11 KRESS FARM RD	HINGHAM	MA	02043
13 OCEAN RD S	DUXBURY	821400093901260	EN PROPERTIES LLC	28 SUNSET RD	DUXBURY	MA	02332
105 GURNET RD	DUXBURY	821370090100080	105 GURNET ROAD LLC	99 RUSSELL AVE	WATERTOWN	MA	02472
109 GURNET RD	DUXBURY	821370090100090	LEONARD JOHN P	PO BOX 1151	DUXBURY	MA	02331
123 GURNET RD	DUXBURY	821380090100120	PETRO LEAH M	123 GURNET RD	DUXBURY	MA	02332
137 GURNET RD	DUXBURY	821380060009010	PLANTE RANDALL & DOGGETT-PLANTE H	99 RUSSELL AVE	WATERTOWN	MA	02472
77 GURNET RD	DUXBURY	821370090100130	SHEEHAN MICHAEL	290 RIVERSIDE DR #2B	NEW YORK	NY	10025
81 GURNET RD	DUXBURY	821370090100010	KELLEY MARY JO ET AL TT	16 WOODBRIDGE RD	HINGHAM	MA	02043
5 CABLE HILL WAY	DUXBURY	821380091600050	CHIMINIELLO FRANCIS	PO BOX 535	GREEN HARBOR	MA	02041
71 OCEAN RD N	DUXBURY	821390093900910	MACKEY ALISON	151 W CANTON ST	BOSTON	MA	02118
41 OCEAN RD N	DUXBURY	821390093901140	SHIEBLER MARY B & THOMAS P TT	PO BOX 334	GREEN HARBOR	MA	02041
39 OCEAN RD N	DUXBURY	821390093901150	DEADY JEFFREY	5 SOUTHGATE LN	HINGHAM	MA	02043
37 OCEAN RD N	DUXBURY	821390093901170	MCLAUGHLIN BRENDAN T	23 RUSKIN ST	WEST ROXBURY	MA	02132
97 GURNET RD	DUXBURY	821370090100060	ARCHAMBAULT ROBERT & MICHELLE A TT	145 STANDISH ST	DUXBURY	MA	02332
101 GURNET RD	DUXBURY	821370090100070	COLEMAN MARY L TT	PO BOX 733	MARSHFIELD	MA	02050
12 BAY AVE	DUXBURY	821360090100750	CALLAHAN LAUREN B TT	12 BAY AVE	DUXBURY	MA	02332
7 BAY AVE	DUXBURY	821360090100730	TEDESCHI TIMOTHY N	7 BAY AVE	DUXBURY	MA	02332
21 BAY AVE	DUXBURY	821360090100710	RYAN JAMES P TT	21 BAY AVE	DUXBURY	MA	02332
25 BAY AVE	DUXBURY	821360090100690	FITZGIBBONS CHARLES & JAMES TT	26 AUTUMN LANE	MARSHFIELD	MA	02050
31 BAY AVE	DUXBURY	821360090100680	DOHERTY EDWARD J	159 MEETINGHOUSE CIR	NEEDHAM	MA	02192
45 BAY AVE	DUXBURY	821360090100640	BRENNICK DOROTHY E TT	52 BLUEBERRY LN	S HAMILTON	MA	01982
0 BAY AVE	DUXBURY	821370090100630	BENINATI ELIZABETH A	8 SNOWS HILL LANE	DOVER	MA	02030
0 BAY AVE	DUXBURY	821370090100620	MCGUINNESS KATHERINE M TT	41 PINE ST	NORWOOD	MA	02062
0 BAY AVE	DUXBURY	821370090100600	BURMAN SAMANTHA TROTMAN	70 WILSONDALE ST	DOVER	MA	02030
0 PLYMOUTH AVE	DUXBURY	821370090100190	MARTIN CANDACE B TT	59 GURNET RD	DUXBURY	MA	02332
0 PLYMOUTH AVE	DUXBURY	821370090101380	REARDON JOHN J TT	31 FALES AVE	NORWOOD	MA	02062
0 PLYMOUTH AVE	DUXBURY	821370090100140	JULIA DENNY SWEENEY QUAL P R TRUST	4465 S JONES BLVD	LAS VEGAS	NV	89103
71 GURNET RD	DUXBURY	821370090100360	KUZINEVICH JOHN J	71 GURNET RD	DUXBURY	MA	02332
83 GURNET RD	DUXBURY	821370090100020	MULHERN DANIEL M TT	83 GURNET ROAD	DUXBURY	MA	02332
87 GURNET RD	DUXBURY	821370090100030	DUNN ROBERT W & CATHERINE E	PO BOX 191	GREEN HARBOR	MA	02041
91 GURNET RD	DUXBURY	821370090100040	COLOMBO DAVID	37 FOX DEN RD	KINGSTON	MA	02364
93 GURNET RD	DUXBURY	821370090100050	MASTROMARINO JOHN L	52 FAIROAKS LN	COHASSET	MA	02025
0 GURNET RD	DUXBURY	821380090100110	MCSHANE KEVIN	103 ROCKLAND ST	CANTON	MA	02021
143 GURNET RD	DUXBURY	821380090100160	SHEEHAN DIANE M TT	60 N MAIN ST #7	NATICK	MA	01760
147 GURNET RD	DUXBURY	821380090100170	DONOVAN NANCY L	12 WARNER RD	ABINGTON	MA	02351
15 CABLE HILL WAY	DUXBURY	821380091600030	BENJES MARY E	PO BOX 272A	DUXBURY	MA	02331
151 GURNET RD	DUXBURY	821380090100180	NIKOPOULOS LAURIE A TT	151 GURNET RD	DUXBURY	MA	02332
0 GURNET RD	DUXBURY	821380090100230	NIKOPOULOS EVANGELOS P	151 GURNET RD	DUXBURY	MA	02332
11 CABLE HILL WAY	DUXBURY	821380091600040	NICHOLS JOHN A & SUSAN M TT	10 NICHOLS RD	NEEDHAM	MA	02492
69 OCEAN RD N	DUXBURY	821390093901010	LEONARD TARYN	49 MAGAZINE ST	CAMBRIDGE	MA	02139

65 OCEAN RD N	DUXBURY	821390093901030	GAYNOR PAUL	65 OCEAN RD N	DUXBURY	MA	02332
63 OCEAN RD N	DUXBURY	821390093901040	RIOLO MARIE C	573 N QUAKER LANE	HYDE PARK	NY	12538
SITE_ADDRESS	**CITY**	**MAP_PAR_ID**	**OWNER**	**OWNER_ADDRESS**	**OWNER_CITY**	**OWNER_STATE**	**OWNER_ZIP**
61 OCEAN RD N	DUXBURY	821390093901050	SPELLMAN TIMOTHY J	61 OCEAN RD N	DUXBURY	MA	02332
59 OCEAN RD N	DUXBURY	821390093901060	DUFFY JAMES J III	10 HUTCHINSON LN	QUINCY	MA	02171
57 OCEAN RD N	DUXBURY	821390093901070	SMITH KERRY ANN, REED SANDRA A &	59 PERSEVERANCE PATH	PLYMOUTH	MA	02360
55 OCEAN RD N	DUXBURY	821390093901080	BUCKLEY CHARLES F III TT	55 OCEAN RD N	DUXBURY	MA	02332
53 OCEAN RD N	DUXBURY	821390093901090	NORRIS DONALD R TT	53 OCEAN RD N	DUXBURY	MA	02332
51 OCEAN RD N	DUXBURY	821390093901100	POTTER DEBRA	45 UPLAND RD	NATICK	MA	01760
49 OCEAN RD N	DUXBURY	821390093901110	CARR BRENDAN M TT	23 VESTA RD	NATICK	MA	01760
45 OCEAN RD N	DUXBURY	821390093901120	ARENA EDWARD & MARTHA C	3 PARKVIEW ST	NATICK	MA	01760
43 OCEAN RD N	DUXBURY	821390093901130	KELLEY THOMAS E	PO BOX 2435	DUXBURY	MA	02331
35 OCEAN RD N	DUXBURY	821390093901180	SHIEBLER ROBERT C	81 BEDFORD ST	BURLINGTON	MA	01803
33 OCEAN RD N	DUXBURY	821390093901190	DODDS ROBERT F	33 OCEAN RD N	DUXBURY	MA	02332
31 OCEAN RD N	DUXBURY	821390093901200	FREER JAMES TT	PO BOX 355	BRYANTVILLE	MA	02327
4 LEWIS CT	DUXBURY	821390004200010	CLIFFORD MICHAEL L	8 MEREDITH DR	N EASTON	MA	02356
3 LEWIS CT	DUXBURY	821390004200020	MURPHY CHRISTINE	PO BOX 745	GREEN HARBOR	MA	02041
23 OCEAN RD S	DUXBURY	821390093901210	DALRYMPLE WILLIAM K	620 LINCOLN ST	DUXBURY	MA	02332
21 OCEAN RD S	DUXBURY	821390093901220	JERNEGAN JACQUELINE G TT	45 FOREST ST	BRAINTREE	MA	02184
19 OCEAN RD S	DUXBURY	821390093901230	JORDAN MICHAEL R & DEBORAH M	21084 CARTHAGENA COURT	ASHBURN	VA	20147
17 OCEAN RD S	DUXBURY	821390093901240	CRISAFULLI FRANCES TT	9 HARRISON ST	NATICK	MA	01760
11 OCEAN RD S	DUXBURY	821400093901270	VERITY JOHN P	29 BAYRIDGE LANE	DUXBURY	MA	02332
9 OCEAN RD S	DUXBURY	821400093901280	9 OCEANSOUTH LLC	9 ELDREDGE LANE	COHASSET	MA	02025
7 OCEAN RD S	DUXBURY	821400093901290	OHS BARRY W	1286 CURVE ST	CARLISLE	MA	01741
5 OCEAN RD S	DUXBURY	821410093901300	HALEY ARTHUR A JR	9 HEMLOCK LN	MILFORD	MA	01757
3 OCEAN RD S	DUXBURY	821410093901310	ANDERSON KATHLEEN G	157 MARKET ST	BROCKTON	MA	02301
1 OCEAN RD S	DUXBURY	821410093901320	1 OCEAN ROAD SOUTH LLC	10 HOWLANDS LANDING	DUXBURY	MA	02332

