Summary Report of Coastal Engineering Analyses

DFIRM Update for Coastal Analysis for Cumberland County, ME

Task Order 8 - Coastal Hazard Analysis Deliverable

Prepared by

Flood Insurance Studies Throughout FEMA Region I

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Section 1
Project Summary

1.1 Introduction

The purpose of this report is to summarize the coastal hydrologic and hydraulic analyses for the Cumberland County, Maine, Digital Flood Insurance Rate Map (DFIRM) Study. The coastal analysis establishes the flood elevations for selected recurrence intervals in the coastal area, namely the cities of Portland, South Portland, and the towns of Brunswick, Cape Elizabeth, Chebeague Island, Cumberland, Falmouth, Freeport, Harpswell, Long Island, Scarborough, and Yarmouth. The coastal engineering analyses were performed using methodologies described in the "Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update" (FEMA 2007a) to Appendix D and "Guidance for Coastal Flooding Analyses and Mapping" (FEMA 2003), referenced hereafter as the FEMA Guidelines and Specifications. Supporting files can be found in the digital data included in the coastal data submittal compiled per guidance in Appendix M (FEMA 2011) of the FEMA Guidelines and Specifications.

The 10-year (10-percent), 50-year (2-percent), 100-year (1-percent), and 500-year (0.2-percent) annual-chance stillwater elevations were taken from the Technical Support Data Notebook (TSDN) report for Cumberland County (FEMA, EME-2003-CO-0340), as they were determined to be the most appropriate for use in this updated coastal analysis. Overland wave heights were calculated for restricted and unrestricted fetch settings using the Wave Height Analysis for Flood Insurance Studies (WHAFIS) software, Version 4.0 (Divoky 2007), within the Coastal Hazard Analysis for Mapping Program (CHAMP) Version 2.0 (FEMA 2007b), following the methodology described in the FEMA Guidelines and Specifications for each coastal transect. Input data for the CHAMP analyses were calculated in standardized calculation worksheets developed using Mathcad software (Parametric Technology Corporation 2007). A limit of moderate wave action (LiMWA) was determined for all areas subject to significant wave attack in accordance with "Procedure Memorandum No. 50 – Policy and Procedures for Identifying and Mapping Areas Subject to Wave Heights Greater than 1.5 feet as an Informational Layer on Flood Insurance Rate Maps (FIRMS)" (FEMA 2008). Wave runup was calculated using methods from the Shore Protection Manual (SPM), Technical Advisory Committee for Water Retaining Structures (TAW), and RUNUP 2.0 as described in the FEMA Guidelines and Specifications.

1.2 County Map of Coverage Area

Cumberland County is located in southwestern Maine. In Cumberland County, there are 25 towns and three cities. The towns of Casco, Harrison, Naples, and Raymond are located in northern Cumberland County. The towns of Bridgton, Frye Island, and Sebago are located in the northwestern portion of the county. The towns of Brunswick, Falmouth, and Freeport are located in the northeastern portion of the county. The towns of Cumberland and Scarborough are located in the southern portion of the county. The towns of Gorham and Standish are located in southwestern Cumberland

County. The towns of Cape Elizabeth and Long Island and the cities of Portland, South Portland, and Westbrook are in the southeastern portion of the county. The towns of Gray, Harpswell, New Gloucester, North Yarmouth, Pownal, and Yarmouth are located in eastern Cumberland County. The Town of Baldwin is in the western portion of the county. The Town of Windham is located in the central portion of Cumberland County. Chebeague Island is an island town located in Casco Bay, 10 miles from Portland.

Cumberland County is bordered on the north by Androscoggin County, Maine, on the northwest by Oxford County, on the northeast by Sagadahoc County, Maine, and on the southwest by York County, Maine.

Cumberland County has the deepest and second largest body of water in the state, Sebago Lake, which supplies tap water to most of the county.

According to census records (U.S. Census Bureau, State and County QuickFacts), the population of Cumberland County was 283,921 in 2012. The total area in Cumberland County consists of 1,217 square miles, including 836 square miles of land and 381 square miles of water area.

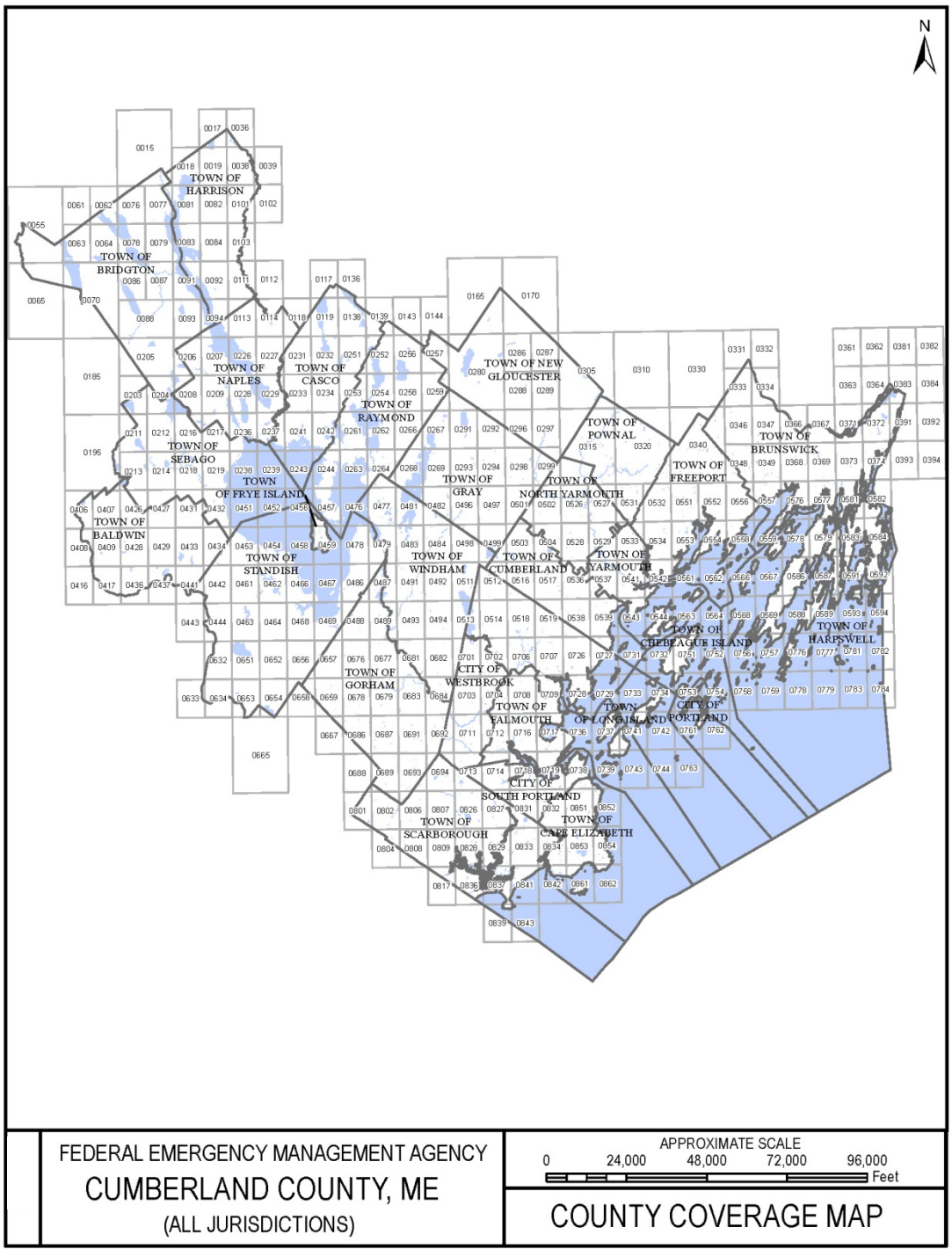

Figure 1 County Map of Coverage Area

Section 2
Engineering Analyses

The coastal flooding analysis consisted of data gathering and review of wave setup, wave height and propagation, erosion, and wave runup analysis and modeling.

There are a total of 161 transects along the coastline of Cumberland County. They are divided into three groups according to the type of study performed by the STARR team. The three groups are referred to in this report as "New Transect," "Updated Map Mod Transects," and "Submitted Transects." Below is a description of each group, and Table 2 shows the number of transect in each community and each transect group.

a) New Transects: This group contains the 30 transects in the towns of Brunswick, Falmouth, Freeport, Long Island, and Yarmouth. A completely new engineering analysis was performed on these transects under FEMA's new Risk Mapping Assessment and Planning (Risk MAP) program.

b) Updated Map Mod Transects: This group contains 876 transects in the City of Portland and the towns of Cape Elizabeth, Chebeague Island, Cumberland, Harpswell, and Scarborough. This study updated the transects that had undergone analysis with funding during FEMA's Map Modernization Program by updating input wave conditions from a newer wave model, which is explained in the Initial Wave Information section.

c) Submitted Transects: This group contains the 4455 transects in the cities of Portland and South Portland and the towns of Cape Elizabeth, Falmouth, and Harpswell. Sebago Technics, on behalf of each of these communities, provided coastal engineering analysis for this group in 2010. The STARR team utilized the 2010 study results for mapping. The titles of the five studies are "Peer Review of Federal Emergency Management Agency for the Town of Cape Elizabeth, Maine, 2010," "Review of FEMA Provisional Coastal Flood Maps for the Town of Falmouth, Maine, 2010," "Peer Review of Federal Emergency Management Agency (FEMA) Mapping – Harpswell, ME, 2010," "Delineation of the VE-Zone on the Northern Side of Portland Harbor, Maine, 2010," and "Delineation of the VE-Zone in South Portland, Maine, 2010."

Figure 2 shows the transect locations of Submitted, Updated Map Mod, and New coastal flooding analysis.

2.1 Data Acquisition

2.1.1 Wind Speed and Duration

An extremal analysis of historic wind gage records was performed to determine the thresholds for peak wind speeds using three Peaks Over Threshold (POT) statistical methods derived from Goda (Goda 2000). The threshold with the highest overall R-squared

correlation to the Fisher-Tippett Type I (Gumbel), Fisher-Tippett Type II (Frechet), or Wiebull distribution was chosen to represent the wind speed at 10 meters elevation. The wind speeds for 10-percent, 2-percent, 1-percent, and 0.2-percent-annual-chance events calculated from the extremal analysis for the National Data Buoy Center (NDBC) Buoy 44005 using the POT method were arithmetically averaged, and the resulting wind speed value was used for Cumberland County Steady-State Spectral Wave Model (STWAVE) modeling.

