APPENDIX D

Coastal Processes Study

Proactive by Design

Geotechnical
Environmental
Ecological
Water
Construction Management

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COASTAL STUDY
SEASIDE STATE PARK
Waterford, CT

GZA File No. 15.0166566.00

May 2017

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1.0 PURPOSE OF THE STUDY

Connecticut Department of Energy and Environmental Protection (CT DEEP) is seeking to redevelop Seaside State Park, a 32-acre waterfront site near Seaside Point in the Town of Waterford, which was originally developed in the 1930s as a tuberculosis sanitorium. A recent study performed by Sasaki Associates presents conceptual designs for four Project alternatives. Each alternative proposes adding or removing nature-based or man-made structures along the Site's coastline that may cause potential impacts to the environment. As such, CT DEEP has requested further evaluation of the four proposed alternatives to evaluate these potential impacts as part of an Environmental Impact Evaluation (EIE). This report focuses on the proposed changes along the waterfront and evaluates the potential impacts of the four alternatives on water levels, waves, flood zone limits, and existing natural features. This report also evaluates feasibility of installing oyster reefs near the existing groins.

2.0 EXISTING CONDITIONS

2.1 METOCEAN DATA ANALYSIS

A review and analysis of historical metocean data was conducted for the purpose of (1) developing an understanding of the existing regional water level, wind, and wave conditions at the Site, and (2) providing input into the models used to study potential impacts of the Project alternatives.

2.2 TIDES AND SEA LEVEL RISE

Tides are the daily rise and fall of the Earth's waters by long period waves that move through the oceans in response to astronomical gravitational forces, predominantly exerted by the moon and sun. The tides in Long Island Sound are diurnal, meaning that during each lunar day (24 hours and 50 minutes) there are two high tides and two low tides that differ in elevation, even in a daily tide cycle.

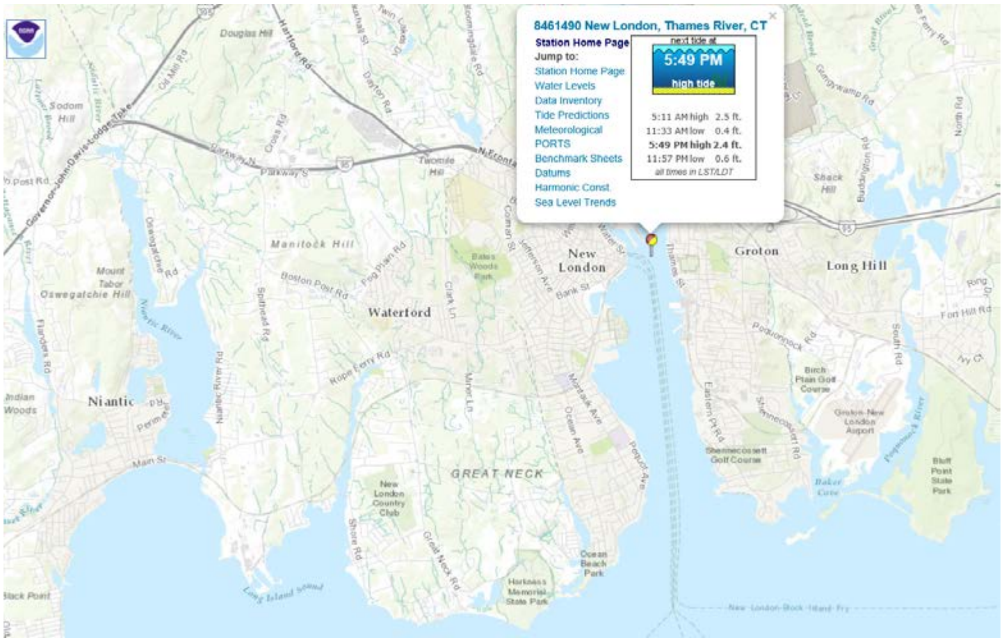


Figure 1 - – NOAA Station 8461490 at New London, Connecticut

GZA retrieved historical tidal data from the National Oceanographic and Atmospheric Administration (NOAA). GZA used NOAA Station 8461490 throughout the study because it is the closest station to the Site and has a very long data inventory, collecting hourly verified water levels since the middle of 1938. NOAA Station 8461490 is located at the State Pier in the Port of New London on the Thames River, just south of the I-95 bridge (Figure 1). Table 1 presents elevations of tidal datums at this station referenced to the North American Vertical Datum of 1988 (NAVD88). At the Site, the mean range of tides (difference between mean high water and mean low water) is 2.56 feet.

Sea Level Rise is the rise of the Earth's waters due to global warming. Global warming causes water levels to rise primarily because of the water volume being added to the oceans by melting land ice. Global warming also causes ocean waters to expand, which contributes to sea level rise. This change in water elevation occurs at a slow rate from year to year, but its cumulative impacts may be significant over the next few decades. The observed sea level trend at the New London, CT, station is shown in Figure 2. The tide station data collected over a 77-year period indicate a mean sea level rise trend of 2.55 millimeters (mm) per year with a 95% confidence interval of +/- 0.23 mm per year.

While the sea level of Long Island Sound is clearly rising, predicting the future rate of sea level rise is complex, highly uncertain, and dependent on many unknown factors (such as future emissions of greenhouse gases, rate of ice melt, etc.). Therefore, it is prudent to consider a range of possible sea level rise outcomes. NOAA and the United States Army Corps of Engineers (USACE) have developed sea level rise projections for use on federal projects in the United States. These projections are available only at NOAA stations that has been in service for a long time (several decades) and are available for the station in New London. The projected sea level rise at New London between the years 1998 and 2100 is shown in Figure 3 (in feet-NAVD). According to these projections, sea levels may be 0.3 – 1 foot higher than their current levels by the year 2030. By 2100, projections show a sea level rise range of 0.8 – 6.8 feet. The range of sea level rise projections increases over time because of increased uncertainty in the projections.

Table 1 - Tidal Datum Elevations at NOAA Station 8461490

Tidal Datum	Elevation (ft-NAVD)
Mean Higher High Water (MHHW)	1.21
Mean High Water (MHW)	0.92
Mean Sea Level (MSL)	-0.30
Mean Tide Level (MTL)	-0.36
Mean Low Water (MLW)	-1.64
Mean Lower Low Water (MLLW)	-1.84

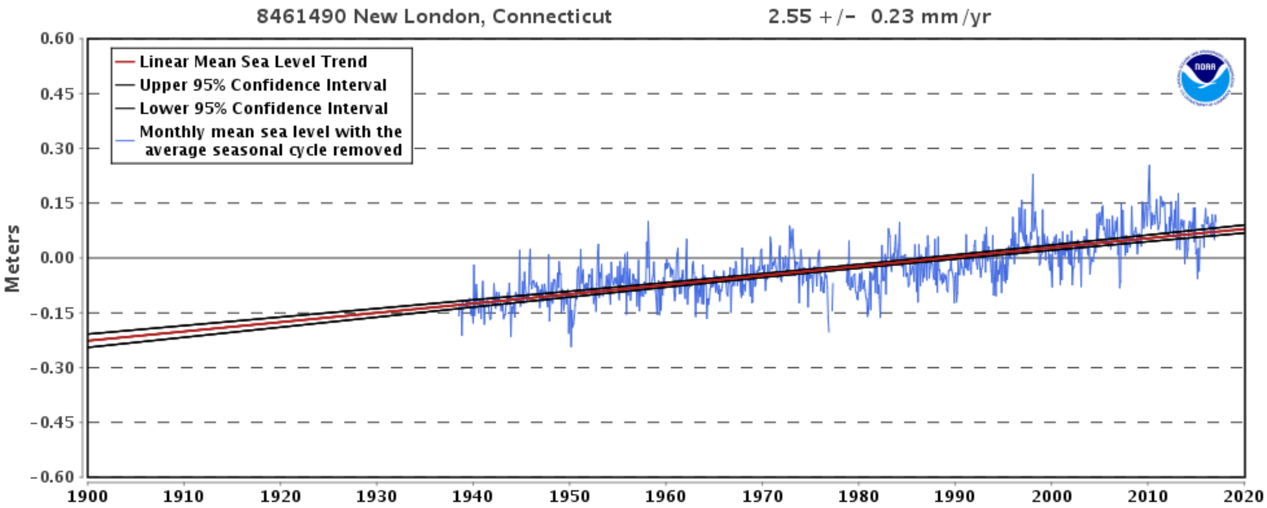


Figure 2 - Mean Sea Level Trend at NOAA Station 8461490 at New London, Connecticut