Section N

Public Notice and EENF Distribution List

PUBLIC NOTICE OF ENVIRONMENTAL REVIEW

PROJECT: Proposed Beach and Dune Nourishment Project

LOCATIONS: Rexhame Public Beach, Winslow Ave. Beach, Fieldston & Sunrise Beaches, and Bay Ave. & Gurnet Rd. Beaches

PROPONENT: Towns of Marshfield and Duxbury

The undersigned is submitting an Expanded Environmental Notification Form ("EENF") to the Secretary of Energy and Environmental Affairs on or before September 30, 2020.

This will initiate review of the above project pursuant to the Massachusetts Environmental Policy Act ("MEPA", M.G.L. c. 30, s.s. 61-62I). Copies of the EENF may be obtained from:

Towns of Marshfield & Duxbury, Proponents
c/o Woods Hole Group, Inc.
Attn: Beth Gurney
107 Waterhouse Road, Bourne, MA 02532
(508) 495-6240
email: bgurney@woodsholegroup.com

An electronic copy of the EENF is also being sent to the Marshfield and Duxbury Conservation Commissions and Planning Boards, where they may be inspected if the Town Halls are open to the public.

The Secretary of Energy and Environmental Affairs will publish notice of the EENF in the Environmental Monitor, will receive public comments on the project for twenty (20) days, and will then decide, within ten (10) days if an environmental Impact Report is needed. A site visit and consultation session on the project may also be scheduled. All persons wishing to comment on the project, or to be notified of a site visit or consultation session, should write to the Secretary of Energy and Environmental Affairs, 100 Cambridge Street, Suite 900, Boston, MA 02114, Attention: MEPA Office, referencing the above project.

By the Towns of Marshfield and Duxbury (Proponents)

Distribution List for Towns of Marshfield & Duxbury, Beach & Dune Nourishment Project,
Marshfield and Duxbury, MA
Supplement to Expanded ENF - Page 1

Dept. Of Environmental Protection
Commissioner's Office
One Winter Street
Boston, MA 02108
helena.boccadoro@mass.gov

Massachusetts Historic Commission
The MA Archives Building
220 Morrissey Boulevard
Boston, MA 02125

DEP/Southeast Regional Office
Attn: MEPA Coordinator
20 Riverside Drive
Lakeville, MA 02347
george.zoto@mass.gov
jonathan.hobill@mass.gov

MDOT – District #5
Attn: MEPA Coordinator
Box 111
1000 County Street
Taunton, MA 02780
barbara.lachance@dot.state.ma.us

Mass. Department of Transportation
Public/Private Development Unit
10 Park Plaza, Suite 4150
Boston, MA 02116
lionel.lucien@dot.state.ma.us

Metropolitan Area Planning Council
Attn: Martin Pillsbury
60 Temple Place/6th Floor
Boston, MA 02111
mpillsbury@mapc.org
bcowan@mapc.org

Coastal Zone Management
Attn: Project Review Coordinator
251 Causeway St., Suite 800
Boston, MA 02114
robert.boeri@mass.gov
patrice.bordonaro@mass.gov

Division of Marine Fisheries
Attn: Environmental Reviewer
836 South Rodney French Blvd.
New Bedford, MA 02744
DMF.EnvReview-South@mass.gov

Natural Heritage & Endangered Species Program
Division of Fisheries & Wildlife
Attn: Environmental Reviewer
1 Rabbit Hill Road
Westborough, MA 01581
melany.cheeseman@mass.gov
emily.holt@mass.gov

Town of Marshfield
Conservation Commission
870 Moraine Street
Marshfield, MA 02050
bgrafton@townofmarshfield.org

Town of Marshfield
Board of Health
870 Moraine Street
Marshfield, MA 02050
Grussell@townofmarshfield.org

Town of Marshfield
Planning Division
870 Moraine Street
Marshfield, MA 02050
Gguimond@townofmarshfield.org

Town of Marshfield
Board of Selectmen
870 Moraine Street
Marshfield, MA 02050
marshfield_selectmen@townofmarshfield.org

Town of Duxbury
Conservation Commission
878 Tremont Street
Duxbury, MA 02332
grady@town.duxbury.ma.us
ossoff@town.duxbury.ma.us

Distribution List for Towns of Marshfield & Duxbury, Beach & Dune Nourishment Project, Marshfield and Duxbury, MA

Supplement to Expanded ENF - Page 2

Town of Duxbury
Board of Health
878 Tremont Street
Duxbury, MA 02332
mayo@town.duxbury.ma.us

Town of Duxbury
Planning Division
878 Tremont Street
Duxbury, MA 02332
massard@town.duxbury.ma.us

Town of Duxbury
Board of Selectmen
878 Tremont Street
Duxbury, MA 02332
oconnor@Town.Duxbury.MA.US

Section O

Project Maps and Plan

WOODS HOLE GROUP
A CLS COMPANY

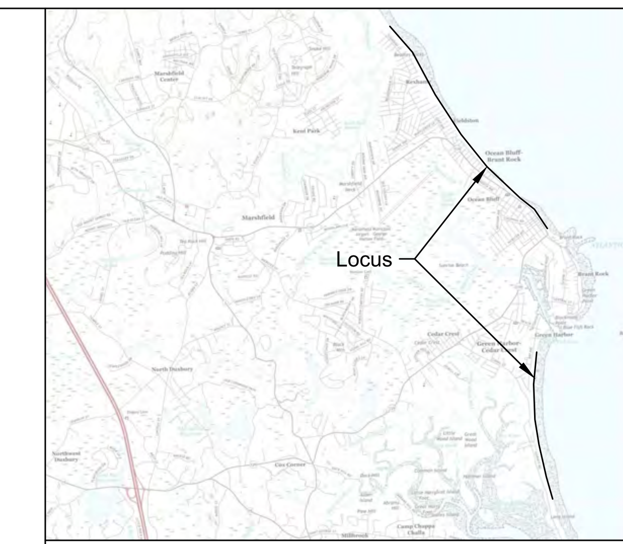
107 Waterhouse Road
Bourne, MA 02532

Towns of Marshfield and Duxbury
Beach Nourishment Sites
Marshfield and Duxbury, MA
USGS Duxbury Quadrangle
Map Scale 1:24,000

WOODS HOLE GROUP
A CLS COMPANY

107 Waterhouse Road
Bourne, MA 02532

Towns of Marshfield and Duxbury
Beach Nourishment Sites
Marshfield and Duxbury, MA
USGS Duxbury Quadrangle
Map Scale 1:24,000



Location Map Not to Scale

WOODS HOLE GROUP
A CLS COMPANY
107 WATERHOUSE ROAD, BOURNE, MA 02532
TELEPHONE: (508) 540-8080 FAX: (508) 540-1001

Graphic Scale

1000 500 0 1000 3000

1" = 1000'

Date	Revisions
	1.
	2.
	3.
	4.
	5.
	6.
	7.