Wind speed data sets used in the extremal analyses were obtained from the National Oceanographic and Atmospheric Administration (NOAA) National Climatic Data Center. The wind data set consists of 1 hour interval data for the period 1979 to 2011 and can be found in the digital data deliverables of the coastal submittal.

2.1.2 Transect Survey Data

A transect survey was performed along the coastline of Cumberland County, at a total of 28 separate locations, in the towns of Brunswick, Falmouth, Freeport, Long Island, and Yarmouth. The survey was performed by Green International Affiliates in January 2012 and submitted in April 2012.

The coastal survey identified coastal structures, including structure type, structure toe and top locations, height, and material. The data were submitted in a shapefile format, which can be found in the spatial folder of the digital data deliverables of the coastal submittal.

2.1.3 Field Inspection Data

A coastal field inspection was conducted from November to December 2011 for the shoreline of the towns of Brunswick, Falmouth, Freeport, Long Island, and Yarmouth. Georeferenced global positioning system (GPS) points and tracks, as well as photographs, were collected and attributed with various descriptive information, such as upland type, coastal formations including dunes and bluffs, coastal vegetation, coastal structures, and shore type.

2.1.4 Coastline Data

The coastline was developed from the 0-foot Light Detection and Ranging (LiDAR) elevation contour developed as detailed in Section 2.2.1 for the coastal area of Cumberland County. The coastline was used as a guide in laying out transects and in determining the starting point of each transect. Coastline data can be found in the spatial folder of the digital data files compiled for the coastal submittal.

2.1.5 Coastal Structures

Coastal structures, such as seawalls and revetments, were identified by the transect survey and field inspection. Data gathered for coastal structures was then digitized using the orthophotography and LiDAR triangulated irregular network (TINs). The coastal structures geographic information system (GIS) shapefile can be found in the digital data files compiled for the coastal submittal.

2.2 Base Maps and Supplemental Materials

The following supplemental materials have been compiled for use during the coastal analysis.

- Topographic maps
- Bathymetric data
- Base maps
- Aerial photographs
- Map Mod engineering analysis files for the City of Portland and the towns of Cape Elizabeth, Cumberland, Harpswell, and Scarborough, including the CHAMP databases, Mathcad sheets, and Automated Coastal Engineering System (ACES) files.
- The submitted engineering analysis by Sebago Technics for the cities of South Portland and Portland and the towns of Cape Elizabeth, Falmouth, and Harpswell.

2.2.1 Topographic and Bathymetric Data

The topographic data for Cumberland County was collected by an aerial LiDAR flight in November 2006. The Sanborn Mapping Company (Sanborn) collected and processed the LiDAR data and delivered the product as a TIN and as ASCII formatted x, y, z masspoints in the North American Vertical Datum of 1988 (NAVD 88). A digital elevation model and 2-foot contours were created from the terrain deliverable. The deliverable consisted of the LiDAR data, a Digital Elevation Model (DEM), and other supporting documentation. Two-foot contours were created from the supplied DEM.

The LiDAR data do not cover areas below 0.0 NAVD 88; therefore, bathymetry data were downloaded from the NOAA website http://egisws01.nos.noaa.gov/servlet/BuildPage?template=bathy.txt&parm1=M040 and are included in the digital data files compiled for the coastal submittal.

2.2.2 Base Maps and Orthophotography

Base map data were originally produced by Dewberry and Davis for the FEMA Map Modernization Project and provided for use by FEMA. Political and transportation features were updated based on the most current available data provided by the Maine Office of GIS (MEGIS).

MEGIS high resolution orthophotography was used for the coastal analysis. The orthophotographs were produced from 3-inch, 6-inch, and 2-foot pixel cells from photography captured during spring 2012. The North American Datum of 1983 (NAD 83) was used as the horizontal datum and Universal Transverse Mercator as the coordinate system.

2.3 Hydrology

2.3.1 Stillwater Elevation

The stillwater elevation (SWEL) is the elevation of the water due to effects of astronomic tides and storm surge on the water surface. Several previous studies were reviewed to determine the most appropriate SWEL values to use in the Cumberland County coastal analysis, including:

- "Tidal Flood Profiles, New England Coastline" (U.S. Army Corps of Engineers [USACE] 1988)
- "Updating Tidal Profiles for the New England Coastline" (Map Mod 2008)
- "Updated Tidal Profiles for the New England Coastline" (STARR 2012)
- Cumberland County, Maine "Technical Support Data Notebook for Coastal Engineering Analysis for Flood Insurance Study Revision" (Ocean and Coastal Consultants, Inc. 2007)

After consulting with FEMA Region I, it was decided that the 10-percent, 2-percent, 1-percent, and 0.2-percent stillwater elevations for updated Map Mod transects should be taken from the TSDN report for Cumberland County.

This report did not update the SWEL values for the new transects; therefore, the 10-percent, 2-percent, 1-percent, and 0.2-percent for the new transects were obtained from the adjacent communities to maintain consistency. The SWEL values are summarized in Table 1 and were obtained as following:

- The SWEL values for the towns of Harpswell, Chebeague Island, Cumberland, and Falmouth and the cities of Portland and South Portland were determined by Sebago Technics and documented in the TSDN report.

- The SWEL values for the towns of Brunswick and Freeport were obtained from the Town of Harpswell.

- The SWEL values for the Town of Long Island were obtained from the City of Portland.

- The SWEL values for the Town of Yarmouth were obtained from the Town of Cumberland.

- The SWEL values for the new transects in the Town of Falmouth were interpolated from the adjacent submitted Falmouth transects.

Table 1: Summary of Coastal Stillwater Elevations

Flooding Source and Location	Elevations (NAVD 88)			
	10-percent-annual-chance	2-percent-annual-chance	1-percent-annual-chance	0.2-percent-annual-chance*
ATLANTIC OCEAN				
Town of Cape Elizabeth	7.9	8.5	8.8	9.5
Town of Scarborough	7.9	8.5	8.8	9.5
CASCO BAY				
Town of Cumberland	8.1	8.7	9.1	9.7
Town of Chebeague Island	8.1	8.7	9.1	9.7
Town of Harpswell	8.1	8.7	9.1	9.7
Town of Cape Elizabeth	7.9	8.5	8.8	9.5
City of Portland	8.0	8.6	8.9	9.5
City of South Portland	8.0	8.6	8.9	9.5
Town of Brunswick	8.1	8.7	9.1	9.7
Town of Freeport	8.1	8.7	9.1	9.7
Town of Long Island	8.0	8.6	8.9	9.5
Town of Yarmouth	8.1	8.7	9.1	9.7
Town of Scarborough	7.9	8.5	8.8	9.5
Town of Falmouth	7.9-8.0	8.5-8.6	8.8-8.9	9.5

2.3.2 Initial Wave Information

The energy-based significant wave height (Hmo) and peak wave period (Tp) are used as inputs to wave setup and wave runup calculations and were calculated using STWAVE. STWAVE is a phased-averaged spectral wave model that simulates depth-induced wave refraction and shoaling, depth- and steepness-induced wave breaking, diffraction, wind-wave growth, and wave-wave interaction and white capping that redistribute and dissipate energy in a growing wave field. The model accepts a spectral form of the wave as an input condition and provides Hmo and Tp results over the gridded model domain.

STARR team developed STWAVE models for the southern coastline of Cumberland County, and the results were obtained from the model for the coastal flooding analysis in the Towns of Chebeague Island, Cumberland, Freeport, Long Island, Scarborough, and Yarmouth.

STWAVE models were developed for the towns of Cape Elizabeth, Falmouth, and Harpswell and the City of Portland by Sebago Technics as part of their study in 2007. STARR team obtained the results from Sebago Technics models for the coastal flooding analysis in these communities.

2.4 Hydraulics

2.4.1 Methodology and Procedures

Wave height is the distance from the wave trough to the wave crest. The height of a wave is dependent upon wind speed and duration, water depth, and length of fetch. Offshore (deepwater) wave heights, wave setup, and wave runup for each transect were calculated using Mathcad sheets developed by STARR to apply methodologies from the Coastal Engineering Manual (USACE 2008) and FEMA Guidelines and Specifications (2007a). Methodologies for each type of calculation are discussed in more detail below. Results from the Mathcad calculations performed for each transect were compiled in a summary spreadsheet.

Overland wave heights were calculated for restricted and unrestricted fetch settings using WHAFIS, Version 4.0 (Divoky 2007), within CHAMP, following the methodology described in the FEMA Guidelines and Specifications (2007a) for each coastal transect.

The general working procedure for the new transects included eight steps: (1) laying out transects; (2) determining off-shore significant wave heights and corresponding wave periods from STWAVE outputs; (3) performing the off-shore engineering analysis; (4) preparing WHAFIS input data and populating the CHAMP database; (5) performing erosion analysis for erodible transects without a coastal structure; (6) performing WHAFIS modeling runs on eroded transects and transects with both intact and failed structures, as applicable; (7) performing wave runup analysis on intact and failed structures; and (8) identifying primary frontal dunes.

The general working procedure for the updated Map Mod transects included five steps: (1) determining off-shore significant wave heights and corresponding wave periods from STWAVE output; (2) updating the existing offshore engineering analysis with the updated wave conditions; (3) updating the existing Map Mod CHAMP databases with the updated wave conditions and the updated wave setup; (4) performing WHAFIS modeling runs on eroded transects and transects with both intact and failed structures, as applicable; and (5) updating the existing runup analysis with the updated wave condition and wave setup or performing a new runup analysis if the existing Map Mod method is not applicable for the intact and the failed transects.

2.4.2 Transect Layout

Transects profiles were located for coastal analyses perpendicular to the average shoreline along areas subject to coastal flooding; transects extend off-shore to areas representative of deep water conditions and extend inland to a point where wave action ceases, in accordance with the User's Manual for Wave Height Analysis (FEMA 1981). Transects were placed with consideration of topographic and structural changes of the land surface, as well as the cultural characteristics of the land, so that they would closely represent local conditions.

Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, transects were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects.

Figure 2 shows the transect layout for Cumberland County, and **Table 2** shows the number of transects for each community. Transects are included in the digital data files compiled for the coastal submittal.

2.4.3 Coastal Engineering Analysis

Coastal engineering analyses were performed for each new and updated Map Mod coastal transect using wave and SWEL data to generate wave setup and wave runup values for open coast transects and transects with vertical structures or revetments and to generate input used in developing CHAMP and WHAFIS input data. Mathcad sheets were developed and applied by STARR for the calculations to help ensure consistency and accuracy. The input data and results of the analysis were compiled for each transect in a summary spreadsheet. The Mathcad sheets and summary spreadsheet are included in the digital data files compiled for the coastal submittal.