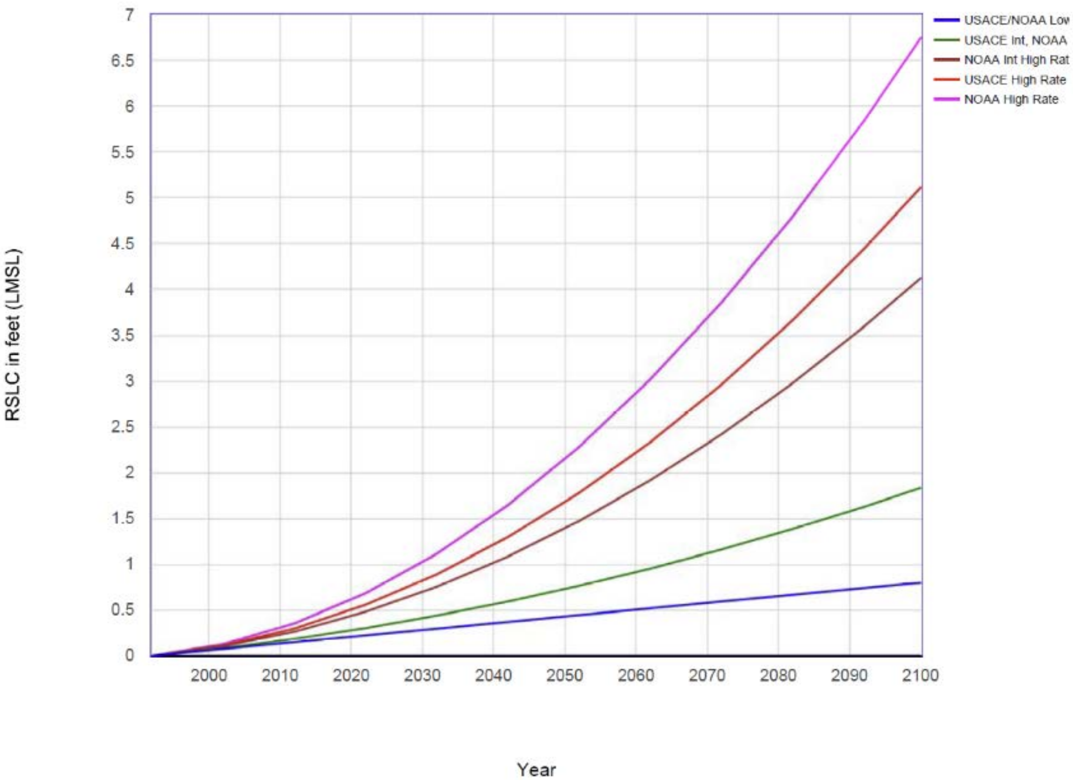
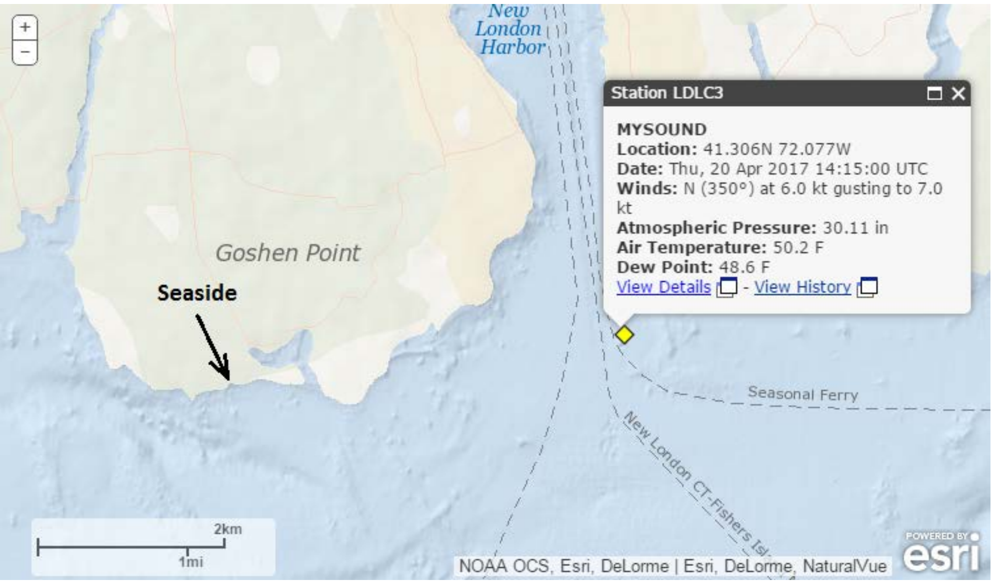


Figure 3 – Relative Sea Level Change Projections at NOAA Station 8461490, New London, CT

2.3 WIND DATA

Wind data was retrieved from NOAA National Data Buoy Center (NDBC) Station LDLC3 located at the Ledge Lighthouse, approximately 3 miles east of the Site. The lighthouse is located at the entrance to the Thames River and New London Harbor as illustrated in Figure 4. Wind data from this station was analyzed to understand wind climatology near the Site and how those changes may impact waves and water levels. Wind data from Station LDLC3 was used as an input parameter to the Simulating Waves Nearshore (SWAN) model which will be described in detail in Section 3.2. Figure 5 presents a wind rose of the data collected at Station LDLC3 between 2004 and 2016. This wind rose shows that over the 12-year data collection period, the majority of the sustained winds were from the Southwest and the Northwest.



Station LDLC3

MYSOUND
Location: 41.306N 72.077W
Date: Thu, 20 Apr 2017 14:15:00 UTC
Winds: N (350°) at 6.0 kt gusting to 7.0 kt
Atmospheric Pressure: 30.11 in
Air Temperature: 50.2 F
Dew Point: 48.6 F
View Details - View History