Surveyed By:
Woods Hole Group
(Transects 1-7 & 18-23)
Town of Marshfield
(Transects 8-17)

Title:
Overall Plan
of Beach and Dune Nourishment Sites
Prepared for: Towns of Marshfield and Duxbury, MA

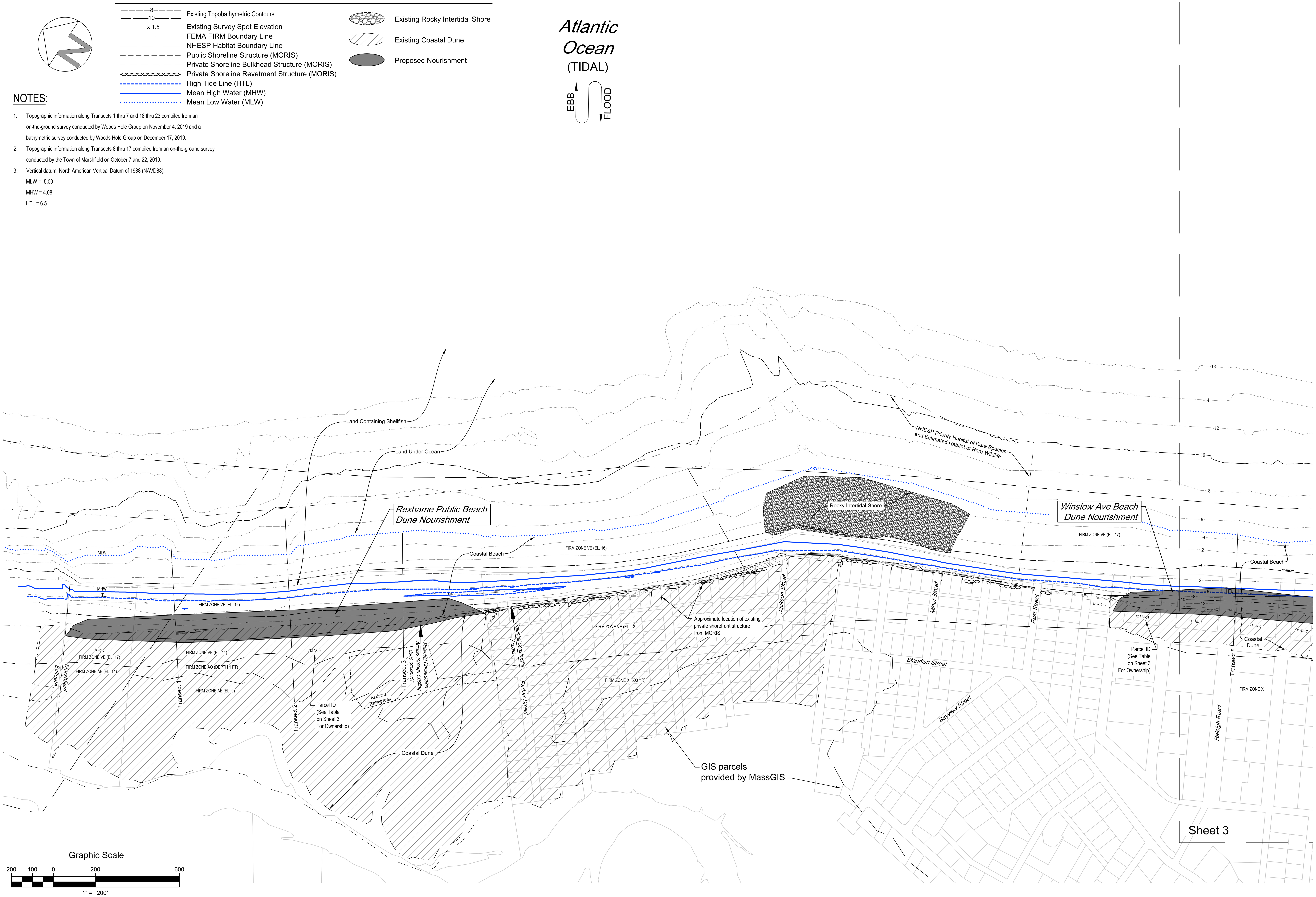
Project Number: 2018-0231
Dwg File:
Scale: 1" = 1,000'
Date: Sept. 23, 2020
Approved:
Drawn: JRK

LEGEND

8 / 10	Existing Topobathymetric Contours
x 1.5	Existing Survey Spot Elevation
	FEMA FIRM Boundary Line
	NHESP Habitat Boundary Line
	Public Shoreline Structure (MORIS)
	Private Shoreline Bulkhead Structure (MORIS)
	Private Shoreline Revetment Structure (MORIS)
	High Tide Line (HTL)
	Mean High Water (MHW)
	Mean Low Water (MLW)
	Existing Rocky Intertidal Shore
	Existing Coastal Dune
	Proposed Nourishment

NOTES:

1. Topographic information along Transects 1 thru 7 and 18 thru 23 compiled from an on-the-ground survey conducted by Woods Hole Group on November 4, 2019 and a bathymetric survey conducted by Woods Hole Group on December 17, 2019.
2. Topographic information along Transects 8 thru 17 compiled from an on-the-ground survey conducted by the Town of Marshfield on October 7 and 22, 2019.
3. Vertical datum: North American Vertical Datum of 1988 (NAVD88).
   MLW = -5.00
   MHW = 4.08
   HTL = 6.5



WOODS HOLE GROUP
A CLS COMPANY
107 WATERHOUSE ROAD, BOURNE, MA 02532
TELEPHONE: (508) 540-8080 FAX: (508) 540-1001

Revisions	Date
1.	
2.	
3.	
4.	
5.	
6.	
7.	

Surveyed By:
Woods Hole Group (Transects 1-7 & 18-23)
Town of Marshfield (Transects 8-17)

Title:
Plan of Beach and Dune Nourishment Sites
Prepared for: Towns of Marshfield and Duxbury, MA

Project Number: 2018-0231
Dwg File:
Scale: 1" = 200'
Date: Sept. 23, 2020
Approved:
Drawn: JRK

2018-0231_WHG_TRANSECTS & CZM BEACH PROFILES.DWG / 9/3/2020

Parcel ID	N/F Owner
Rexhame Public Beach Parcels	
J14-03-01	Sea Rivers Trust
J13-02-31	Town of Marshfield
Winslow Ave. Beach Parcels	
K11-36-01	Town of Marshfield
K11-35-01	Town of Marshfield
K11-34-01	Town of Marshfield
K11-33-02	Town of Marshfield
K11-33-01	Town of Marshfield
K11-28-01	Town of Marshfield
Fieldston & Sunrise Beaches	
L11-01-04	DONOVAN LEO J JR & NANCY M TRS
L11-01-03	DIBENEDETTO DAVID C TRUSTEE
L11-01-02	DONAHUE CLARKE BARBARA A
L11-02-05	PRIMO SANDRA M
L11-02-04	COLLEY SADIE A
L11-02-02	STONE ROBERT J & KAREN A
L11-03-07	MACLELLAN ALLISON
L11-03-06	MACLELLAN TIMOTHY D & JANET M
L11-03-05	MAHER STEPHEN M &
L11-04-09	LEROY LINDA J TR M HALL
L11-04-08	GIARGIARGI HUGO E TRUSTEE
L11-05-07	ODONOVAN CONOR F & CASSANDRA
L11-05-06	SULLIVAN JOAN E TRUSTEE
L11-05-05A	GRIFFIN JOHN H & JANICE M
L10-04-10	CARLUCCI KATHLEEN
L10-04-09	WAINWRIGHT ERIKA H & BRENT & MARK
L10-04-08	SHEEHAN RICHARD E
L10-05-10	MOWBRAY CAROLYN P