CHAMP is a Microsoft (MS) Windows-interfaced Visual Basic language program that allows the user to enter data, perform coastal engineering analyses, view and tabulate results, and chart summary information for each representative transect along a coastline within a user-friendly graphical interface. With CHAMP, the user can import digital elevation data; perform storm-induced erosion treatments, wave height, and wave runup analyses; plot summary graphics of the results; and create summary tables and reports in a single environment. CHAMP version 2.0 (FEMA 2007b) was used to perform erosion analyses, run WHAFIS, and apply RUNUP 2.0 to transects without coastal structures. Application of CHAMP followed the instructions in the FEMA Guidelines and Specifications (FEMA 2007a) and the Coastal Hazard Analysis Modeling Program user's guide found in the software documentation (FEMA 2007b).

Details of the methodologies applied are described in the following sub-sections.

2.4.3.1 Wave Setup

Wave setup can be a significant contributor to the total water level at the shoreline and was included in the determination of coastal base flood elevations. Wave setup is defined as the increase in total stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope.

Wave setup values were calculated for each coastal transect using the Direct Integration Method (DIM), developed by Goda (2000), as described in the FEMA Guidelines and Specifications, Equation D.2.6-1. For those coastal transects where a structure was located, documentation was gathered on the structure, and the wave setup against the coastal structure was also calculated.

Wave setup calculations were performed and documented in the Mathcad sheets located in the digital data files compiled for the coastal submittal.

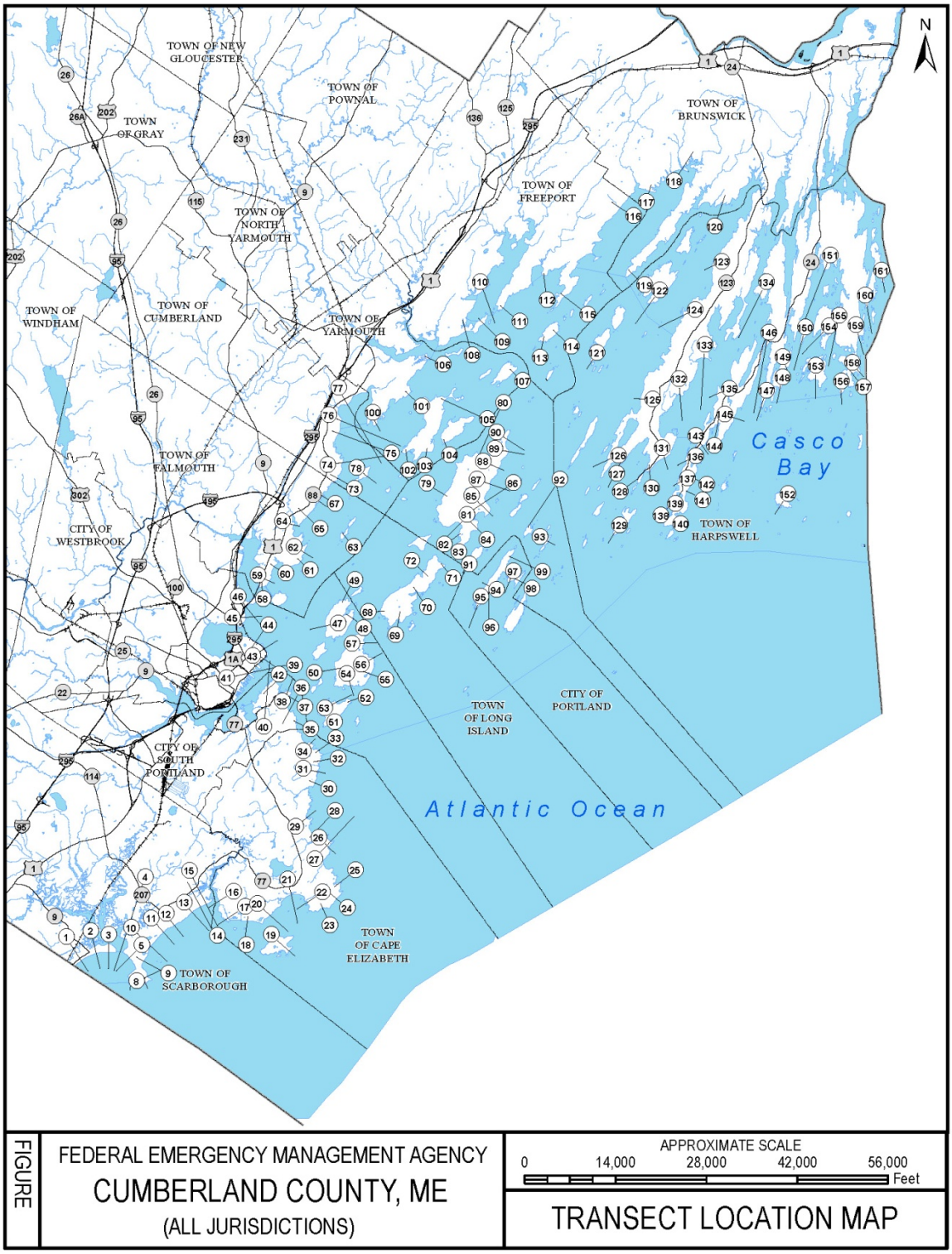

Figure 2 Transect Layout

Table 2: Number of Transects for Communities

Community	New Transects	Updated Map Mod Transects	Submitted Transects	Total
Town of Cape Elizabeth		10	9	19
Town of Chebeague Island		15		15
Town of Cumberland		6		6
Town of Falmouth	4		6	10
Town of Freeport	9			9
Town of Harpswell		19	22	41
Town of Long Island	5			5
City of Portland		21	2	23
Town of Scarborough		15		15
City of South Portland			6	6
Town of Yarmouth	8			8
TOTAL	30	86	45	161

2.4.3.2 Overland Wave Propagation

The fundamental analysis of overland wave effects for a Flood Insurance Study (FIS) is provided by FEMA's Wave Height Analysis For Flood Insurance Studies computer program, WHAFIS 4.0, a computer program that uses representative transects to compute wave crest elevations in a given study area. Topographic, vegetative, and cultural features are identified along each specified transect landward of the shoreline. WHAFIS uses this and other input information to calculate wave heights, wave crest elevations, flood insurance risk zone designations, and flood zone boundaries along the transects.

The original basis for the WHAFIS model was the 1977 National Academy of Sciences (NAS) report "Methodology for Calculating Wave Action Effects Associated with Storm Surges" (NAS 1977). The NAS methodology accounted for varying fetch lengths, barriers to wave transmission, and the regeneration of waves over flooded land areas. Since the incorporation of the NAS methodology into the initial version of WHAFIS, periodic upgrades have been made to WHAFIS to incorporate improved or additional wave considerations.

The wave action conservation equation governs wave regeneration caused by wind and wave dissipation by marsh plants in the model. This equation is supplemented by the conservation of wave equation, which expresses the spatial variation of the wave period at the peak of the wave spectrum. The wave energy (equivalently, wave height) and wave period respond to changes in wind conditions, water depths, and obstructions as a wave propagates. These equations are solved as a function of distance along the wave analysis transect.

The WHAFIS 4.0 model used in this study was fully documented in Technical Documentation for WHAFIS Program Version 3.0 by FEMA in September 1988 and

Supplementary WHAFIS Documentation for WHAFIS 4.0 in August 2007 (Divoky 2007). WHAFIS 4.0 incorporates 500-year wind speeds in the model in addition to the 100-year, 1-percent-annual-chance wind speeds used in WHAFIS 3.0 as well as makes other improvements to the program.

WHAFIS 4.0 was applied using CHAMP to calculate overland wave height propagation and establish base flood elevations. For profiles with vertical structures or revetments, a failed structure analysis was performed, and a new profile of the failed structure was generated and analyzed.

To populate the WHAFIS database in CHAMP, transect data were extracted from the GIS shapefiles as point features along the defined transects. First, the coordinates of the station corresponding to the point where each transect intersected with the shoreline (0.0-foot contour) were extracted. Land and bathymetry elevation, station, and source data were also extracted using a custom tool for ArcGIS, developed by STARR. The data were extracted at 2-foot intervals. Manual adjustments near the shoreline had to be made. All points seaward of the 0.0 contour used the bathymetry elevation. Points seaward of the 0.0 contour with an elevation higher than 0.0 were removed, with the exception of offshore islands. Points representing the (0.0, 0.0) locations were appended. The extracted points were then sorted, and the stationing was reset. As a next step the WHAFIS card information was extracted for each point. Since WHAFIS accepts only up to 400 points, the resulting point features were "thinned," utilizing a custom tool. This tool uses the Ramer-Douglas-Peucker algorithm to reduce the number of points along the transects within the acceptable range for use in WHAFIS.

A CHAMP_Input.csv file was created. It contains the Transect ID, fetch length, wave height, wave period, 1-percent and 0.2-percent annual-chance SWEL, total water elevation, total water elevation including wave setup on a failed structure, flooding source, flooding type, SWEL source, fetch source, wave setup method, structure type, toe and top elevations of structures, 2-percent wave runup, and 2-percent runup on failed structures. Two template CHAMP databases, one for intact structures and one for failed structures, were then populated with the GIS data and the data from the CHAMP_Input.csv file. The CHAMP input files and databases are included in the digital data files compiled for the coastal submittal.

WHAFIS carding was developed using the WHAFIS Carding Guidance included in the reference materials for CHAMP software in accordance with the Overland Wave Propagation section in the FEMA Guidelines and Specifications (FEMA 2007b). Spatial files and tables were developed into a WHAFIS geodatabase, and the WHAFIS carding was applied to the spatial files using aerial photographs, field inspection data, and topographic contours. The shapefile is included in the digital data files compiled for the coastal submittal. The WHAFIS card coding task included creating a digital file (vector) that represents each card value used in a WHAFIS database. The following data were used:

- Coastal transect features
- Bathymetric data

- Land DEM
- Aerial photographs
- Contour features
- Field notes
- Digital photographs
- Survey data
- SWEL data for coastline

In addition to the CHAMP databases, WHAFIS requires a vegetation parameter file, named "mg.dat." The WHAFIS executable, input and output files, together with the transect profiles and vegetation parameter files for each transect, are included in the digital data files compiled for the coastal submittal.