Figure 4 - Buoy data at Station LDLC3 from National Data Buoy Center

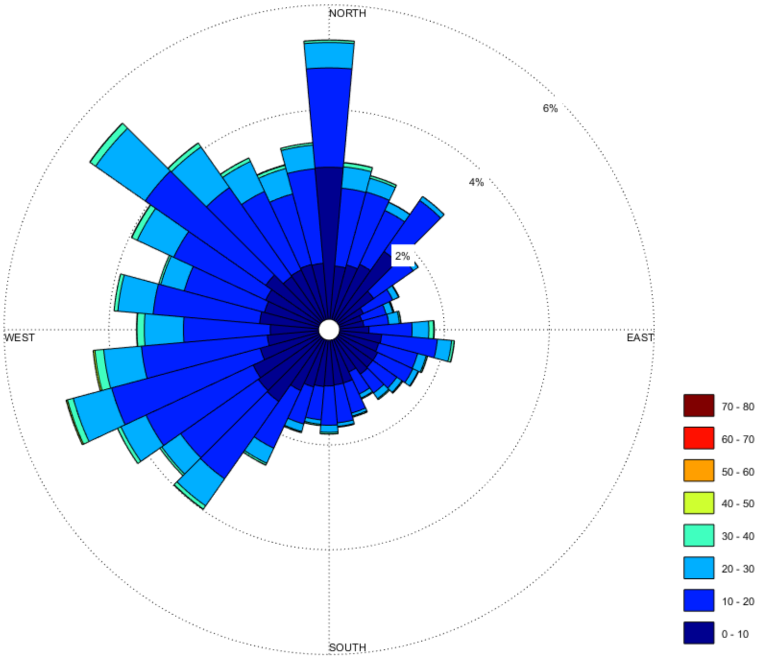
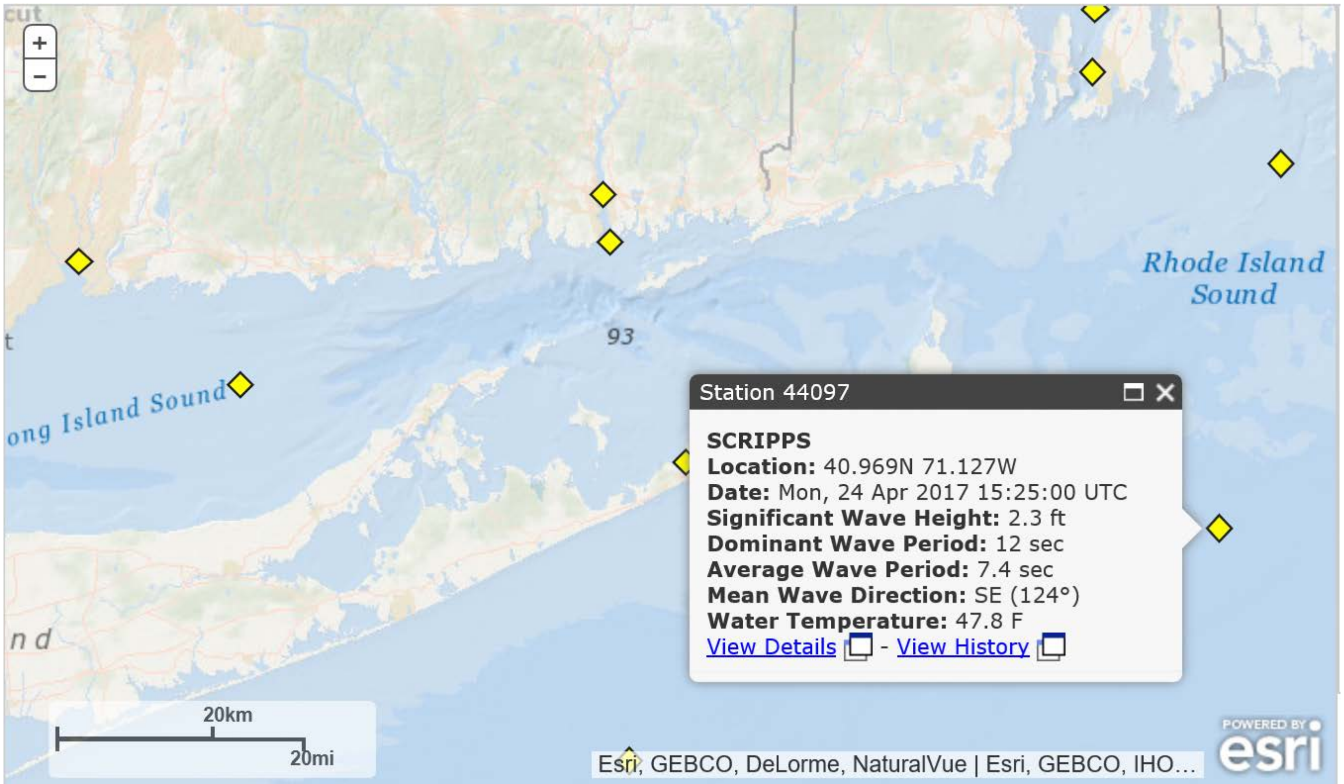


Figure 5 - Wind Rose at NDBC Station LDLC3 based on Observations of Wind Speed and Direction from 2004 to 2016. Wind Speed Magnitude in mph.

2.4 WAVE DATA

The final parameter studied as a part of the metocean analysis was wave activity. Because historical wave data was not available in close proximity to the Site, wave data for the Site needed to be modeled in SWAN with input from wave buoys farther from the Site. The closest such buoy is NOAA NDBC Buoy 44039 which is located in central Long Island Sound. Unfortunately, historical data from this station is erratic with large gaps in either wave height, wave period, or wave direction, making it a poor data set for input to the SWAN model. NOAA NDBC Buoy 44097 is the next closest wave buoy to the Site, and is located southeast of Block Island, Rhode Island (Figure 6). Wave data from this station is more complete and therefore was used as input to the SWAN model. A statistical analysis of the modeled wave data was conducted to reveal seasonal patterns in wave direction and magnitude. SWAN model setup and results are presented in detail under Section 3.2 – Wave Modeling.



Station 44097

SCRIPPS
Location: 40.969N 71.127W
Date: Mon, 24 Apr 2017 15:25:00 UTC
Significant Wave Height: 2.3 ft
Dominant Wave Period: 12 sec
Average Wave Period: 7.4 sec
Mean Wave Direction: SE (124°)
Water Temperature: 47.8 F
View Details - View History

Figure 6 - Buoy data at Station 44097 from National Data Buoy Center

2.5 FLOOD RISK

GZA used the Federal Insurance Management Agency's (FEMA) Flood Insurance Rate Maps (FIRMs) to identify existing flood risk at the Site (Figure 7). While creating coastal FIRMs, FEMA runs flood risk analyses along one-dimensional transects. These transects are placed some distance apart from each other, depending on the change in climatology, coastal geomorphology and the flood proneness of the site. FIRMs are mapped to reflect exact results of the flood risk analyses at the transects and by means of interpolation at any area in between. Topographic contours are used as a guidance tool while mapping areas between transects.

The Site is located between coastal transects 29 and 30 of the effective FIRM (FEMA Panel 09011C0492J, effective August 5, 2013). The positioning of the transects in relation to the Site indicates that flood risk at the Site was mapped by means of interpolation of flood risk analysis results. FEMA mapped V-zones using runup mapping method at transect 29 and wave overtopping splash zone at transect 30. One-percent annual chance stillwater elevation (SWEL) extracted from the Flood Insurance Study (FIS) at the Site is 9.4 feet-NAVD88. The flood zone seaward of the seawall is VE 16, indicating a maximum water elevation of 16 ft-NAVD88 and wave heights greater than 3 feet. With the sheltering effects of the seawall, flood zone reduces to AE 12 (Maximum water elevation of 12 ft-NAVD88 with wave heights smaller than 3 feet) landward of the seawall and the 100-year floodplain terminates before reaching the Main Hospital building.

FEMA FIRMs present the 500-year floodplain as a bathtub model. In other words, the surge associated with a 500-year storm event is expected to inundate land with a ground elevation lower than the surge elevation. This mapping method does not include the impacts of waves or flood components such as wave setup. The Main Hospital and a part of the Employee Residence is located in the 500-year floodplain (Shaded Zone X). Even though a one-percent annual chance storm would not cause flooding at these two structures, a less frequent event such as the 500-year storm event could cause coastal flood damage at the buildings.