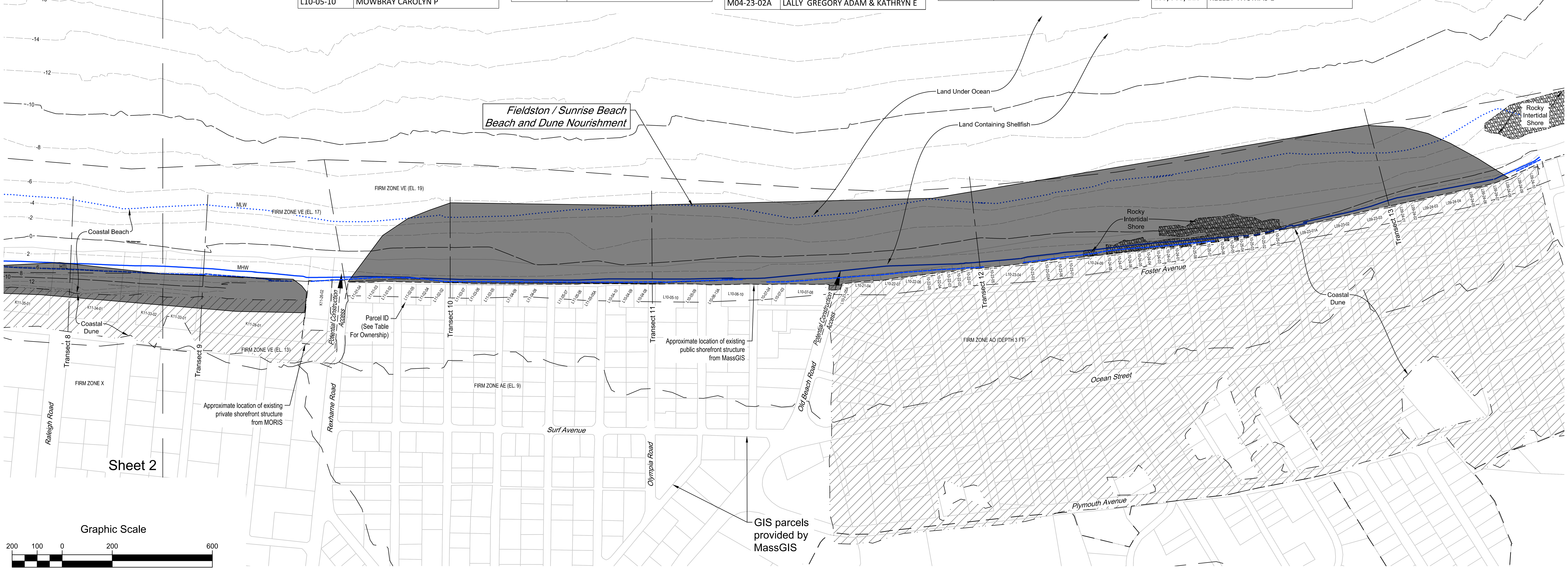
L10-05-09	AFK ENTERPRISES LLC
L10-06-13A	PIZZIFERRI JOSEPH M TR
L10-06-10	LOTTI PINO B
L10-07-04	LOTTI PINO B
L10-07-03	PATRICIA E OBRIEN LIVING TRUST
L10-07-08	GRANNIS KEITH W & KRISTEN E
L10-21-05A	DADDARIO JAMES F & SUSAN
L10-21-04	BENDER DANIEL S & DANIELLE E
L10-22-07	ADAMS GLENDA R
L10-22-06	MULLEN VIRGINIA M & HUGH E
L10-22-05	DIGIACOMO JOAN M TR
L10-22-04	BIRK TONI JO & PESCOSOLIDO P PESCOSOLIDO PAUL TRS
L10-22-03	FOSTER AVENUE LLC
L10-22-02	MAJENSKI DOROTHY
L10-22-01	GRINDLE LEE J & RAFFA JOANNE
L10-23-05	SAVINI JOHN N JR & MARY K TRS
L10-23-04	WALDRON WALTER J JR
L10-23-03	HANLON TARA M TR
L10-23-02A	KETTENDORF NOMINEE TRUST
L10-23-06	BRENNAN LUKE F III &
L10-23-01	NIELSEN KAROLE TR
L10-24-09	CODY MICHAEL T TRUSTEE
L10-24-08	MARTEL ARTHUR & MOLLISON ELIZ
L10-24-07	STANTON MATTHEW MEACOM &
L10-24-06	ROTH JOHN E ET AL
L10-24-05	RYAN MARY ANDREA ETAL
L10-24-04	ZABLOCKI JOHN M & MARIA C
L10-24-03	GRIFFIN MARY G
L10-24-02	DION PETER M & ANN S
L10-24-01	BERRY CECILE H
L10-25-08	DONOVAN SEAN M
L10-25-07	ETHIER RAYMOND L & DEBORAH
L10-25-06	OREILLY ELIZABETH
L10-25-05	DRISCOLL JOHN E JR & MAJORIE
L10-25-04	POWELL FRANK T & JANITA V
L10-25-03	LILLIS JACQUELINE A

L10-25-02	MILLER LOUISE DANIELS
L10-25-01	GILLIS THOMAS M & KERRI K
L09-23-01A	KNIGHT ROBERT L JR
L09-23-02	MONIZ JOHN III
L09-23-03	TOWN OF MARSHFIELD CON COMM
L09-24-01	MORAN M ARY B & ROBERT J TRS
L09-24-02	BISCEGLIA PAUL M
L09-24-03	COSTELLO EDWARD J & MARY N
L09-24-04	FLANNERY MARY F
L09-24-05	GIORDANI RICHARD TR
L09-24-06	MCLAUGHLIN SEAN
L09-24-07	MAHONEY NANCY M
L09-24-08	SOUSA MICHAEL A
Bay Ave & Gurnet Rd Beaches - Marshfield	
M05-06-03	DONNELLY JEFFREY J & DANA M
M05-06-02	COLLINS SCOTT T TRUSTEE
M05-06-01	DORSEY MICHAEL J & AMY M
M04-20-07	DOHERTY GEORGE F JR & MARY F
M04-20-06	GILL ROBERT E & RITA S
M04-20-05	GROSSMAN MICHAEL S & MEAGAN S
M04-20-04	ST OURS FREDERICK H & SINATRA MARY ELLEN TRS
M04-20-03	MCCORMACK MARTIN
M04-20-02A	MAURO JAMES & DANA
M04-20-08	HANLAN DEBORAH P
M04-20-01	FLAVIN JANE E
M04-21-05	GRADY JOHN K
M04-21-04	DONNELLY JAMES C & MARY C
M04-21-03	OCONNOR FRANK C III & CAROL A
M04-21-02	SUNSHINE REALTY TRUST
M04-21-01	MCCARTHY RONALD C & SUSAN P TR
M04-22-05	EDER KONRAD
M04-22-04	PACKER DAMIAN T &
M04-22-03	KEFAUVER DAVID & JOANNE
M04-22-02	HACKETT JOSEPH P & ELLIE
M04-22-01	DEININGER ROBERT J & ELINOR C TRUST
M04-23-02A	LALLY GREGORY ADAM & KATHRYN E

Bay Ave & Gurnet Rd Beaches - Duxbury	
136/901/075	CALLAHAN LAUREN B TT
136/901/073	TEDESCHI TIMOTHY N
136/901/071	RYAN JAMES P TT
136/901/069	FITZGIBBONS CHARLES & JAMES TT
136/901/068	DOHERTY EDWARD J
136/901/064	BRENNICK DOROTHY E TT
137/901/063	BENINATI ELIZABETH A
137/901/062	MCGUINNESS KATHERINE M TT
137/901/060	BURMAN SAMANTHA TROTMAN
137/901/019	MARTIN CANDACE B TT
137/901/138	REARDON JOHN J TT
137/901/014	JULIA DENNY SWEENEY QUAL P R TRUST
137/901/036	KUZINEVICH JOHN J
137/901/013	SHEEHAN MICHAEL
137/901/001	KELLEY MARY JO ET AL TT
137/901/002	MULHERN DANIEL M TT
137/901/003	DUNN ROBERT W & CATHERINE E
137/901/004	COLOMBO DAVID
137/901/005	MASTROMARINO JOHN L
137/901/006	ARCHAMBAULT ROBERT & MICHELLE A TT
137/901/007	COLEMAN MARY L TT
137/901/008	105 GURNET ROAD LLC

137/901/009	LEONARD JOHN P
138/901/011	MCSHANE KEVIN
138/901/012	PETRO LEAH M
138/600/901	PLANTE RANDALL & DOGGETT-PLANTE H
138/901/016	SHEEHAN DIANE M TT
138/901/017	DONOVAN NANCY L
138/901/018	NIKOPOULOS LAURIE A TT
138/916/003	BENJES MARY E
138/916/004	NICHOLS JOHN A & SUSAN M TT
138/916/005	CHIMINIELLO FRANCIS
139/939/091	MACKEY ALISON
139/939/101	LEONARD TARYN
139/939/103	GAYNOR PAUL
139/939/104	RIOLO MARIE C
139/939/105	SPELLMAN TIMOTHY J
139/939/106	DUFFY JAMES J III
139/939/107	SMITH KERRY ANN, REED SANDRA A &
139/939/108	BUCKLEY CHARLES F III TT
139/939/109	NORRIS DONALD R TT
139/939/110	POTTER DEBRA
139/939/111	CARR BRENDAN M TT
139/939/112	ARENA EDWARD & MARTHA C
139/939/113	KELLEY THOMAS E

139/939/114	SHIEBLER MARY B & THOMAS P TT
139/939/115	DEADY JEFFREY
139/939/117	MCLAUGHLIN BRENDAN T
139/939/118	SHIEBLER ROBERT C
139/939/119	DODDS ROBERT F
139/939/120	FREER JAMES TT
139/042/001	CLIFFORD MICHAEL L
139/042/002	MURPHY CHRISTINE
139/939/121	DALRYMPLE WILLIAM K
139/939/122	JERNEGAN JACQUELINE G TT
139/939/123	JORDAN MICHAEL R & DEBORAH M
139/939/124	CRISAFULLI FRANCES TT
139/939/125	PALMIERI JOHN R
140/939/126	EN PROPERTIES LLC
140/939/127	VERITY JOHN P
140/939/128	9 OCEANSOUTH LLC
140/939/129	OHS BARRY W
141/939/130	HALEY ARTHUR A JR
141/939/131	ANDERSON KATHLEEN G
141/939/132	1 OCEAN ROAD SOUTH LLC