Along each transect, wave heights and wave crest elevations were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. Wave heights were calculated to the nearest 0.1 foot, and wave crest elevations were determined at whole-foot increments. The calculations were carried inland along the transect until the wave crest elevation was permanently less than 0.5 foot above the stillwater elevation or the coastal flooding met another flood source (i.e., a riverine flood source) with an equal water-surface elevation. The results of the calculations are accurate until local topography, vegetation, or cultural development of the area undergoes any major changes.

Detailed information on the physical and cultural features of the study area was obtained from aerial photography and LiDAR data. The land-use and land cover data were obtained from MEGIS aerial photography and 2004 land cover data.

Figure 3 shows a typical transect profile and illustrates the effects of energy dissipation and regeneration of a wave as it moves inland. This figure shows the wave crest elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches.

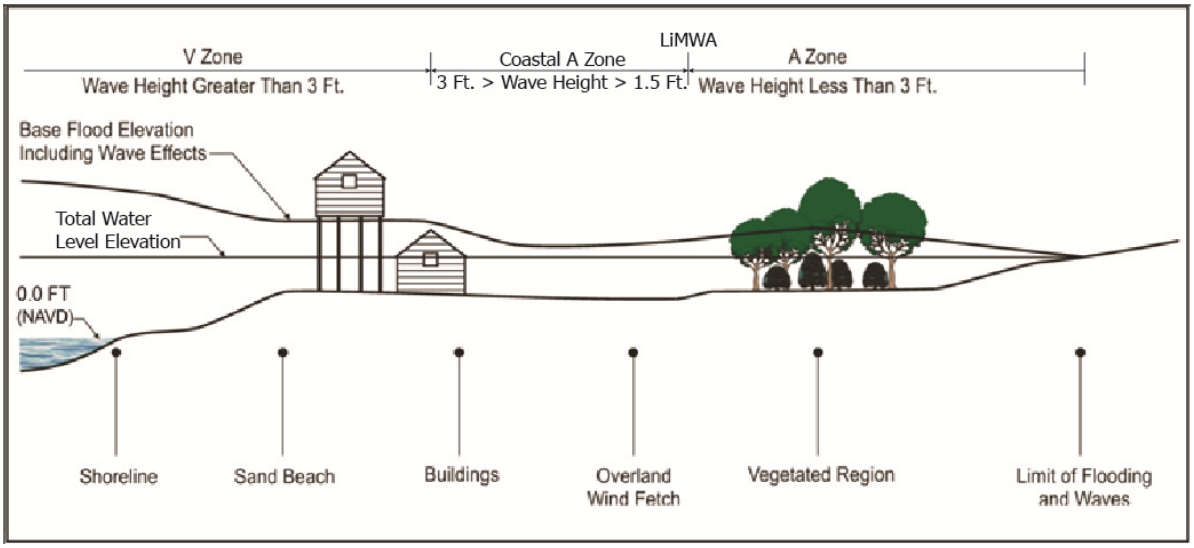

Figure 3 Wave Crest Variations along a WHAFIS Transect

Areas of coastline subject to significant wave attack are referred to as coastal high hazard zones. The USACE (1975) has established the 3-foot breaking wave as the criterion for identifying the limit of coastal high hazard zones. The 3-foot wave has been established as the minimum size wave capable of causing major damage to conventional wood frame and brick veneer structures. WHAFIS results show where the waves are greater than 3 feet (VE zone) and less than 3 feet (AE zone). Figure 3 illustrates the relationship between the local stillwater elevations, the ground profile, and the location of the V/A zone boundary. This inland limit of the coastal high hazard area is delineated to ensure that adequate insurance rates apply and appropriate construction standards are imposed should local agencies permit building in this coastal high hazard area.

The LiMWA is determined and defined as the location of the 1.5-foot wave. Typical constructions in areas of wave heights less than 3-feet high have experienced damage, suggesting that construction requirements within some areas of the AE zone should be more like those requirements for the VE zone. Testing and investigations have confirmed that a wave height greater than 1.5 feet can cause structure failure. The LiMWA was determined for all areas subject to significant wave attack in accordance with "Procedure Memorandum No. 50 – Policy and Procedures for Identifying and Mapping Areas Subject to Wave Heights Greater than 1.5 feet as an Informational Layer on Flood Insurance Rate Maps (FIRMs)" (FEMA 2008).

The effects of wave hazards in the Zone AE areas (or shoreline in areas where VE Zones are not identified) and the limit of the LiMWA boundary are similar to, but less severe than, those in Zone VE where 3-foot breaking waves are projected during a 1-percent-annual-chance flooding event.

For transects where erosion was applied using CHAMP, the WHAFIS table for an eroded transect in the CHAMP input database was then adjusted manually to match the transect

profile in the CHAMP erosion results in the EROSION table of the CHAMP input geodatabase. WHAFIS card fields were changed to inland fetch (IF) for these points. WHAFIS records between the toe and top of the eroded section of the profile were removed to match the EROSION table.

2.4.3.3 Wave Runup and Overtopping

Wave runup is the up rush of water caused by the interaction of waves with the area of shoreline where the stillwater hits the land or other barrier intercepting the stillwater level. The wave runup elevation is the vertical height above the stillwater level ultimately attained by the extremity of the up rushing water. Wave runup at a shore barrier can provide flood hazards above and beyond those from stillwater inundation. Guidance in the FEMA Guidelines and Specifications (FEMA 2007a) suggests using the 2-percent wave runup value, the value exceeded by 2 percent of the runup events. The 2-percent wave runup value is particularly important for steep slopes and vertical structures.

Wave runup was calculated for each coastal transect using methods as described in the FEMA Guidelines and Specifications (FEMA 2007a). Runup estimates were developed for vertical walls using the guidance in Figure D.2.8-3 of the FEMA Guidelines and Specifications (FEMA 2007a) taken from the Shore Protection Manual (USACE 1984). Technical Advisory Committee for Water Retaining Structures (TAW) method was applied for sloped structures with a slope steeper than 1:8. For slopes milder than 1:8, the FEMA Wave Runup Model RUNUP 2.0 was used. Both the SPM and RUNUP 2.0 provide mean wave runup. The mean wave runup was multiplied by 2.2 to obtain the 2-percent runup height. Wave runup elevation was added to the stillwater elevation and does not include wave setup.

When the runup is greater than or equal to 3 feet above the maximum ground elevation, the base flood elevation was determined to be 3 feet above the ground crest elevation in accordance with guidance in the FEMA Guidelines and Specifications (FEMA 2007a). Computed runup was not adjusted if less than 3 feet above the ground crest.

When runup overtops a barrier, such as a partially eroded bluff or a structure, the floodwater percolates into the bed and/or runs along the back slope until it reaches another flooding source or a ponding area. Standardized procedures for the treatment of shallow water flooding and ponding were applied as described in the FEMA Guidelines and Specifications (FEMA 2007a).

In areas where wave runup elevations dominate over wave heights, such as areas with steeply sloped beaches, bluffs, and/or shore-parallel flood protection structures, there is no evidence to date of significant damage to residential structures by runup depths less than 3 feet. However, to simplify representation, the LiMWA was continued immediately landward of the VE/AE boundary in areas where wave runup elevations dominate. Similarly, in areas where the Zone VE designation is based on the presence of a primary frontal dune or wave overtopping, the LiMWA was also delineated immediately landward of the Zone VE/AE boundary.

Where uncertified coastal structures, such as vertical walls and revetments were present, additional analysis for wave runup was performed on profiles assuming the structure will partially fail during the base flood. The post-failure slope applied for this analysis was 1:3 for sloped revetments and 1:1.5 for vertical walls, which is within the range suggested by the FEMA Guidelines and Specifications (FEMA 2007a).

Mathcad files for wave runup calculated using SPM and TAW methods are included in the digital data files compiled for the coastal submittal. Wave runup was also calculated using RUNUP 2.0 in cases where there were no coastal structures. Input and output files for RUNUP 2.0 analyses are located in the digital data files compiled for the coastal submittal.

2.4.3.4 Erosion

During significant coastal storms, shoreline profiles are altered due to episodic erosion and can allow for greater landward propagation of waves. As a result, flood hazard analysis and mapping was based on eroded profiles, where applicable. For this study, the eroded profile was calculated within the Erosion Module of CHAMP version 2.0 for sand beaches with a well-defined dune in accordance with the FEMA Guidelines and Specifications (FEMA 2007a/b). The guidance identifies the size of the frontal dune reservoir, or the cross-sectional area of the dune above the 1-percent-annual-chance SWEL, as the key attribute in determining the relative stability of the dune.

Erosion analysis using CHAMP was performed for profiles with erodible dunes and without coastal structures, such as vertical walls or revetments. The dune subject to erosion is a sandy feature with potentially light vegetation. Any thickly vegetated, rocky, silty, or clayey dune features or bluffs were not eroded. Predicted post-storm erosion profiles were used for analysis of wave heights associated with coastal storm surge flooding, where appropriate.

Guidance in Appendix D, Section D.2.9.3.1 of the FEMA Guidelines and Specifications (FEMA 2007) and the CHAMP users' manual (FEMA 2007b) was followed for selecting the dune peak and toe. The toe of the dune was generally an inflection point in the profile where the slope of the profile transitions from a mild slope to a steeper slope. The peak of the dune is generally the highest point on the dune of interest that is not caused by an anthropogenic source or vegetation. The toe and peak of dune determine the overall dune reservoir. If the dune reservoir exceeded 540 square feet in cross-sectional area, then the storm-induced erosion resulted in dune face retreat. If the cross-sectional area was less than 540 square feet, then the dune was removed, resulting in a ground profile slope of 1:50 running through the dune toe.

For transects where erosion was applied, the erosion transect profile in the CHAMP EROSION table was populated with at least two new points added into the profile identifying the toe and top of the eroded areas of the profile.

2.4.3.5 Identification of Primary Frontal Dunes

Primary frontal dunes (PFDs) were identified in the communities of Cape Elizabeth and Scarborough. Provided below is a summary of the analyses performed. All revised coastal analyses were performed in accordance with the FEMA Guidelines and Specifications (FEMA 2007a).

In accordance with 44 Code of Federal Regulations (CFR) Section 59.1 of the National Flood Insurance Program (NFIP), the effect of the PFD on coastal high hazard area (V Zone) mapping was evaluated for the communities of Cape Elizabeth and Scarborough. Identification of the PFD was based upon a FEMA-approved numerical approach for analyzing the dune's dimensional characteristics. Using this methodology, the landward toe of the PFD is delineated based on knowledge of local geological processes and remote sensing/GIS technologies utilizing LiDAR data.