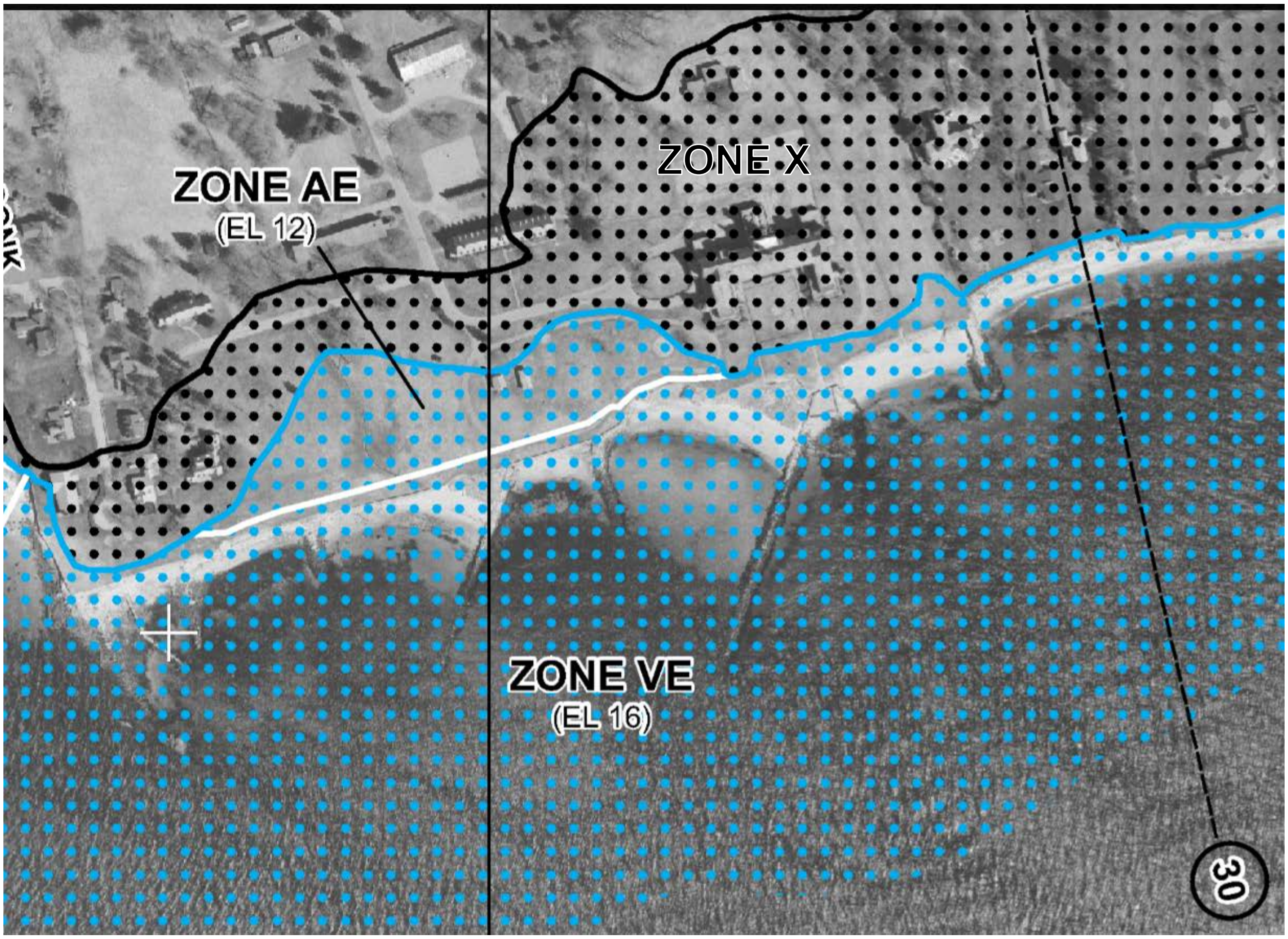


Figure 7 – FEMA Flood Insurance Rate Map at the project Site (FEMA Panel 09011C0492J, effective August 5, 2013)

3.0 NUMERICAL MODELING OF WAVES AND FLOOD RISK

3.1 DEVELOPMENT OF DIGITAL ELEVATION MODEL (DEM)

A Digital Elevation Model (DEM) of Site topography and bathymetry was created to use as a model input for the SWAN modeling effort.

GZA conducted an extensive review of available sources of data from State and federal agencies and ultimately chose to use data downloaded from the NOAA National Centers for Environmental Information Bathymetric Data Viewer. This service compiles the most up to date topographic LIDAR (light detection and ranging) data and multibeam bathymetric data which is publicly available and provides the data for download. GZA used the NOAA Coastal Relief Model (CRM) because it covered the entire model domain with a reasonable data resolution.

3.2 SWAN WAVE MODELING

SWAN is a third-generation wave model used to obtain realistic estimates of short-crested wind generated wave parameters in coastal areas, lakes, and estuaries. GZA used SWAN to simulate wave conditions at the Site because of the lack of measured data near the Site. The SWAN mesh covers a wide area extending out of the Long Island Sound, placing the offshore boundary of the mesh coincident with the NOAA Buoy 44097. Figure 8 presents the SWAN model domain consisting of 29,930 unstructured finite elements and NOAA Buoy 44097 at the mesh boundary. Figure 9 presents the model mesh with bathymetry and topography contours from CRM interpolated onto it.