2018-0231_WHG_TRANSECTS & CZM BEACH PROFILES.DWG / 9/3/2020

WOODS HOLE GROUP
A CLS COMPANY
107 WATERHOUSE ROAD, BOURNE, MA 02532
TELEPHONE: (508) 540-8080 FAX: (508) 540-1001

	Revisions	Date
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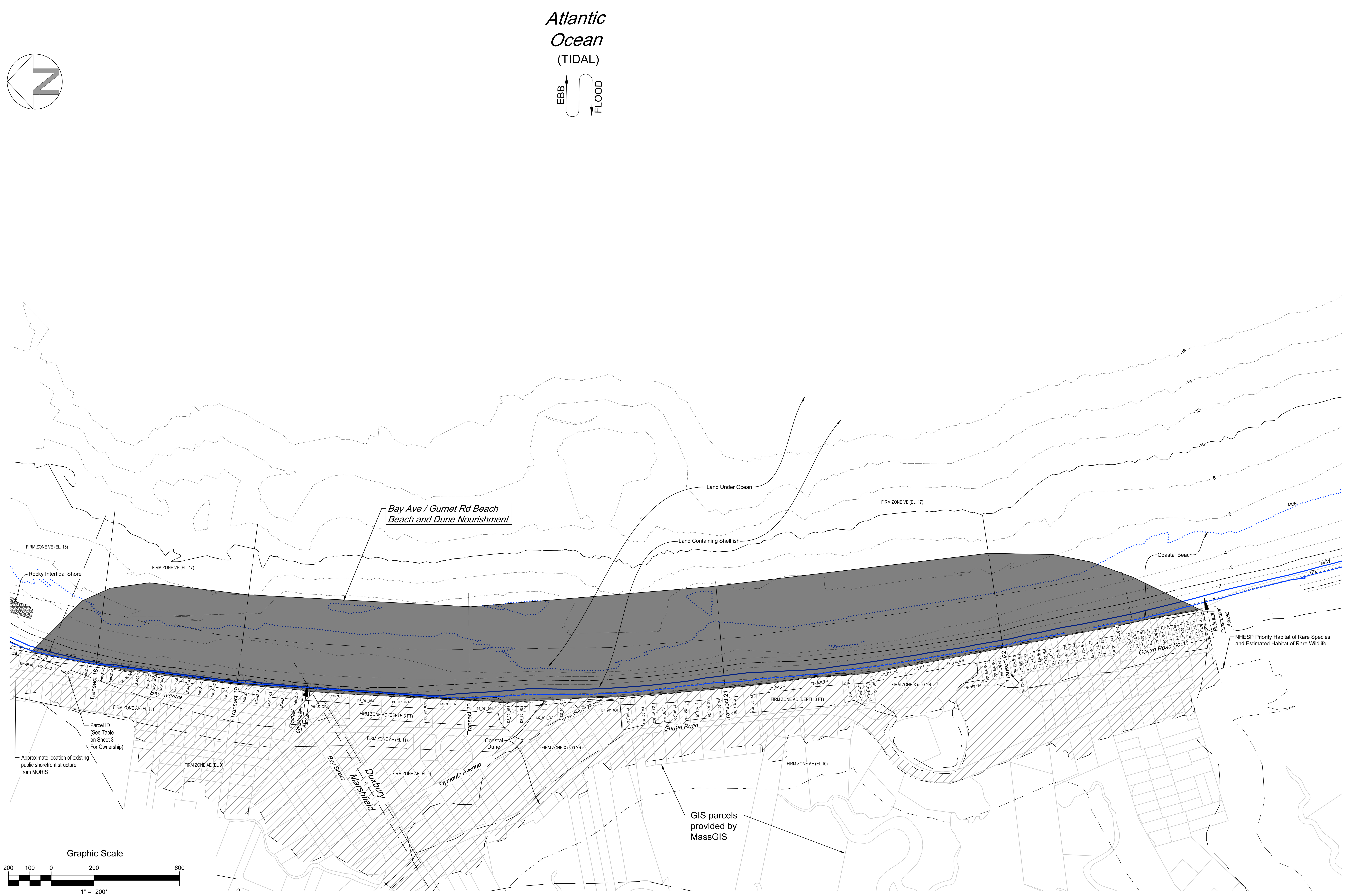
Surveyed By:
Woods Hole Group (Transects 1-7 & 18-23)
Town of Marshfield (Transects 8-17)

Title:
Plan
of Beach and Dune Nourishment Sites
Prepared for: Towns of Marshfield and Duxbury, MA

Project Number: 2018-0231
Dwg File:
Scale: 1" = 200'
Date: Sept. 23, 2020
Approved:
Drawn: JRK



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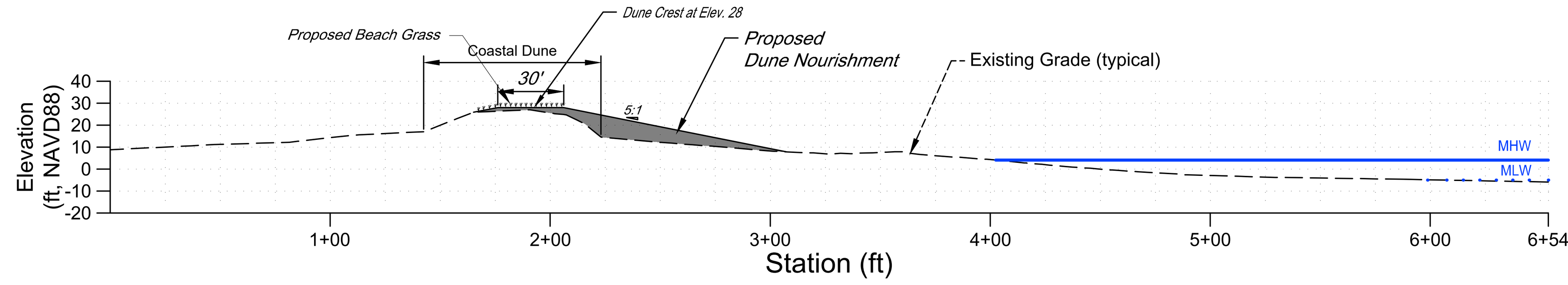

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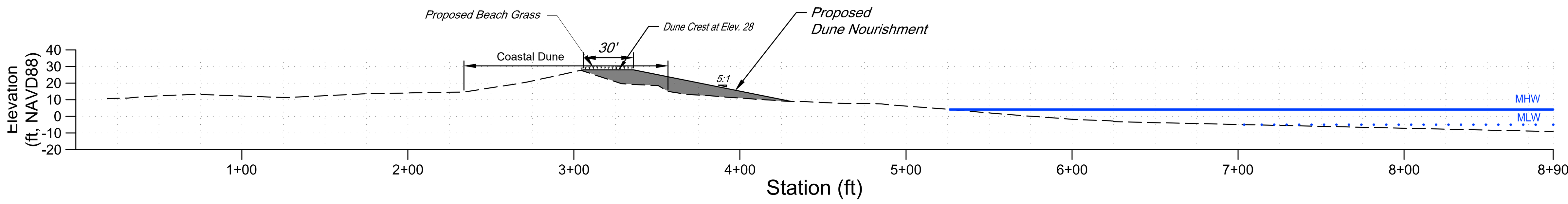

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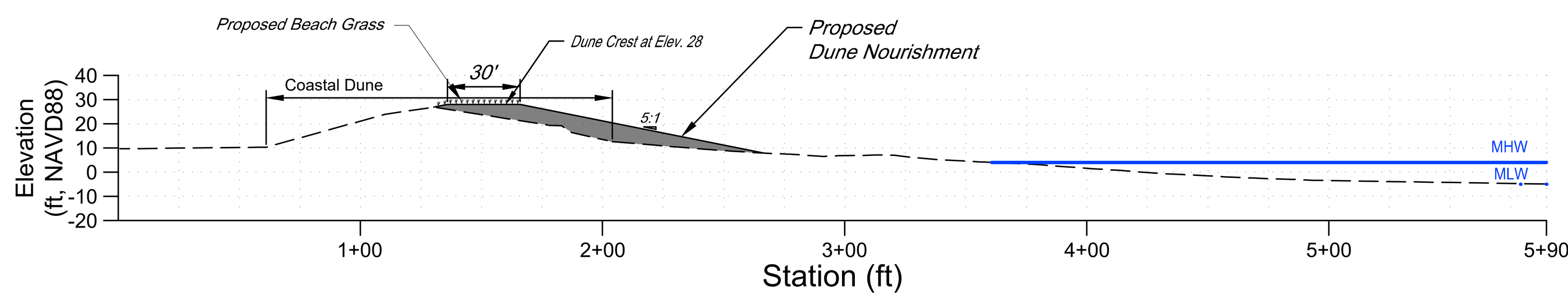