2.4.4 Coastal Engineering Results

Table 3 is the coastal data table, which summarizes the transect description, numbering, location, stillwater elevations, and zone designation and 1-percent-annual-chance Base Flood Elevations (BFE) in feet NAVD88.

Table 3: Coastal Data Table

Community Name	Transect	Description	Latitude and Longitude at Start of WHAFIS Transect (NAD83)		Stillwater Elevations (feet NAVD88)				Zone Designation and BFE (feet NAVD 88)
					10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	
TOWN OF SCARBOROUGH	CM-001	The transect is located along the Atlantic Ocean shoreline, extending to the north along Sea Rose Lane toward East Grand Avenue.	256490	2904472	7.9	8.5	8.8	9.5	AE 13-14 VE 16
TOWN OF SCARBOROUGH	CM-002	The transect is located along the Atlantic Ocean Shoreline, extending north along Avenue One Extension toward Jones Creek Drive.	7482	2906709	7.9	8.5	8.8	9.5	AE 12-14 VE 15
TOWN OF SCARBOROUGH	CM-003	The transect is located along the Atlantic Ocean Shoreline at a point approximately 875 feet east of the intersection of Pillsbury Drive and Avenue Five Extension, extending to the north toward King Street.	257709	2908461	7.9	8.5	8.8	9.5	AE 12-15 VE 15
TOWN OF SCARBOROUGH	CM-004	The transect extends to the northeast through the mouth of the Scarborough River and portion of Ferry Beach State Park toward Old Neck Road.	259973	2910986	7.9	8.5	8.8	9.5	AE 12-14 VE 14-15
TOWN OF SCARBOROUGH	CM-005	The transect is located along the Atlantic Ocean shoreline at a point approximately 1,500 feet southeast of Ferry Rock, extending to the northeast toward Ferry Road.	257013	2911649	7.9	8.5	8.8	9.5	AE 12-14 VE 14
TOWN OF SCARBOROUGH	CM-006	The transect is located along the Atlantic Ocean shoreline at a point approximately 500 feet east of Checkly Point, extending to the north toward Winslow Homer Road.	253051	2911849	7.9	8.5	8.8	9.5	VE 23
TOWN OF SCARBOROUGH	CM-007	The transect is located along the Atlantic Ocean shoreline at a point approximately 200 feet east of Lookout Point, extending to the north toward Winslow Homer Road.	252990	2914183	7.9	8.5	8.8	9.5	VE 23
TOWN OF SCARBOROUGH	CM-008	The transect is located along the Atlantic Ocean shoreline at a point approximately 850 feet northwest of East Point, extending to the southwest toward Winslow Homer Road.	254189	2914475	7.9	8.5	8.8	9.5	VE 19
TOWN OF SCARBOROUGH	CM-009	The transect is located along the Atlantic Ocean shoreline, extending to the northwest along Saccarrappa Lane toward Black Point Road.	256527	2913975	7.9	8.5	8.8	9.5	AE 13-15 VE 15
TOWN OF SCARBOROUGH	CM-010	The transect is located along the Atlantic Ocean shoreline at a point approximately 2,000 feet northeast of Massacre Lane, extending to the northwest along the state park access road toward Black Point Road.	258727	2915134	7.9	8.5	8.8	9.5	AE 13-14 VE 15
TOWN OF SCARBOROUGH	CM-011	The transect is located along the Atlantic Ocean shoreline, extending to the northwest along the slough end of Atlantic Drive toward Black Point Road.	260880	2917091	7.9	8.5	8.8	9.5	AE 14 VE 15
TOWN OF SCARBOROUGH	CM-012	The transect is located along the Atlantic Ocean shoreline at a point approximately 900 feet east of Kirkwood Road, extending to the northwest toward Spurwink Road.	261930	2918791	7.9	8.5	8.8	9.5	VE 28
TOWN OF SCARBOROUGH	CM-013	The transect is located along the Atlantic Ocean shoreline at a point approximately 800 feet southwest of Cliff Street, extending to the northwest toward Greenwood Avenue.	263869	2921584	7.9	8.5	8.8	9.5	VE 25
TOWN OF SCARBOROUGH	CM-014	The transect is located along the Atlantic Ocean shoreline, extending to the northwest along Ocean Avenue toward Greenwood Avenue.	264637	2922826	7.9	8.5	8.8	9.5	AE 9 VE 18
TOWN OF SCARBOROUGH	CM-015	The transect is located along the Atlantic Ocean shoreline, extending to the northwest along Vesper Street toward Greenwood Avenue.	264866	2923801	7.9	8.5	8.8	9.5	AE 9-15 VE 15
TOWN OF CAPE ELIZABETH	CM-016	The transect is located along the Spurwink River shoreline at a point approximately 1,400 feet north of the intersection of Winter Lane and Lower River Road, extending to the northeast toward Spurwink Farm Airfield.	265531	2925563	7.9	8.5	8.8	9.5	VE 18
TOWN OF CAPE ELIZABETH	CM-017	The transect is located along the Atlantic Ocean shoreline at a point approximately 300 feet northwest of the Cod Rocks, extending to the northeast toward Little Pond Road.	262696	2926639	7.9	8.5	8.8	9.5	VE 20
TOWN OF CAPE ELIZABETH	CM-018	The transect is located at the south end of Monastery Road, extending to the north.	262433	2929971	7.9	8.5	8.8	9.5	AE 12 VE 14
TOWN OF CAPE ELIZABETH	CM-019	The transect is located along the Richmond Island shoreline at a point approximately 800 feet southwest of Watts Point, extending to the northwest.	257722	2936382	7.9	8.5	8.8	9.5	VE 21
TOWN OF CAPE ELIZABETH	CM-020	The transect is located along the Atlantic Ocean shoreline at a point approximately 2,350 feet southwest of Jordan Point, extending to the northwest toward Breakwater Farm Road.	263274	2933515	7.9	8.5	8.8	9.5	AE 22 VE 22
TOWN OF CAPE ELIZABETH	CM-021	The transect is located approximately midway along the Crescent Beach, extending to the north along the park access road toward Bowery Beach Road.	266265	2936772	7.9	8.5	8.8	9.5	AE 12 VE 13
TOWN OF CAPE ELIZABETH	CM-022	The transect is located approximately midway along the Maxwell Cove shoreline, extending to the northeast toward Two Lights Road.	265122	2939131	7.9	8.5	8.8	9.5	AE 19 VE 19
TOWN OF CAPE	CM-023	The transect is located approximately midway along the Hallicom Cove shoreline, extending to the northwest toward	264256	2941548	7.9	8.5	8.8	9.5	VE 28

Community Name	Transect	Description	Latitude and Longitude at Start of WHAFIS Transect (NAD83)		Stillwater Elevations (feet NAVD88)				Zone Designation and BFE (feet NAVD 88)
					10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	
ELIZABETH		Angell Point Road.							
TOWN OF CAPE ELIZABETH	CM-024	The transect is located along the Atlantic Ocean shoreline at a point approximately 1,700 feet south of Dyer Point, extending to the northwest toward Beacon Lane.	265533	2943801	7.9	8.5	8.8	9.5	VE 22
TOWN OF CAPE ELIZABETH	CM-025	The transect is located at the intersection of Hannaford Cove Road and Cunner Lane, extending to the northwest along Hannaford Road.	268210	2944312	7.9	8.5	8.8	9.5	VE 18
TOWN OF CAPE ELIZABETH	CM-026	The transect is located along the Atlantic Ocean shoreline at a point approximately 650 feet south of Trundy Point, extending to the northwest toward Reef Road.	273630	2942648	7.9	8.5	8.8	9.5	VE 20
TOWN OF CAPE ELIZABETH	CM-027	The transect is located at the north end of Reef Road, extending to the southeast toward Katahdin Road.	274440	2942957	7.9	8.5	8.8	9.5	VE 18
TOWN OF CAPE ELIZABETH	CM-028	The transect is located along the Atlantic Ocean shoreline at a point approximately midway between Old Mill Road and Alewife Cove Road, extending to the southwest toward Shore Road.	275975	2940586	7.9	8.5	8.8	9.5	VE 19
TOWN OF CAPE ELIZABETH	CM-029	The transect is located approximately midway along the Zeb Cove shoreline, extending to the southwest toward Ocean House Road.	278208	2939373	7.9	8.5	8.8	9.5	VE 21
TOWN OF CAPE ELIZABETH	CM-030	The transect is located at the north end of Lawson Road extending to the northwest toward Shore Road.	283438	2940909	7.9	8.5	8.8	9.5	VE 21
TOWN OF CAPE ELIZABETH	CM-031	The transect is located along the Atlantic Ocean shoreline at a point approximately 200 feet north of Singles Road, extending to the northwest toward Shore Road.	285249	2941173	7.9	8.5	8.8	9.5	VE 18
TOWN OF CAPE ELIZABETH	CM-032	The transect is located along the Atlantic Ocean shoreline at a point midway between Humphreys Road and Delano Park Entrance 1, extending to the west toward Shore Road.	286971	2941698	7.9	8.5	8.8	9.5	VE 40
TOWN OF CAPE ELIZABETH	CM-033	The transect is located along the Atlantic Ocean shoreline at a point approximately 750 feet north of Captain Strout Circle, extending to the southwest toward Ocean Road.	288533	2941351	7.9	8.5	8.8	9.5	VE 26
TOWN OF CAPE ELIZABETH	CM-034	The transect is located at the northeast end of Surf Road extending to the southwest toward Shore Road.	289683	2940237	7.9	8.5	8.8	9.5	VE 20
CITY OF SOUTH PORTLAND	CM-035	The transect is located at a point along the Danford Cove, extending to the northwest along Ledge Road toward Loveitts Field Road.	292973	2937926	8.0	8.6	8.9	9.5	VE 25
CITY OF SOUTH PORTLAND	CM-036	This transect is located along Simonton Cove at a point approximately midway between Willard Street and Dreake Street, extending to the southwest toward Preble Street.	294717	2936958	8.0	8.6	8.9	9.5	AE 10-11 VE 12
CITY OF SOUTH PORTLAND	CM-037	The transect is located at a point approximately 1,000 feet south of the Spring Point extending to the west toward Fort Hill.	296891	2937012	8.0	8.6	8.9	9.5	VE 22
CITY OF SOUTH PORTLAND	CM-038	The transect is located at a point approximately 300 feet west of Spring Point and extending to the southwest toward Fort Hill.	297761	2936765	8.0	8.6	8.9	9.5	AE 15 VE 15
CITY OF SOUTH PORTLAND	CM-039	The transect is located along the eastern shoreline of the City of South Portland at a point approximately 500 feet southeast of Portland Breakwater Light, extending to the southwest toward Preble Street.	299186	2934956	8.0	8.6	8.9	9.5	AE 12 VE 13
CITY OF SOUTH PORTLAND	CM-040	The transect is located along the Fore River shoreline at a point approximately 1,500 feet southwest of Portland Breakwater Light, extending to the south toward Front Street.	298682	2933649	8.0	8.6	8.9	9.5	VE 13
CITY OF PORTLAND	CM-041	The transect is located along the Portland Harbor waterfront at a point approximately 200 feet east of the intersection of Commercial Street and Old Wharf Street, extending to the west toward Fore Street.	300634	2931104	8.0	8.6	8.9	9.5	VE 13-14
CITY OF PORTLAND	CM-042	The transect is located along the Portland Harbor waterfront at a point approximately 1,000 feet southwest of Fish Point, extending to the northwest toward the intersection of Eastern Prom and Obrion Street.	302752	2933184	8.0	8.6	8.9	9.5	VE 14
CITY OF PORTLAND	CM-043	The transect is located along the eastern shoreline of the City of Portland at a point approximately between Cutter Street and Fish Point, extending to the southwest toward Eastern Prom.	304358	2933318	8.0	8.6	8.9	9.5	VE 14
CITY OF PORTLAND	CM-044	The transect is located along the eastern shoreline of the City of Portland at a point approximately 900 feet northwest of Cutter Street, extending to the southwest toward Eastern Prom.	305414	2931917	8.0	8.6	8.9	9.5	VE 15
CITY OF PORTLAND	CM-045	The transect is located along the eastern shoreline of the City of Portland at the eastern end of Chester Street, extending to the west toward I-295.	309214	2930409	8.0	8.6	8.9	9.5	VE 19
CITY OF PORTLAND	CM-046	The transect is located along the eastern shoreline of the City of Portland, approximately 1,800 feet south of Martins Point, extending to the northwest along Olympia Street.	310828	2930547	8.0	8.6	8.9	9.5	VE 15
CITY OF PORTLAND	CM-047	The transect is located along the western shoreline of Great Diamond Island, approximately 850 feet northwest of the	307660	2942701	8.0	8.6	8.9	9.5	VE 12