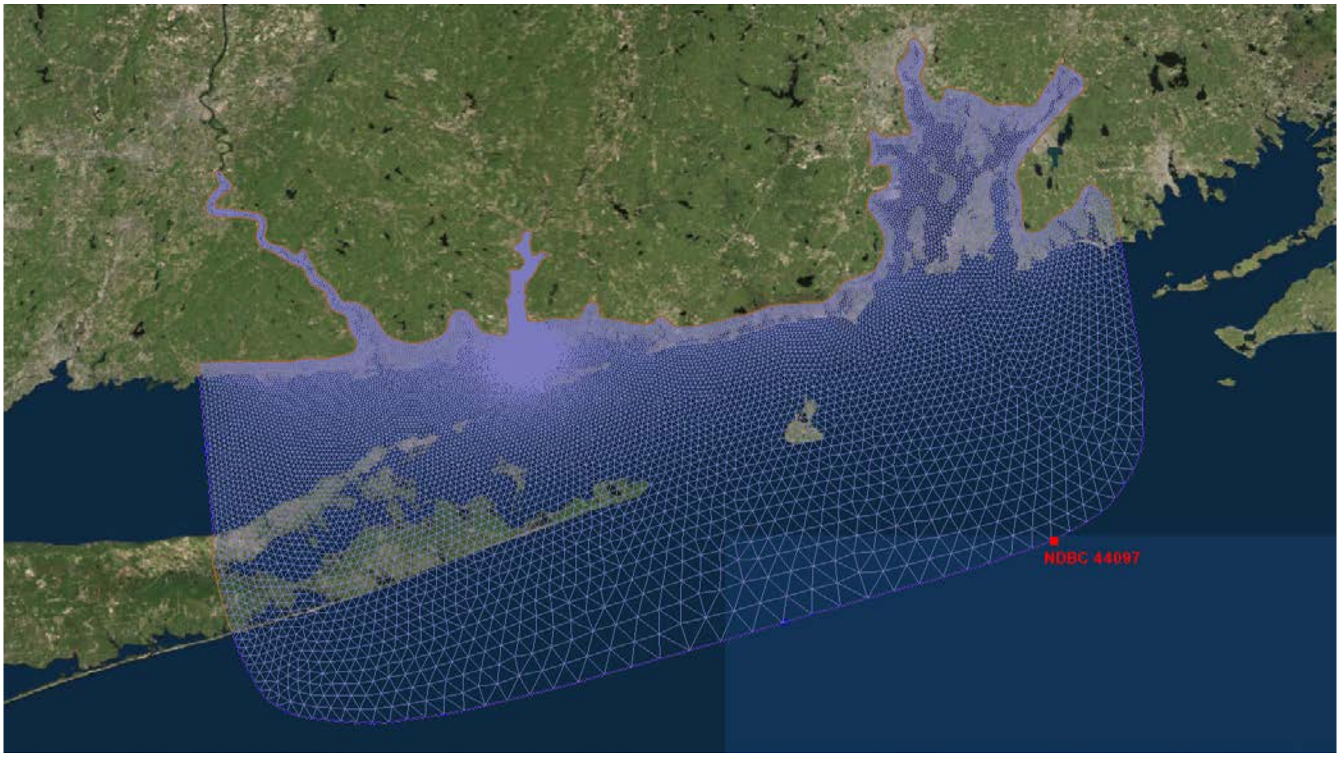


Figure 8 - SWAN Model Domain

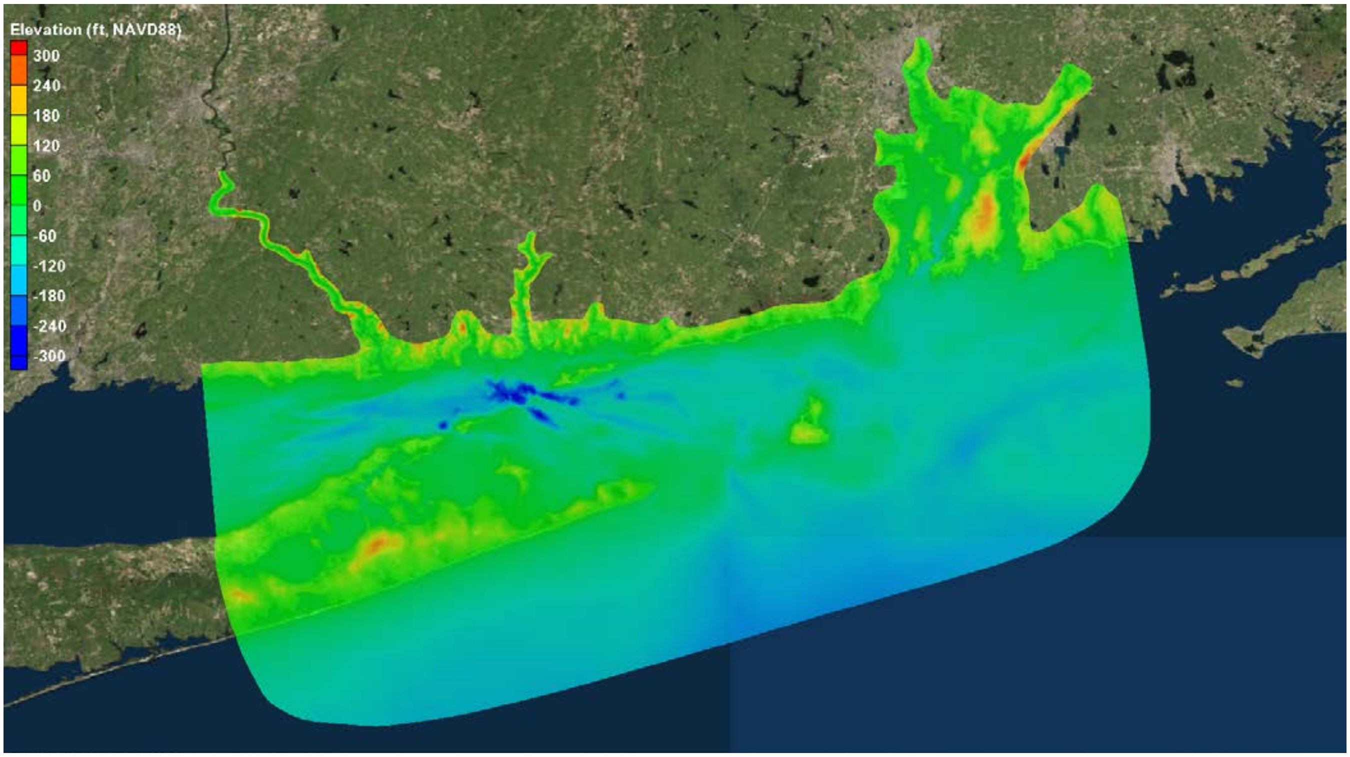


Figure 9 - Elevation of the SWAN Computational Domain.

GZA simulated waves over a one-year period. The large extent of the model acted as a restricting factor to run simulations over multiple years. Running the model over one year allowed a fine enough mesh resolution to resolve bathymetric features and allowed reasonable run time for the model. GZA reviewed the completeness of input data sets to determine the most recent and complete year of data across input parameters and determined that data from 2014 was the best data set available. Below is a summary of the input parameters reviewed. Details about these parameters are discussed in Section 2.1 – Metocean Data Analysis.

- Water level data from NOAA Station 8461490 at the State Pier in New London;
- Wind data from NDBC Station LDLC3 located at the mouth of the Thames River; and
- Wave data from NDBC buoy 44097 located in the Atlantic Ocean southeast of Block Island, Rhode Island.

The SWAN simulated wave characteristics at the Site in the year 2014 are output at a mesh node approximately 1,500 feet to the south of the Project coastline located at the seaward end of the navigation channel (Figure 10). GZA created a wave rose based on the output wave data (Figure 11), which indicates the dominant direction for most of the smaller waves (less than three feet in height) is from the southeast in the vicinity of the Site. The wave rose also indicates that storm events that generate waves with greater than three feet of wave height is from the southwest.

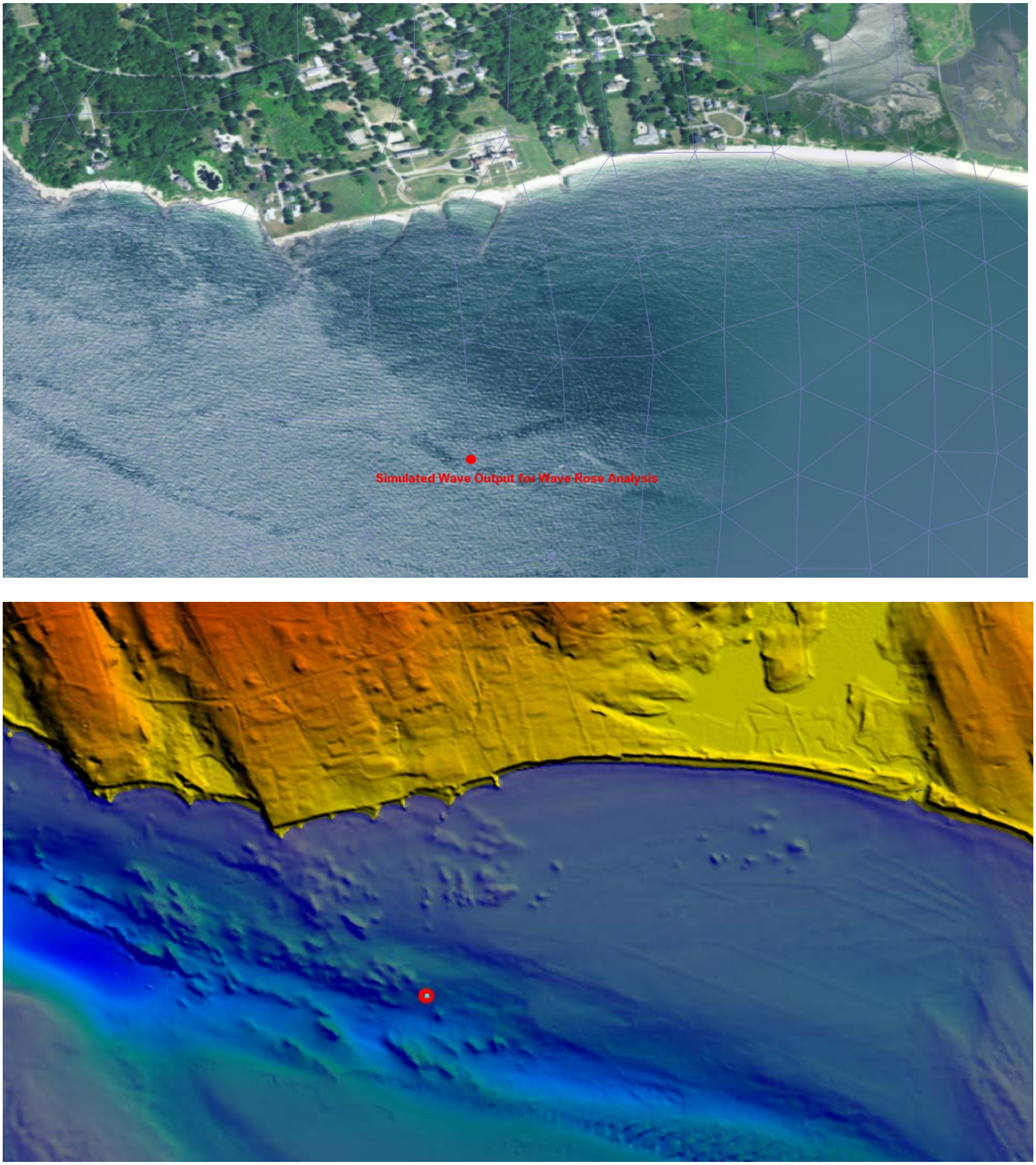


Figure 10 – (a) Simulated Wave Output Station for Wave Rose Analysis, (b) Wave Output Station with Bathymetric Contours