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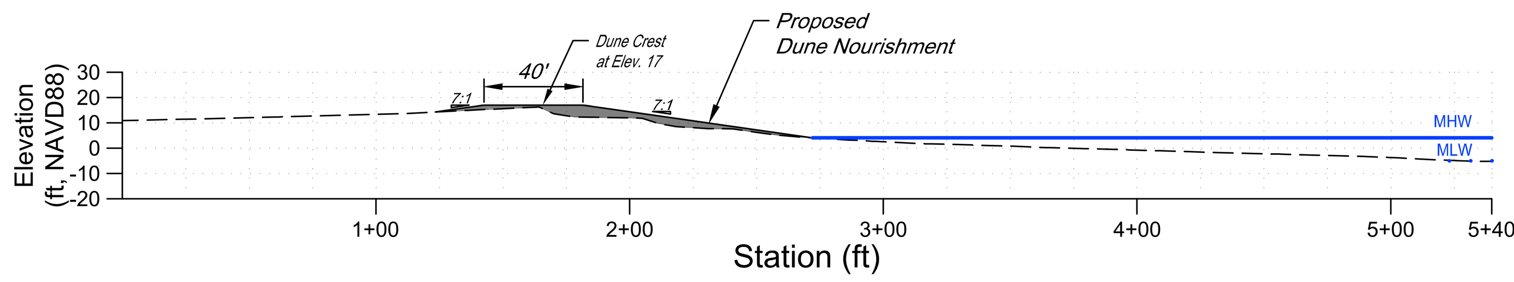

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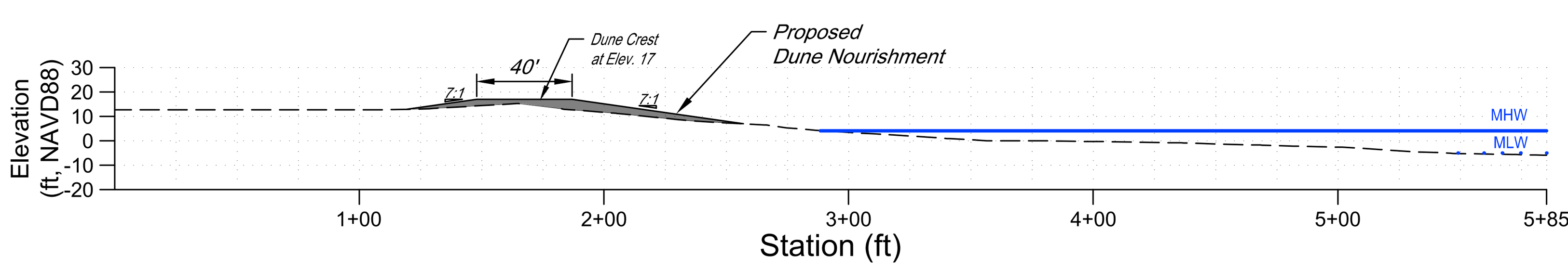

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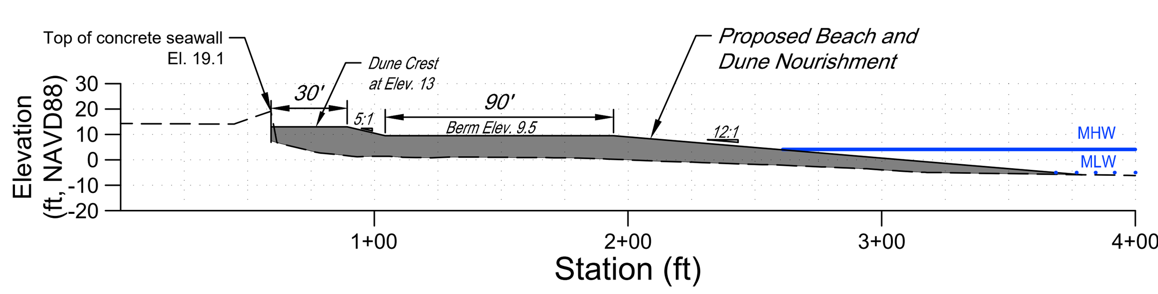

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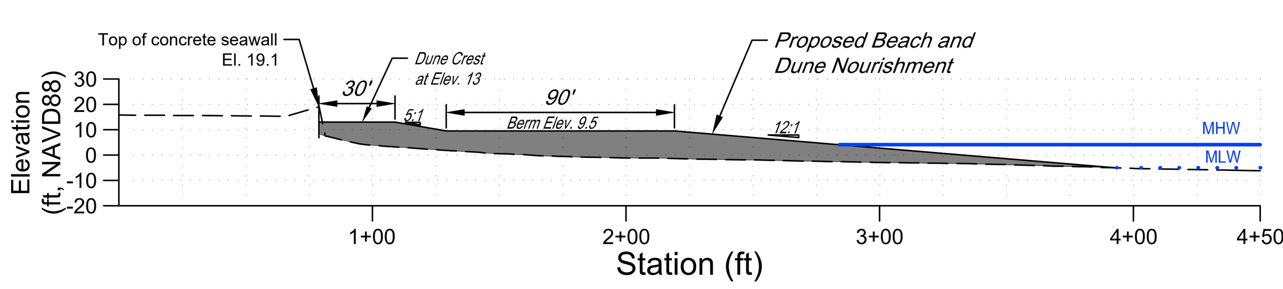

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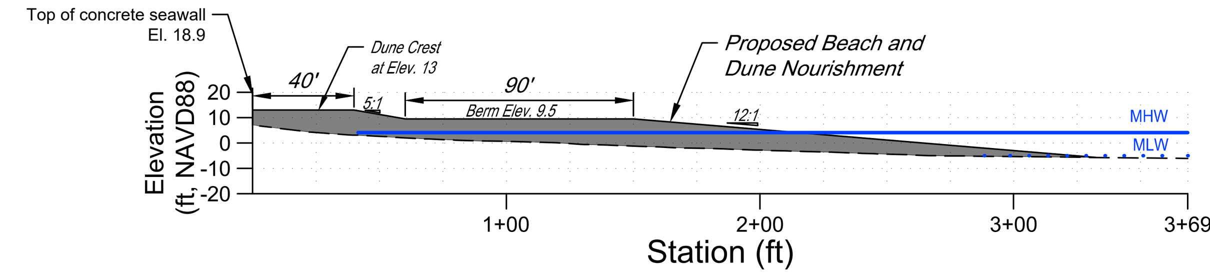

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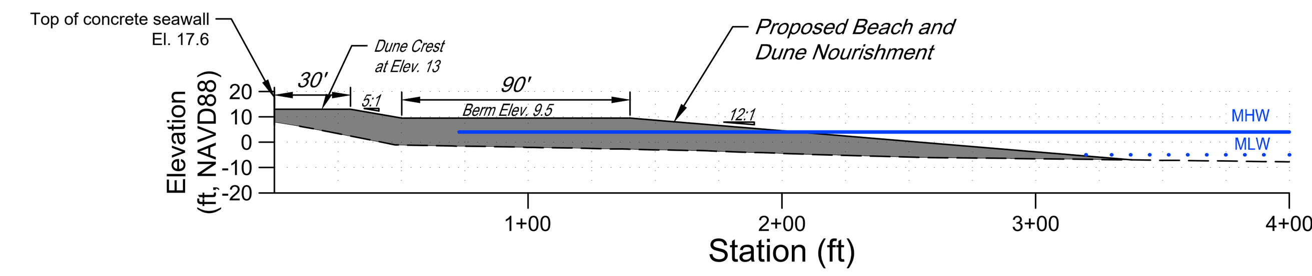

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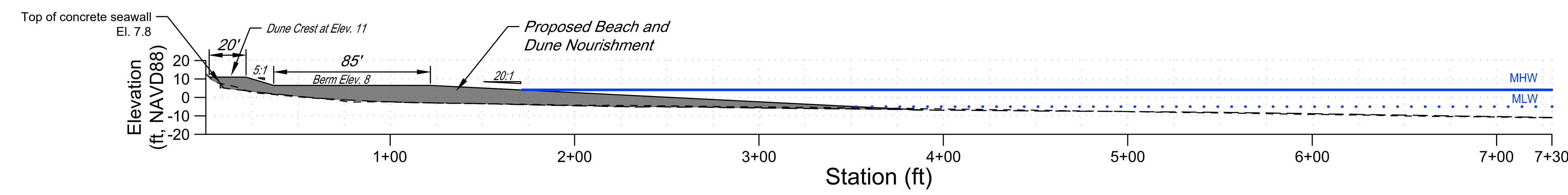