Community Name	Transect	Description	Latitude and Longitude at Start of WHAFIS Transect (NAD83)		Stillwater Elevations (feet NAVD88) 10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	Zone Designation and BFE (feet NAVD 88)
		intersection of Cleeve Street and Spring Avenue, extending to the east toward Cleeve Street.							
CITY OF PORTLAND	CM-048	The transect is located along the eastern shoreline of Great Diamond Island at the southern end of Eastside Drive, extending to the northwest along Weymouth Way.	308621	2947035	8.0	8.6	8.9	9.5	VE 21
CITY OF PORTLAND	CM-049	The transect is located at a point along the northern shoreline of Great Diamond Island, approximately midway along Indian Cove, extending to the southwest toward Seal Cove Lane.	311717	2945539	8.0	8.6	8.9	9.5	VE 17
CITY OF PORTLAND	CM-050	The transect is located along the western shoreline of Peaks Island extending to the east along Elizabeth Street.	301003	2944062	8.0	8.6	8.9	9.5	VE 25
CITY OF PORTLAND	CM-051	The transect is located along the eastern shoreline of Cushing Island at a point approximately 1,000 feet north of Catfish Rock, extending to the northwest.	293035	2943567	8.0	8.6	8.9	9.5	VE 14
CITY OF PORTLAND	CM-052	The transect is located at the northeastern point of Whitehead, extending to the southwest.	296083	2946452	8.0	8.6	8.9	9.5	VE 24
CITY OF PORTLAND	CM-053	The transect is located at a point along the western shoreline of Spicers Cove, extending southwest.	295947	2944333	8.0	8.6	8.9	9.5	VE 16-19
CITY OF PORTLAND	CM-054	The transect is located at a point along the southern shoreline of Peaks Island, extending to the northwest along Seashore Avenue toward the intersection with Maple Street.	298506	2946403	8.0	8.6	8.9	9.5	VE 19
CITY OF PORTLAND	CM-055	The transect is located at a point along the eastern shoreline of Peaks Island approximately 200 feet northeast of the intersection of Seashore Avenue and Alder Brook Road, extending to the northwest toward Florida Avenue.	300122	2949696	8.0	8.6	8.9	9.5	VE 18
CITY OF PORTLAND	CM-056	The transect is located at the intersection of Seashore Avenue and Hussey Road, extending to the southwest toward the intersection of Hussey Road and Reservoir Road.	302669	2950096	8.0	8.6	8.9	9.5	VE 26
CITY OF PORTLAND	CM-057	The transect is located at a point along the eastern shoreline of Peaks Island, approximately midway between Josiahs Cove and Elm Tree Cove, extending to the west toward Reed Avenue.	304899	2948643	8.0	8.6	8.9	9.5	VE 23
TOWN OF FALMOUTH	CM-058	The transect is located at Casco Bay shoreline in the vicinity of the intersection of Bayshore Drive and Reg Roc Drive, extending north toward Presumpscot River.	313807	2932989	7.9	8.5	8.8	9.5	VE 12
TOWN OF FALMOUTH	CM-059	The transect is located at Casco Bay shoreline in the vicinity of the intersection of Shoreline Drive and McKinley Road, extending northwest paralleling McKinley Road.	314714	2934257	7.9	8.5	8.8	9.5	VE 12
TOWN OF FALMOUTH	CM-060	The transect is located at Casco Bay shoreline in the vicinity of the intersection of Brown Street and Carroll Street, extending northwest toward Highway 1.	316954	2934959	7.9	8.5	8.8	9.5	VE 14
TOWN OF FALMOUTH	CM-061	The transect is located at Casco Bay shoreline in the vicinity of the intersection of Waters Edge Road and Waites Landing Road, extending northwest toward Landing Woods Lane.	317651	2939040	7.9	8.5	8.8	9.5	VE 15
TOWN OF FALMOUTH	CM-062	The transect is located at Casco Bay shoreline in the vicinity of the end of Menikoe Point Road, extending northwest to end at a point approximately 150 feet west of the intersection of Waites Landing Road and Elm Drive.	319061	2939597	7.9	8.5	8.8	9.5	AE 10 VE 13
TOWN OF FALMOUTH	CM-063	The transect is located at Casco Bay shoreline crossing the Clapboard Island.	321480	2945889	7.9	8.5	8.8	9.5	VE 17
TOWN OF FALMOUTH	CM-064	The transect is located at Casco Bay shoreline in the vicinity of the intersection of Old Mill Road and Edgewater Street, extending Northwest to State Highway 88.	323305	2938115	8.0	8.6	8.9	9.5	VE 18
TOWN OF FALMOUTH	CM-065	The transect is located at Casco Bay shoreline at a point approximately 1,900 feet northeast of the mouth of Mill Creek, extending northwest intersecting with Foreside Road.	324500	2940196	8.0	8.6	8.9	9.5	VE 14
TOWN OF FALMOUTH	CM-066	The transect is located at Casco Bay shoreline in the vicinity of Old Powerhouse Road, extending northwest, paralleling Old Powerhouse Road to Foreside Road.	326852	2942102	8.0	8.6	8.9	9.5	VE 14
TOWN OF FALMOUTH	CM-067	The transect is located at Casco Bay shoreline in the vicinity of Ayers Court, extending northwest along Burgess Street.	327605	2942683	8.0	8.6	8.9	9.5	VE 16
TOWN OF LONG ISLAND	CM-068	The transect is located at Casco Bay shoreline at West Point, Long Island, extending east toward the intersection of Island Ave and End Lane.	309854	2951130	8.0	8.6	8.9	9.5	VE 20
TOWN OF LONG ISLAND	CM-069	The transect is located at Casco Bay shoreline at Wreck Cove, Long Island, extending north-northeast toward the intersection of Ocean Street and Gorham Ave.	308499	2953966	8.0	8.6	8.9	9.5	AE 13 VE 16
TOWN OF LONG ISLAND	CM-070	The transect is located at Casco Bay shoreline at a point approximately 450 feet southwest of the intersection of Fern Ave and Harbor Grace Street, Long Island, extending northwest intersecting Fern Ave.	312405	2956998	8.0	8.6	8.9	9.5	AE 12 VE 14
TOWN OF LONG ISLAND	CM-071	The transect is located at Casco Bay shoreline in the vicinity of Eastern Ave, Long Island, extending northwest toward the north end of Frances Lane.	316383	2961121	8.0	8.6	8.9	9.5	VE 15
TOWN OF LONG ISLAND	CM-072	The transect is located at Casco Bay shoreline in the vicinity of a sharp bend in Island Ave, east of Long Cove, Long Island, extending to intersect Island Ave and Stepping Stone Lane.	315837	2957871	8.0	8.6	8.9	9.5	VE 13
TOWN OF CUMBERLA	CM-073	The transect is located at the eastern shoreline of the Town of Cumberland mainland along Stornoway Road, extending to the	330225	2945103	8.1	8.7	9.1	9.7	VE 18