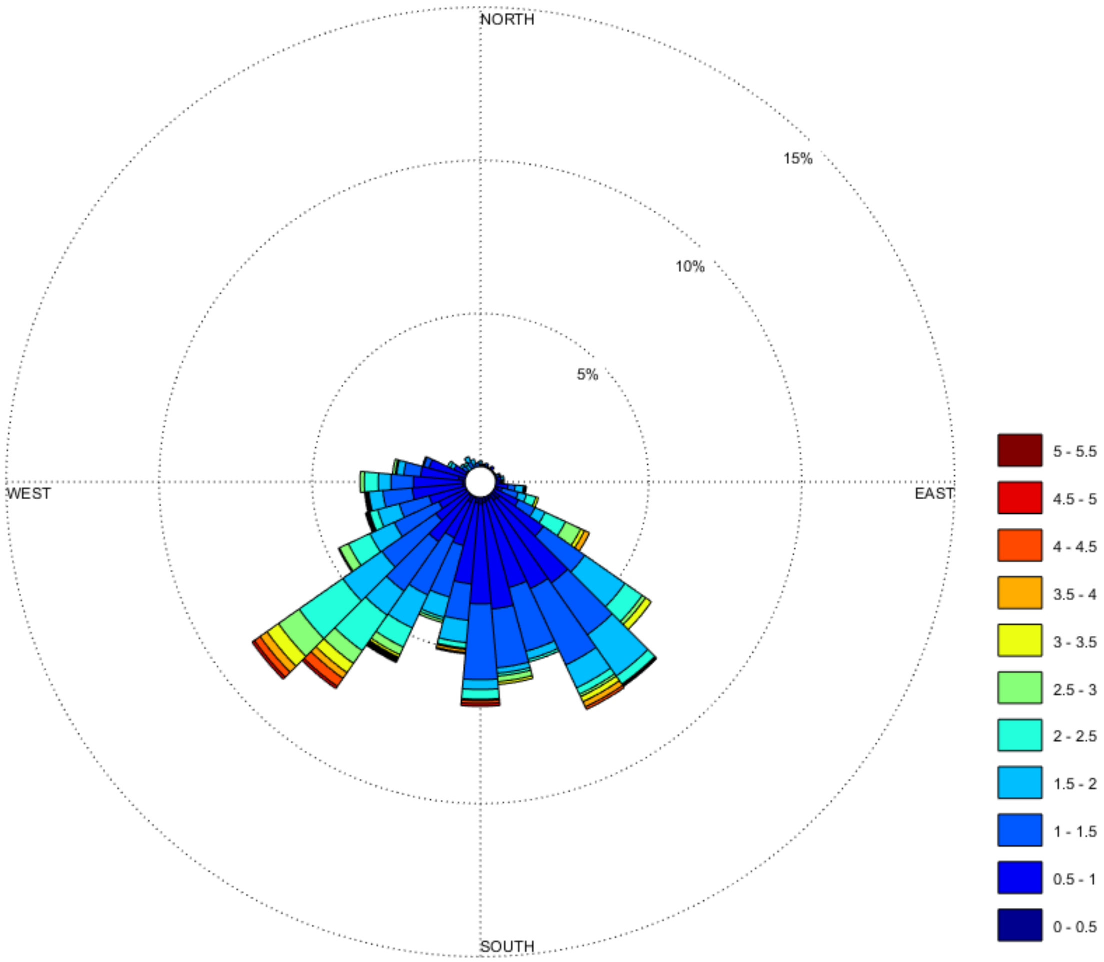


Figure 11- Wave Rose at Seaside vicinity based on SWAN modeled waves in 2014. Significant Wave Height Magnitude in feet.

3.3 OVERLAND PROPAGATION MODELING – WHAFIS

The Wave Height Analysis for Flood Insurance Studies (WHAFIS) model was developed to predict wave heights associated with coastal storms that cause surge. The model calculates wave heights and flood zone elevations as waves propagate landward. WHAFIS uses surge height, wave setup, and wave height at the shoreline as inputs to the model and incorporates impacts of shoreline erosion, friction under different land use conditions, and regeneration of waves over inland bodies of water.

For the Ecological Park alternative, which involves the removal of the seawall, additional WHAFIS modeling was performed to investigate the impact of seawall removal on flood elevations and the extent of the impacts. GZA re-ran the WHAFIS model at a transect presented in Figure 12. The WHAFIS transect was placed at a central location in the Project area between existing groins where the sheltering effect of the groins is minimal to calculate flood risk conservatively.

Figure 12- WHAFIS Transect Location

With the Ecological Park alternative, all existing groins at the Site would be maintained as wave protection measures and the seawall would be replaced with a dune feature.

The main components of coastal flooding are storm surge and wave effects. Storm surge is the rise of the ocean surface in response to barometric pressure variations and to the stress of the wind acting over the water surface. Because the surge level is dependent on climatologic events, and not geomorphology or manmade structures, none of the proposed alternatives would impact storm surge level at the Site. Similarly, wave conditions at the Site would not be impacted because the Ecological Park alternative proposes to keep the main wave sheltering structures (groins) in place. As such, GZA used the same 100-year total water elevations (SWEL and wave setup) from the effective Flood Insurance Study and calculated depth limited waves at the shoreline for this scenario. The only component that could lead to a change in flood elevations and extent of inundation is the soft water/land interface created by the removal of the seawall. The proposed dune is a natural and soft feature and hence could erode during a storm event. FEMA has specific guidelines around dune erosion for sandy beaches. As a summary, FEMA determined that any dune having a cross-sectional area of less than 540 square feet (or 20 cubic yards volume per foot along shoreline) would be removed completely by a 100-year storm event. Since this

Project alternative is only at a conceptual design level, without engineering design documents that determined the geometric characteristics, crest elevation of the dune, and volume, GZA took a conservative approach and assumed the dune would be completely removed during a 100-year storm event. Removal of the seawall causes a milder profile slope and necessitates an overland wave propagation analysis as opposed to a runup analysis as in the effective FIRM to map the flood risk zones. Figure 13 presents the eroded beach profile determined according to FEMA guidelines and used in the WHAFIS analysis.