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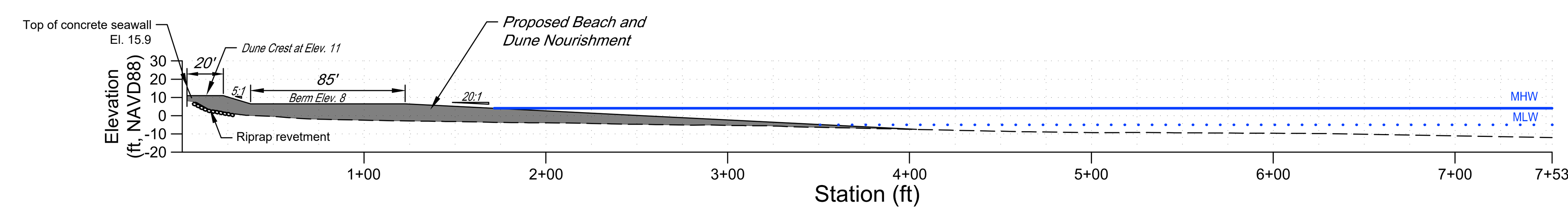

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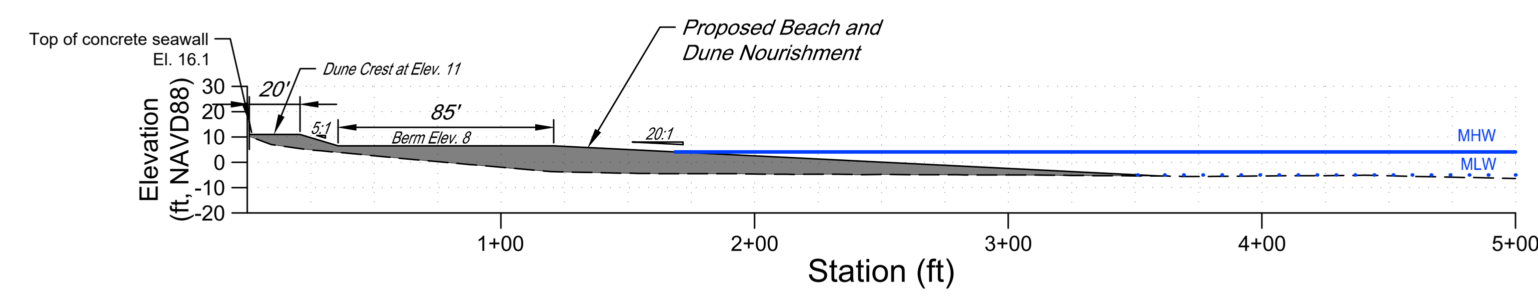

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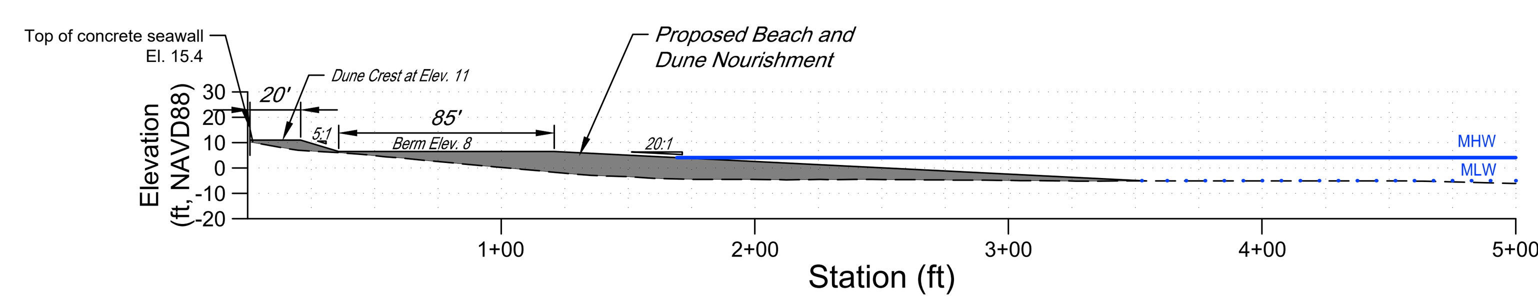

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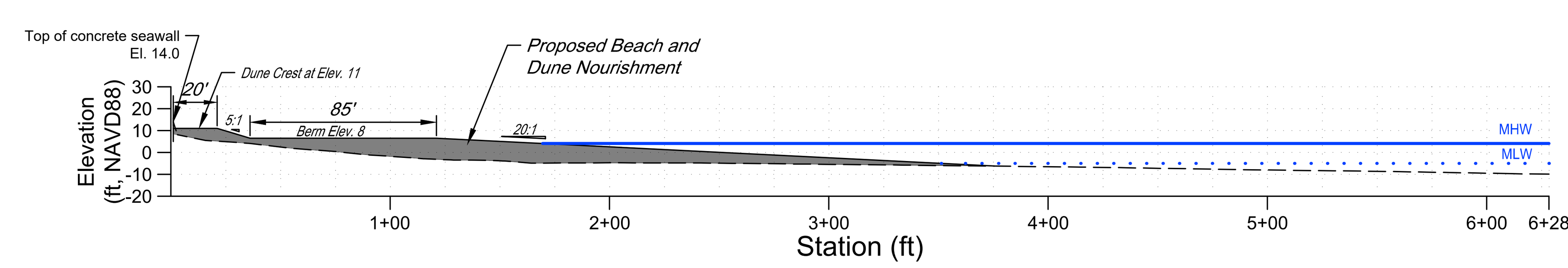
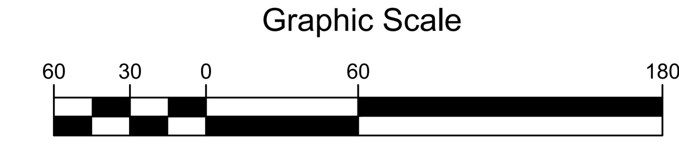


TRANSECT 22

Graphic Scale



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Surveyed By: Woods Hole Group (Transects 1-7 & 18-23); Town of Marshfield (Transects 8-17)

Title: Transect Profiles of Beach and Dune Nourishment Sites Prepared for: Towns of Marshfield and Duxbury, MA

Project Number: 2018-0231
Dwg File:
Scale: 1" = 60'
Date: Sept. 23, 2020
Approved:
Drawn: JRK

2018-0231_WHG_TRANSECTS & CZM BEACH PROFILES.DWG / 9/3/2020

Plan Notes:

References:
See Sheets 2, 3 and 4 for parcel references.

Flood Notes:
Flood Zone VE, Elevations 25, 19, 17, 16, 14, and 13 from FEMA FIRM Panels 25023C0143K, 25023C0231K, 25023C0232K, 25023C0234K, 25023C0242K dated 11/4/2016, LOMR 19-01-0097P eff. 1/10/2020, and LOMR 20-01-0284P eff. 7/6/2020.

Survey Notes:
1. Topographic information along Transects 1 thru 7 and 18 thru 23 compiled from an on-the-ground survey conducted by Woods Hole Group on November 4, 2019 and a bathymetric survey conducted by Woods Hole Group on December 17, 2019.
2. Topographic information along Transects 8 thru 17 compiled from an on-the-ground survey conducted by the Town of Marshfield on October 7 and 22, 2019.
3. Property boundaries shown hereon were obtained from a combination of MassGIS property line database information. Such property lines are approximate only and are not to be construed as property lines obtained from an accurate boundary survey, and are subject to such changes as an accurate boundary survey may disclose.

Datum Notes:
Vertical datum: North American Vertical Datum of 1988 (NAVD88).
MLW = -5.00
MTL = -0.50
MHW = 4.08
HTL = 6.5

Permit Plan:
This plan is for permitting purposes only. The plan describes the full scope of the project; however, the Contractor shall coordinate with the Engineer for detailing prior to providing a bid on this project.

General Notes:
1. Performance of the work shall be in compliance with the plans and details, and any permit requirements issued by the Towns of Marshfield and Duxbury, State of Massachusetts, USACE, or other regulatory agencies for the referenced project and described herein.
2. The purpose of this project is to increase coastal resilience using nature-based solutions on Rexhame Public Beach, Winslow Ave. Beach, Fieldston and Sunrise Beaches and Bay Ave, and Gurnet Rd. Beaches in Marshfield and Duxbury, MA, as shown on the plan and details. The proposed work includes dune and beach nourishment.
3. Prior to work on any beach the Contractor shall attend a pre-construction on-site meeting, which shall be attended by the Engineer and representatives from the appropriate Marshfield or Duxbury Conservation Commission. The Contractor shall present to the Engineer and the Conservation Commission representatives the proposed methods and means to construct the proposed project.
4. No construction vehicles shall be stored on the coastal beach or the vegetated coastal dunes overnight.
5. During periods of high-water levels, all equipment shall be moved to the construction access areas.
6. No excessive idling of construction vehicles shall occur.
7. Refueling shall occur only on hardscaped areas.
8. The Contractor shall not vary from the plans, specifications, Orders of Conditions, or instructions provided at the pre-construction meeting, without first obtaining approval of the Conservation Commission representatives and the Engineer.
9. The work at Rexhame Public Beach and Bay Ave/Gurnet Rd Beaches is located within the Priority Habitats of Rare Species and Estimated Habitats of Rare Wildlife in accordance with the Massachusetts Natural Heritage Atlas, 14th Edition.
10. All fill material required shall be compatible to the existing location receiving it.
11. Once completed, components of the project should be inspected on a regular basis.
12. Woods Hole Group cannot make warranties and encourages diligent inspection and potential maintenance of all project components.
13. The proposed designs are not expected to be a long-term solution and are susceptible to damage during coastal storms and potentially significant damage during coastal storm events.