Community Name	Transect	Description	Latitude and Longitude at Start of WHAFIS Transect (NAD83)		Stillwater Elevations (feet NAVD88) 10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	Zone Designation and BFE (feet NAVD 88)
ND		northwest toward Foreside Road.							
TOWN OF CUMBERLAND	CM-074	The transect is located at the eastern shoreline of the Town of Cumberland mainland along Ole Musket Road, extending to the west toward Foreside Road.	332798	2945824	8.1	8.7	9.1	9.7	VE 14
TOWN OF CUMBERLAND	CM-075	The transect is located at the eastern shoreline of the Town of Cumberland mainland along Wildwood Boulevard, extending to the northwest toward Foreside Road.	337282	2945274	8.1	8.7	9.1	9.7	VE 20
TOWN OF CUMBERLAND	CM-076	The transect is located at the eastern shoreline of the Spear Hill area, directly south of the pier, extending to the northwest toward Foreside Road.	339211	2945688	8.1	8.7	9.1	9.7	VE 17
TOWN OF CUMBERLAND	CM-077	The transect is located at the eastern shoreline of the Town of Cumberland mainland, in the vicinity of the intersection of Blue Heron Lane and Ledge Road, extending to the northwest toward Foreside Road.	341681	2946668	8.1	8.7	9.1	9.7	VE 19
TOWN OF CUMBERLAND	CM-078	The transect is located at a point approximately midway along the eastern shoreline of Sturdivant Island, extending to the northwest.	330610	2949545	8.1	8.7	9.1	9.7	VE 18
TOWN OF CHEBEAGUE ISLAND	CM-079	The transect is located at the northern end of Island View Road extending to the southwest toward North Road.	327663	2961255	8.1	8.7	9.1	9.7	VE 15
TOWN OF CHEBEAGUE ISLAND	CM-080	The transect is located at the southwest end of Sunset Road, extending to the southeast toward North Road.	333767	2966850	8.1	8.7	9.1	9.7	VE 20
TOWN OF CHEBEAGUE ISLAND	CM-081	The transect is located at Chandlers Cove, extending to the northeast along Durgin Lane toward South Street.	323061	2963663	8.1	8.7	9.1	9.7	VE 12
TOWN OF CHEBEAGUE ISLAND	CM-082	The transect is located approximately 300 feet southwest of Ashley Lane, extending to the northeast toward Bennett Cove Road.	321333	2963382	8.1	8.7	9.1	9.7	VE 18
TOWN OF CHEBEAGUE ISLAND	CM-083	The transect is located approximately 650 feet northeast of the southern end of Deer Point, extending to the north.	319185	2963567	8.1	8.7	9.1	9.7	VE 19
TOWN OF CHEBEAGUE ISLAND	CM-084	The transect is located at Jenks Landing, extending to the northwest along Sandy Point Road.	322272	2966424	8.1	8.7	9.1	9.7	VE 12
TOWN OF CHEBEAGUE ISLAND	CM-085	The transect is located at the eastern end of Waldo Point along Roses Point Road northwest toward John Small Road.	324698	2968238	8.1	8.7	9.1	9.7	VE 19
TOWN OF CHEBEAGUE ISLAND	CM-086	The transect is located at a point approximately midway along the northern shoreline of Waldo Point, extending to the southwest toward Roses Point Road.	326433	2967685	8.1	8.7	9.1	9.7	VE 12
TOWN OF CHEBEAGUE ISLAND	CM-087	The transect is located at a point along the eastern shoreline of Great Chebeague Island at the eastern end of Central Landing Road, extending to the northwest toward South Road.	329096	2968435	8.1	8.7	9.1	9.7	VE 17
TOWN OF CHEBEAGUE ISLAND	CM-088	The transect is located at a point along the eastern shoreline of Great Chebeague Island approximately midway between Springettes Road and Brookwood Lane, extending to the northwest toward South Road.	331525	2969851	8.1	8.7	9.1	9.7	AE 10 VE 13
TOWN OF CHEBEAGUE ISLAND	CM-089	This transect is located at a point along the eastern shoreline of Great Chebeague Island, extending to the west along Capps Road toward South Road.	334093	2971296	8.1	8.7	9.1	9.7	VE 21
TOWN OF CHEBEAGUE ISLAND	CM-090	The transect is located along the eastern shoreline of Great Chebeague Island, extending to the northwest along Willow Street toward East Shore Drive.	335921	2971196	8.1	8.7	9.1	9.7	VE 13
TOWN OF CHEBEAGUE ISLAND	CM-091	The transect is located at the southern tip of Hope Island, extending to the northeast.	316281	2964435	8.1	8.7	9.1	9.7	VE 26
TOWN OF CHEBEAGUE ISLAND	CM-092	The transect is located along the northern shoreline of Stave Island approximately midway along the cove on the north side of the island, extending to the southwest.	323011	2974549	8.1	8.7	9.1	9.7	VE 14
TOWN OF CHEBEAGUE ISLAND	CM-093	The transect is located at a point approximately midway along eastern shoreline of Bates Island, extending to the northwest.	320134	2977214	8.1	8.7	9.1	9.7	VE 18
CITY OF PORTLAND	CM-094	The transect is located at a point along the western shoreline of Cliff Island, approximately 650 feet west of the intersection of Ferry Road and Beach Road, extending to the east toward Island Avenue.	313652	2967553	8.0	8.6	8.9	9.5	VE 13
CITY OF PORTLAND	CM-095	The transect is located at the southern tip of Cliff Island, extending to the northeast.	309828	2965913	8.0	8.6	8.9	9.5	VE 19
CITY OF PORTLAND	CM-096	The transect is located along Cliff Street, starting at the southern end of the road and extending to the northeast.	312491	2967946	8.0	8.6	8.9	9.5	VE 15
CITY OF PORTLAND	CM-097	The transect is located along Cliff Street, starting at the southern end of the road and extending to the northeast.	313995	2971050	8.0	8.6	8.9	9.5	VE 13
CITY OF PORTLAND	CM-098	The transect is located at a point approximately midway along the eastern most shoreline of Cliff Island extending to the northwest toward Cliff Street.	314193	2972679	8.0	8.6	8.9	9.5	AE 12 VE 25

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					10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	
CITY OF PORTLAND	CM-099	The transect is located at the northeast shoreline of Cliff Island, extending to the northwest toward the northern end of Church Road and Sunset Road.	317817	2971425	8.0	8.6	8.9	9.5	VE 17
TOWN OF YARMOUTH	CM-100	The transect is located at Casco Bay shoreline in the vicinity of the intersection of Battery Point Lane and Princes Point Road, extending to the northwest toward Princes Point Road.	338560	2951071	8.1	8.7	9.1	9.7	VE 12
TOWN OF YARMOUTH	CM-101	The transect is located at Casco Bay shoreline in the vicinity of the intersection of Channel Point Road and Seaborne Drive, extending to the northwest paralleling to Gilman Road	343124	2956081	8.1	8.7	9.1	9.7	VE 12
TOWN OF YARMOUTH	CM-102	The transect is located at Casco Bay shoreline at a point approximately 700 feet east of Birch Point, Cousins Island, extending to intersect with the eastern most part of Cousins Street.	334055	2955540	8.1	8.7	9.1	9.7	VE 12
TOWN OF YARMOUTH	CM-103	The transect is located at Casco Bay shoreline at a point approximately 1,400 feet southwest of the intersection between Spruce Point Road and Wharf Road, extending to intersect Spruce Point Road, on Cousins Island.	334091	2958658	8.1	8.7	9.1	9.7	VE 12
TOWN OF YARMOUTH	CM-104	The transect is located at Casco Bay shoreline at a point approximately 150 feet south of the southeast bend of Little John Road, extending to parallel the eastern part of Little John Road, on Little John Island.	335606	2961491	8.1	8.7	9.1	9.7	VE 16
TOWN OF YARMOUTH	CM-105	The transect is located at Casco Bay shoreline at a point approximately 1,300 feet from the T intersection of Sea Meadows Lane and Cornfield Road, extending to end at the northeastern end of Groves road on Cousins Island.	342084	2961660	8.1	8.7	9.1	9.7	VE 13
TOWN OF YARMOUTH	CM-106	The transect is located at Casco Bay shoreline at the Parker Point on the southern shore of Royal River mouth.	348482	2959592	8.1	8.7	9.1	9.7	VE 14
TOWN OF YARMOUTH	CM-107	The transect is located at Casco Bay shoreline at the east part of Moshier Island, extending over the high point of the island.	346236	2972236	8.1	8.7	9.1	9.7	VE 16
TOWN OF FREEPORT	CM-108	The transect is located at Casco Bay shoreline at a point approximately 260 feet south - southeast of the intersection between Staplespoint Road and Starboard, extending in to the north part of inner Staples Cove.	352622	2964986	8.1	8.7	9.1	9.7	AE 9-10 VE 15
TOWN OF FREEPORT	CM-109	The transect is located at Casco Bay shoreline at a point approximately 500 feet southeast of the intersection between Winslow Park Way and Black Willow, extending into the southwest part of Harraseeket River near Staples Cove.	353810	2967861	8.1	8.7	9.1	9.7	AE 10 VE 23
TOWN OF FREEPORT	CM-110	The transect is located at Harraseeket River shoreline a point approximately 400 feet south of the intersections between Harraseeket Road and Dixon Road, extending from Casco Bay to Harraseeket Road	358972	2967810	8.1	8.7	9.1	9.7	VE 14
TOWN OF FREEPORT	CM-111	The transect is located at Casco Bay shoreline in the vicinity of Moore Point, extending to a point approximately 50 feet northeast of the intersection between Wolfe's Neck Road and Lmc Lane.	356215	2970843	8.1	8.7	9.1	9.7	VE 14
TOWN OF FREEPORT	CM-112	The transect is located at Casco Bay shoreline in the vicinity of lower Ocean View Road east of the mouth of Little River, extending north toward Ocean View Road.	361087	2977132	8.1	8.7	9.1	9.7	VE 14
TOWN OF FREEPORT	CM-113	The transect is located at Casco Bay shoreline in the vicinity of south Bustins Island Road on Bustins Island at a point approximately 1900 feet west of The Nubble Island, extending north in to the Bustins Island.	350844	2976833	8.1	8.7	9.1	9.7	VE 14
TOWN OF FREEPORT	CM-114	The transect is located at Casco Bay shoreline in the vicinity of east Bustins Island Road on Bustins Island at a point approximately 1,700 feet northeast of The Nubble Island, extending northwest in to the Bustins Island.	352224	2978956	8.1	8.7	9.1	9.7	VE 17
TOWN OF FREEPORT	CM-115	The transect is located at Casco Bay shoreline at a point approximately 260 feet southeast of the Y intersection between Lower Flying Point Road and Cunningham Road, extending to intersect with Lower Flying Point Road.	357856	2980271	8.1	8.7	9.1	9.7	VE 16
TOWN OF FREEPORT	CM-116	The transect is located at Maquoit Bay shoreline at a point approximately 1,100 feet southeast of the intersection between Flying Point Road and Fiddlehead Road, extending northwest to parallel Fiddlehead Road.	371356	2989065	8.1	8.7	9.1	9.7	VE 14
TOWN OF BRUNSWICK	CM-117	The transect is located at Maquoit Bay shoreline at a point approximately 1,000 feet west of Bunganuc Point, extending northeast to intersect with the end of Bunganuc Landing Road.	373790	2993590	8.1	8.7	9.1	9.7	AE 10 VE 19
TOWN OF BRUNSWICK	CM-118	The transect is located at Maquoit Bay shoreline at Wharton Point approximately 300 feet southeast of the intersection between Woodside Road and Maquoit Road, extending northeast toward Rossmore Road.	376947	2998557	8.1	8.7	9.1	9.7	AE 10 VE 12
TOWN OF BRUNSWICK	CM-119	The transect is located at Middle Bay shoreline at a point approximately 1,250 feet south -southwest of the intersection between Marginal Road and Central Ave, extending northwest intersecting E Marginal Road and Central Ave.	361280	2990703	8.1	8.7	9.1	9.7	VE 14
TOWN OF BRUNSWICK	CM-120	The transect is located at Middle Bay shoreline at a point approximately 800 feet east of Simpsons Point Road, extending northeast toward Ocean Drive.	371439	3004708	8.1	8.7	9.1	9.7	VE 12