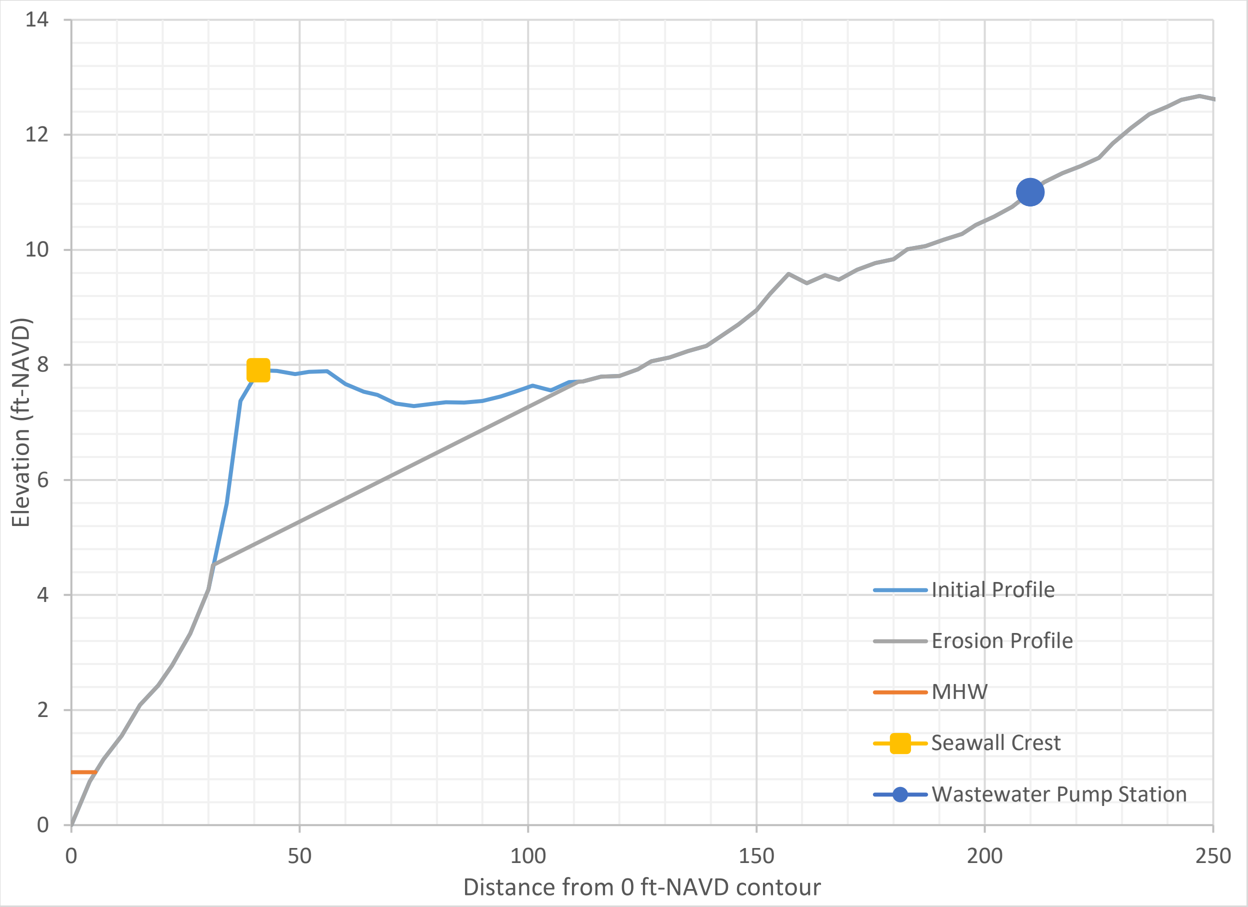


Figure 13 – Initial and Eroded Shoreline Profiles at the WHAFIS Transect

Figure 14 presents a map of the flood zones and their extent under a 100-year coastal storm event. A comparison of the updated flood risk map to the effective FIRM (Section 2.2, Figure 7) reveals that removal of the seawall would cause flood elevations to increase, but it would not impact flood inundation boundaries significantly. The main reason the flood boundaries would remain similar is that the surge level is not impacted by the seawall removal. In the effective FIRM, wave energy at the shoreline is attenuated by the seawall via wave breaking. Therefore, high velocity VE zones stay seaward of the seawall. When the seawall is removed high energy waves (greater than 3 feet in height) would erode the dune and propagate inland with the elevated storm water levels, causing flood elevations landward of the seawall to increase. One obvious outcome of increased flood elevations would be higher flood insurance rates. A second important impact would be on building guidelines. FEMA has different guidelines building under Special Flood Hazard Area depending on the flood zones and wave conditions. Building under high velocity VE zones have the most stringent rules and expanding the VE zones inland would cause these building codes to impact a larger area. Existing site and proposed alternatives do not have buildings within the Special Flood Hazard Area with the exception of the wastewater pump station; however, it is GZA's recommendation to keep the implications of larger VE zones on building codes in case building plans at the site change in the future.

It is important to note that the modeled FEMA flood zones shown in Figure 14 were created using a more detailed, higher resolution model than what FEMA used to create the FIRM maps (Figure 7); therefore, the existing FIRM maps are not directly comparable to the map that simulates the changes in flood boundaries/elevations with the seawall removal. However, conclusions can still be drawn about changes in flood boundaries and elevations.

As described under Section 2.2, FEMA FIRMs delineate the 500-year floodplain solely by the surge elevation, without the impacts of waves, and, as mentioned earlier in this section, surge levels depend on climatologic events rather than geomorphology or man-made structures. Therefore, FEMA's 500-year flood elevation and boundaries would not be impacted with any of the proposed changes.

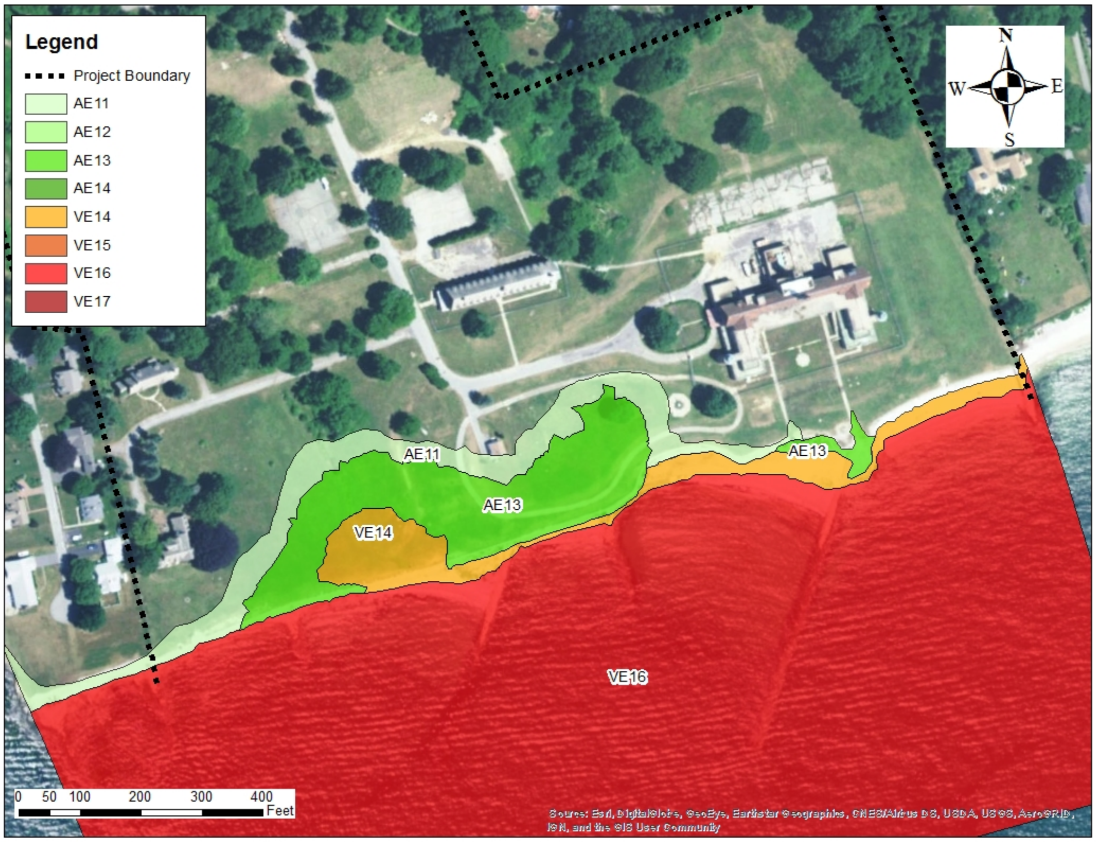
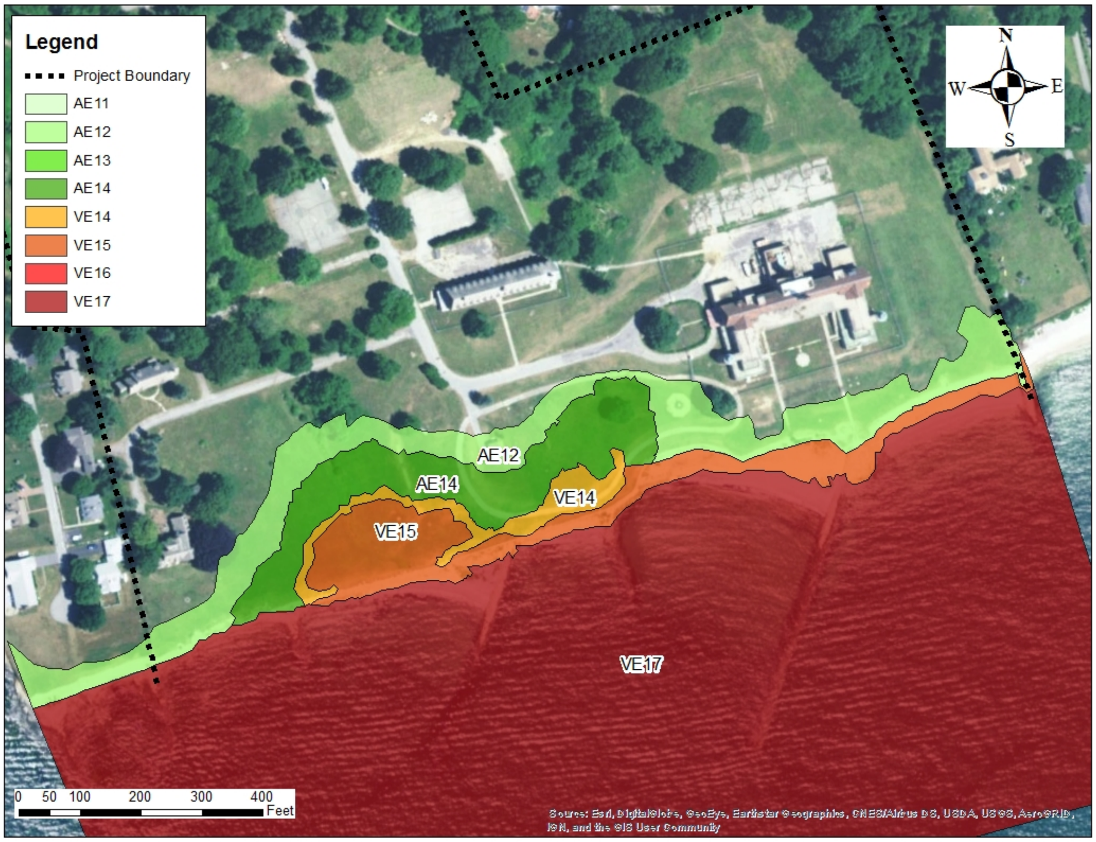