Rexhame Public Beach - Dune Nourishment Notes:
1. The dune nourishment project presented herein is intended to provide enhanced storm damage protection and improve wildlife habitat and recreation areas.
2. The length of the Rexhame Public Beach dune nourishment is approximately 1,980 ft. and the proposed footprint is approximately 5.34 acres.
3. 47,240 cubic yards of dune compatible sand shall be placed above Mean High Water.
4. A limit of project activity shall be established and shall be maintained throughout until project completion. The limit of work shall serve as a visual and physical marker for construction activities.
5. It is anticipated that the source for the dune nourishment shall come from either material trucked in from upland sources or hydraulically dredged and pumped to the site.
6. If upland sources are used, the nourishment material should be clean, dune compatible sediment brought to the site by the Contractor. It is required that the Contractor have the sediment source tested by a qualified laboratory to ensure adequate dune compatibility prior to any placement of the nourishment material.
7. Construction access and staging shall be from Parker St or the Rexhame Public Beach parking lot in Marshfield. Upon completion of the project, all disturbed areas shall be re-graded and re-vegetated to match pre-construction conditions.
8. After placement, the dune nourishment material shall be graded to the proposed dune width, slope and elevation indicated on the plans.
9. The dune nourishment project specifies a dune crest elevation of 28 feet NAVD88 and a dune width of 30 feet.
10. All dune slopes shall be constructed to 5H:1V, as indicated on the plan.
11. Areas between the provided cross-sections should be tapered as shown in the plan view. All dune elevations, slopes, heights, etc. shall be smoothly tapered between the various cross sections.
12. Following final grading, planting landward of the dune crest shall be performed by hand. Planting shall take place in late winter and early spring (February through April). American beach grass shall be planted by hand; two to three beach grass culms shall be placed in each hole, approximately 7-9 inches deep and spaced 36 inches on center (OC) in shorebird nesting areas, 18 inches OC in other areas.
13. The dune system shall be inspected by the Engineer following the completion of the work.

Winslow Ave. Beach - Dune Nourishment Notes:
1. The dune nourishment project presented herein is intended to provide enhanced storm damage protection.
2. The length of the Winslow Ave. Beach dune nourishment is approximately 1,500 ft. and the proposed footprint is approximately 3.54 acres.
3. 17,850 cubic yards of dune compatible sand shall be placed above Mean High Water.
4. A limit of project activity shall be established and shall be maintained throughout until project completion. The limit of work shall serve as a visual and physical marker for construction activities.
5. It is anticipated that the source for the dune nourishment shall come from material trucked in from upland sources.
6. The nourishment material should be clean, dune compatible sediment brought to the site by the Contractor. It is required that the Contractor have the sediment source tested by a qualified laboratory to ensure adequate dune compatibility prior to any placement of the nourishment material.
7. Construction access and staging shall be from Rexhame Rd or Waterman Ave. Upon completion of the project, all disturbed areas shall be re-graded and re-vegetated to match pre-construction conditions.
8. After placement, the dune nourishment material shall be graded to the proposed dune width, slope and elevation indicated on the plans.
9. The dune nourishment project specifies a dune crest elevation of 17 feet NAVD88 and a dune width of 40 feet.
10. All dune slopes shall be constructed to 7H:1V, as indicated on the plan.
11. Areas between the provided cross-sections should be tapered as shown in the plan view. All dune elevations, slopes, heights, etc. shall be smoothly tapered between the various cross sections.
12. The dune system shall be inspected by the Engineer following the completion of the work.

Fieldston/Sunrise Beach - Beach and Dune Nourishment Notes:
1. The beach and dune nourishment project presented herein is intended to increase overall beach width, improve habitat areas, and provide enhancements for storm damage protection.
2. The length of the Fieldston/Sunrise Beach beach and dune nourishment component is approximately 4,650 ft and the proposed footprint is approximately 30.5 acres.
3. 389,770 cubic yards of beach and dune compatible sand shall be placed.
4. A limit of project activity shall be established and shall be maintained throughout until project completion. The limit of work shall serve as a visual and physical marker for construction activities.
5. It is anticipated that the source for the dune nourishment shall come from either material trucked in from upland sources or hydraulically dredged and pumped to the site.
6. If upland sources are used, the nourishment material should be clean, beach and dune-compatible sediment brought to the site by the Contractor. It is required that the Contractor have the sediment source tested by a qualified laboratory to ensure adequate beach compatibility prior to any placement of the nourishment material.
7. Construction access and staging shall be from Rexhame Rd or Old Beach Rd. Upon completion of the project, all disturbed areas shall be re-graded and re-vegetated to match pre-construction conditions.
8. After placement, the beach and dune nourishment material shall be graded to the proposed dune and berm widths, slopes and elevations indicated on the plans.
9. The beach and dune nourishment project specifies a dune crest elevation of 13 feet NAVD88, a dune crest width of 30 ft., a beach berm elevation of 9.5 feet, and a beach berm width of 90 feet, along 4,650 ft. of the beach.
10. The beach slopes shall be constructed to 12H:1V, as indicated on the plan.
11. The dune slopes shall be constructed to 5H:1V, as indicated on the plan.
12. Both the northern and southern ends of the coastal dune/beach shall taper into the existing dune/beach on a 10H:1V slope.
13. Areas between the provided cross-sections should be tapered as shown in the plan view. All dune and beach elevations, slopes, heights, etc. shall be smoothly tapered between the various cross sections.
14. The beach and dune systems shall be inspected by the Engineer following the completion of the work.

Bay Ave./Gurnet Road Beach - Beach and Dune Nourishment Notes:
1. The beach and dune nourishment project presented herein is intended to increase overall beach width, improve habitat areas, and provide enhancements for storm damage protection.
2. The length of the Bay Ave/Gurnet Road Beach beach and dune nourishment component is approximately 6,010 ft. and the proposed footprint is approximately 50.3 acres.
3. 313,160 cubic yards of beach and dune compatible sand shall be placed.
4. A limit of project activity shall be established and shall be maintained throughout until project completion. The limit of work shall serve as a visual and physical marker for construction activities.
5. It is anticipated that the source for the dune nourishment shall come from either material trucked in from upland sources or hydraulically dredged and pumped to the site.
6. If upland sources are used, the nourishment material should be clean, beach and dune-compatible sediment brought to the site by the Contractor. It is required that the Contractor have the sediment source tested by a qualified laboratory to ensure adequate beach compatibility prior to any placement of the nourishment material.
7. Construction access and staging shall be from the Bay Ave ramp in Marshfield or the south end of Ocean Rd South in Duxbury. Upon completion of the project, all disturbed areas shall be re-graded and re-vegetated to match pre-construction conditions.
8. After placement, the beach and dune nourishment material shall be graded to the proposed dune and berm widths, slopes and elevations indicated on the plans.
9. The beach and dune nourishment project specifies a dune crest elevation of 11 feet NAVD88, a dune width of 20 feet, a beach berm elevation of 8.0 feet NAVD88, and a beach berm width of 85 feet, along 6,010 ft. of the beach.
10. The beach slopes shall be constructed to 20H:1V, as indicated on the plan.
11. The dune slopes shall be constructed to 5H:1V, as indicated on the plan.
12. Both the northern and southern ends of the coastal dune/beach shall taper into the existing dune/beach on a 10H:1V slope.
13. Areas between the provided cross-sections should be tapered as shown in the plan view. All dune and beach elevations, slopes, heights, etc. shall be smoothly tapered between the various cross sections.
14. The beach and dune systems shall be inspected by the Engineer following the completion of the work.

Qualifier Note:
The proposed beach and dune nourishment presented herein follows stable slopes for unconsolidated sediment and maximizes the volume of sediment within the nourishment footprint. The owners understand the proposed designs are not expected to be a long-term solution and are susceptible to damage and loss during coastal storms.

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Surveyed By:

Title: Plan Notes
for Beach and Dune Nourishment
Prepared for: Towns of Marshfield and Duxbury, MA

Project Number: 2018-0231
Dwg File:
Scale: 1" = 60'
Date: Sept. 23, 2020
Approved:
Drawn: JRK

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