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					10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	
TOWN OF HARPSWELL	CM-121	The transect is located at the southern tip of Lower Goose Island, extending to the northeast.	347656	2984261	8.1	8.7	9.1	9.7	VE 18
TOWN OF HARPSWELL	CM-122	The transect is located at the southeastern tip of Birch Island, extending to the northeast.	356168	2993198	8.1	8.7	9.1	9.7	VE 17
TOWN OF HARPSWELL	CM-123	The transect is located along the Middle Bay shoreline at a point approximately 900 feet northeast of Bear Paw Road, extending to the northeast toward Spy Rock Road.	362046	3002962	8.1	8.7	9.1	9.7	VE 15
TOWN OF HARPSWELL	CM-124	The transect is located along the Middle Bay shoreline, extending to the northeast along Wood Landing Road.	354524	2998330	8.1	8.7	9.1	9.7	VE 16
TOWN OF HARPSWELL	CM-125	The transect is located along the Middle Bay shoreline at a point approximately 600 feet north of Sun Liner Drive, extending to the east toward Harpswell Neck Road.	341874	2991687	8.1	8.7	9.1	9.7	VE 16
TOWN OF HARPSWELL	CM-126	The transect is located along the Middle Bay shoreline, at a point approximately 500 feet north of the intersection of Basin Point Road and Barrows Lane, extending to the northeast toward Basin Cove.	332503	2986508	8.1	8.7	9.1	9.7	VE 16
TOWN OF HARPSWELL	CM-127	The transect is located at Ash Point, extending to the northeast toward Ash Point Road.	331790	2988343	8.1	8.7	9.1	9.7	VE 18
TOWN OF HARPSWELL	CM-128	The transect is located at the southern end of Harpswell Neck Road, extending to the northeast toward Hurricane Ridge Road.	329463	2991000	8.1	8.7	9.1	9.7	VE 14-17
TOWN OF HARPSWELL	CM-129	The transect is located at the southern end of Haskell Island, extending to the northeast.	320890	2987139	8.1	8.7	9.1	9.7	VE 22
TOWN OF HARPSWELL	CM-130	The transect is located at Graveyard Point, extending to the north toward Harpswell Neck Road.	330541	2992951	8.1	8.7	9.1	9.7	VE 22
TOWN OF HARPSWELL	CM-131	The transect is located Along the Harpswell Sound shoreline at a point approximately 300 feet east of Merriconeag Lane, extending to the northwest toward Intervale Road.	332638	2995319	8.1	8.7	9.1	9.7	VE 24
TOWN OF HARPSWELL	CM-132	The transect is located at the southern end of Shore Acres Road, extending to the north toward Thompson Road.	342448	2997802	8.1	8.7	9.1	9.7	VE 13
TOWN OF HARPSWELL	CM-133	The transect is located at a point approximately midway along Clarks Cove, extending to the north toward Morse Shore Road.	347969	3001560	8.1	8.7	9.1	9.7	VE 16
TOWN OF HARPSWELL	CM-134	The transect is located at the head of Harpswell Sound, extending to the north along Doughty Point Road.	357480	3010299	8.1	8.7	9.1	9.7	VE 16
TOWN OF HARPSWELL	CM-135	The transect is located along the Harpswell Sound shoreline at the western end of Tower Hill Road, extending to the northeast toward Harpswell Islands Road.	342388	3003425	8.1	8.7	9.1	9.7	VE 19
TOWN OF HARPSWELL	CM-136	The transect is located along the Merriconeag Sound shoreline at a point approximately 350 feet west of the intersection of Harpswell Islands Road and Garrison Cove Road, extending to the northeast toward Water Cove.	332169	2998531	8.1	8.7	9.1	9.7	VE 14
TOWN OF HARPSWELL	CM-137	The transect is located along the Merriconeag Sound shoreline at a point approximately 250 feet southwest of Steamboat Road, extending to the northeast toward Harpswell Islands Road.	328674	2997122	8.1	8.7	9.1	9.7	VE 22
TOWN OF HARPSWELL	CM-138	The transect is located at the southern end of Abner Point, extending to the north along Abner Point Road.	324809	2995533	8.1	8.7	9.1	9.7	VE 25
TOWN OF HARPSWELL	CM-139	The transect is located along the Mackerel Cove shoreline, approximately midway between Harpswell Islands Road and Abner Point Road, extending to the north toward the intersection of Harpswell Islands Road and Abner Point Road.	327206	2997660	8.1	8.7	9.1	9.7	VE 12
TOWN OF HARPSWELL	CM-140	The transect is located along the eastern shoreline of Baileys Island at the eastern end of Eastbrook Lane, extending to the northwest along Spruce Ledge Road toward Harpswell Islands Road.	322991	2997078	8.1	8.7	9.1	9.7	VE 26
TOWN OF HARPSWELL	CM-141	The transect is located along the eastern shoreline of Baileys Island at a point approximately 750 feet east of the intersection of Harpswell Islands Avenue and Mermaid Lane, extending to the northwest toward Abner Point Road.	327556	2998712	8.1	8.7	9.1	9.7	VE 27
TOWN OF HARPSWELL	CM-142	The transect is located along the eastern shoreline of Baileys Island, extending to the northwest along Linnell Drive toward Harpswell Islands Road.	329640	2999591	8.1	8.7	9.1	9.7	VE 23
TOWN OF HARPSWELL	CM-143	The transect is located along the southeastern shoreline of Orrs Island at a point approximately 400 feet south of the intersection of Harpswell Islands Road and Gleneita Road, extending to the northwest toward Grassy Road.	334538	3001126	8.1	8.7	9.1	9.7	VE 22
TOWN OF HARPSWELL	CM-144	The transect is located along the Lowell Cove shoreline at a point approximately 900 feet south of the intersection of Lowells Cove Road and Lane Road, extending to the north along Lane Road.	337285	3003423	8.1	8.7	9.1	9.7	VE 14
TOWN OF HARPSWELL	CM-145	The transect is located Along the eastern shoreline of Orrs Island at a point approximately 750 feet west of the intersection of Blueberry Lane and Blueberry Ridge Road.	338733	3006092	8.1	8.7	9.1	9.7	VE 30
TOWN OF HARPSWELL	CM-146	The transect is located at the southern end of Totman Point Road, extending to the north toward Harpswell Islands Road.	349526	3011155	8.1	8.7	9.1	9.7	VE 12
TOWN OF HARPSWELL	CM-147	The transect is located at the southern tip of Gun Point, extending to the northeast along Gun Point Road.	340385	3010298	8.1	8.7	9.1	9.7	VE 15

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TOWN OF HARPSWELL	CM-148	The transect is located along the Long Point shoreline at a point approximately 275 feet east of the southern intersection of Tuttle Drive and Long Point Road.	342840	3013152	8.1	8.7	9.1	9.7	VE 23
TOWN OF HARPSWELL	CM-149	The transect is located along Quahog Bay at a point approximately 300 feet southeast of the intersection of Long Point Road and Spunky Way, extending to the northwest toward Long Point Road.	346230	3014321	8.1	8.7	9.1	9.7	VE 23
TOWN OF HARPSWELL	CM-150	The transect is located at the southern tip of Pole Island, extending to the north.	349999	3016581	8.1	8.7	9.1	9.7	VE 14
TOWN OF HARPSWELL	CM-151	The transect is located at the southern end of Twin Coves Lane, extending to the northeast toward Brickyard Cove.	361013	3020272	8.1	8.7	9.1	9.7	VE 12
TOWN OF HARPSWELL	CM-152	The transect is located at the southwest tip of Ragged Island, extending to the northeast.	324827	3012850	8.1	8.7	9.1	9.7	AE 15 VE 24
TOWN OF HARPSWELL	CM-153	The transect is located at a point approximately midway along the southern shoreline of Yarmouth Island, extending to the north.	344353	3018734	8.1	8.7	9.1	9.7	VE 35
TOWN OF HARPSWELL	CM-154	The transect is located at a point approximately 1,000 feet south of Little Ponds Road extending to the northeast.	351329	3019652	8.1	8.7	9.1	9.7	AE 12 VE 12-14
TOWN OF HARPSWELL	CM-155	The transect is located along Hen Cove shoreline at the intersection of Bethel Point Road and Hen Cove Road, extending to the north along Bethel Point Road.	351644	3021894	8.1	8.7	9.1	9.7	VE 11-14
TOWN OF HARPSWELL	CM-156	The transect is located at the southern tip of West Cundys Point, extending to the north along W Cundys Point Road.	342087	3022643	8.1	8.7	9.1	9.7	VE 19
TOWN OF HARPSWELL	CM-157	The transect is located along Sandy Cove at a point approximately 750 feet southeast of the intersection of Cundys Point Road and West Cundys Point Road, extending to the northwest toward Cundys Point Road.	345109	3024532	8.1	8.7	9.1	9.7	VE 13
TOWN OF HARPSWELL	CM-158	The transect is located along the eastern shoreline of the Town of Harpswell at a point approximately 750 feet north of Fort Point, extending to the northwest toward East Cundys Point Road.	345503	3025541	8.1	8.7	9.1	9.7	VE 24
TOWN OF HARPSWELL	CM-159	The transect is located at the head of Cundy Harbor at a point approximately 500 feet east of the intersection of Field Road and Cundy Harbor Road, extending to the north toward Holbrook Street.	350922	3025498	8.1	8.7	9.1	9.7	VE 20
TOWN OF HARPSWELL	CM-160	The transect is located at the southern end of Starboard Lane, extending to the north along Dingley Island.	355330	3026888	8.1	8.7	9.1	9.7	VE 12
TOWN OF HARPSWELL	CM-161	The transect is located at the southern tip of Long Island, extending to the north.	359097	3029373	8.1	8.7	9.1	9.7	VE 23

Section 3
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