Figure 14– Updated 100-year Flood Elevation Zones without the Seawall



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 15 – Updated 100-year Flood Elevation Zones without the Seawall under Sea Level Rise conditions in 50 years

GZA also analyzed 100-year flood elevation zones without the seawall with the impacts of sea level rise. Sea level rise projections were obtained from USACE's intermediate sea level rise projection at the New London tide gage. The projected still water elevation in case of a 100-year storm event is 10.2 feet-NAVD in 50 years. GZA updated the WHAFIS run with the new Stillwater elevation (100-year SWEL plus Sea Level Rise) and the depth limited wave at the project shoreline. Figure 15 presents flood zone elevations and their extent with the impact of sea level rise. Impacts of sea level rise would increase the flood zones by approximately 1 foot throughout the project site. It would also cause VE zones to cover a larger footprint, expanding the zones landward.

GZA also investigated changes to flood elevations at neighboring properties caused by the proposed alternatives at the Site. The main component of flood, the surge level, is determined by climatologic processes and cannot be altered by the proposed changes. Unlike surge height, the wave component of flooding could be altered by either removing structures providing wave protection, such as the groins, or by adding green or gray structures that would attenuate wave energy. A detailed review of the four Project alternatives revealed that none of the alternatives included removal of the existing groins or adding wave protection measures that would provide additional wave attenuation along the entire length of the shoreline. Therefore, the proposed changes at the shoreline would not impact the wave conditions at the Site or at neighboring properties. Since both component of flooding would not be impacted by the proposed alternatives, flood zones and limits would remain unchanged at neighboring properties.

4.0 ENVIRONMENTAL IMPACTS OF PROPOSED ALTERNATIVES

4.1 DESTINATION PARK ALTERNATIVE

The Destination Park alternative includes realigning the seawall to give it a curved look along a proposed boardwalk. The new seawall would also include gaps in the middle to allow tidal water in and out of the proposed wet meadows. Seawalls are hard (gray) structures constructed to form a coastal defense against coastal processes such as the tides, waves or tsunamis. Creating gaps along the structure to allow water flow in and out would create a weak point which would be detrimental to its structural integrity. Especially during surge events, water will be forced to pass through a constricted opening, causing flow velocity to increase. Higher flow velocities would increase scour behind the seawall.

Constructing a new seawall with openings would also impact flood elevations. While performing Flood Insurance Studies, FEMA places transects to execute analysis at the most flood-prone location at a Site. The wall opening would be the most flood-prone location at Seaside and flood maps created under this scenario would be similar to the one presented in Figure 14.

This alternative would also include adding three tidal pools next to existing groins. The exiting groins provide a relatively sheltered site from waves. Adding tidal pools between the groins could provide additional wave attenuation; however, the intensity is not anticipated to be significant, since these features would be built very close to the shoreline, with relatively short structure heights.

One other feature included this alternative is the fishing pier. It is GZA's understanding that this pier would be built by capping the existing groin or placing the pier on piles while retained most, if not all, of the existing stone. The existing groin would not be extended and its crest elevation would not be significantly altered. With these assumptions, the fishing pier would not cause a change in wave conditions or the sediment transport patterns at the Site.

4.2 ECOLOGICAL PARK ALTERNATIVE

The most significant component of the Ecological Park alternative would be the removal of the seawall and placement of the dune feature. The obvious impact of this change is the change to the flood elevations, which is discussed in detail under Section 3.3. To summarize, removing the seawall would eliminate the hard water/land interface and would allow natural erosion processes to occur. During significant storm events such as the one-percent annual chance storm, erosion of the land would allow higher waves to propagate inland, increasing flood elevations at the Site.

Another impact of creating a soft water/land interface would be the change in sediment transport. Beaches are dynamic environments with constant movement of sediment as long as there is enough sediment to travel and there is no obstruction to prevent the transport. Sediment transport occurs in two directions: 1) parallel to the shoreline (longshore) and 2) perpendicular to the shoreline (cross-shore). Longshore sediment transport (also known as littoral transport) is driven by the angle of waves in relation to the shoreline as they approach the beach. Cross-shore sediment transport is driven by wave steepness with steeper storm waves typically scouring the beach and transporting sand offshore while less steep summer waves transporting sand back to the beach (Wright and Short, 1984).

Coastal structures such as seawalls cause additional erosive processes like wave reflection and scouring depleting sediment source at the beach. On the other hand, groins obstruct alongshore sediment transport processes, trapping sediment where they are constructed and reducing the amount of sediment transported to downdrift beaches.

The existing Site condition includes both a seawall and multiple submerged and exposed groins. Removal of the seawall would eliminate additional erosive processes; however, keeping the groins in place would not allow sediment transport processes to occur naturally. Removal of the seawall would allow sediment to be added to the local sediment budget via cross-shore sediment transport. However, the majority of the sediment added to the sediment budget would be trapped locally, since the groins obstruct alongshore sediment transport mechanisms.

One other feature included in this alternative is the fishing pier. A discussion about the impacts of the fishing pier is provided under the Destination Park alternative.

4.3 PASSIVE RECREATION PARK ALTERNATIVE

The Passive Recreation Park alternative does not propose any changes at the Site's shoreline and therefore this alternative does not have any potential environmental impacts related to flooding or wave action.

4.4 HYBRID PARK ALTERNATIVE

On the seaward side of the seawall, the Hybrid Park alternative includes adding oyster reefs and a fishing pier. Oyster reefs are dense, expansive clusters of oyster formed by oyster larvae settling on shells of other oysters. Oysters have a critical role in maintaining water quality and recycling water and nutrients within an ecosystem. Oysters are filter feeders and they feed by planktons and particles in the water and they remove chemicals, nutrients and pollutants from the water. Oysters also stabilize shorelines and prevent erosion by acting as a wave attenuation feature. When used as a shoreline stabilization measure, oyster reefs are placed approximately parallel to the shoreline preferably as clusters with a gap in between to allow water to flow around them in order not to interfere with the natural flow of currents (Figure 16). Oyster reefs create a low energy nearshore environment by attenuating larger waves. As a result, they reduce erosive forces at the shoreline and allow sediment carried in the water column to settle landward of the reefs.

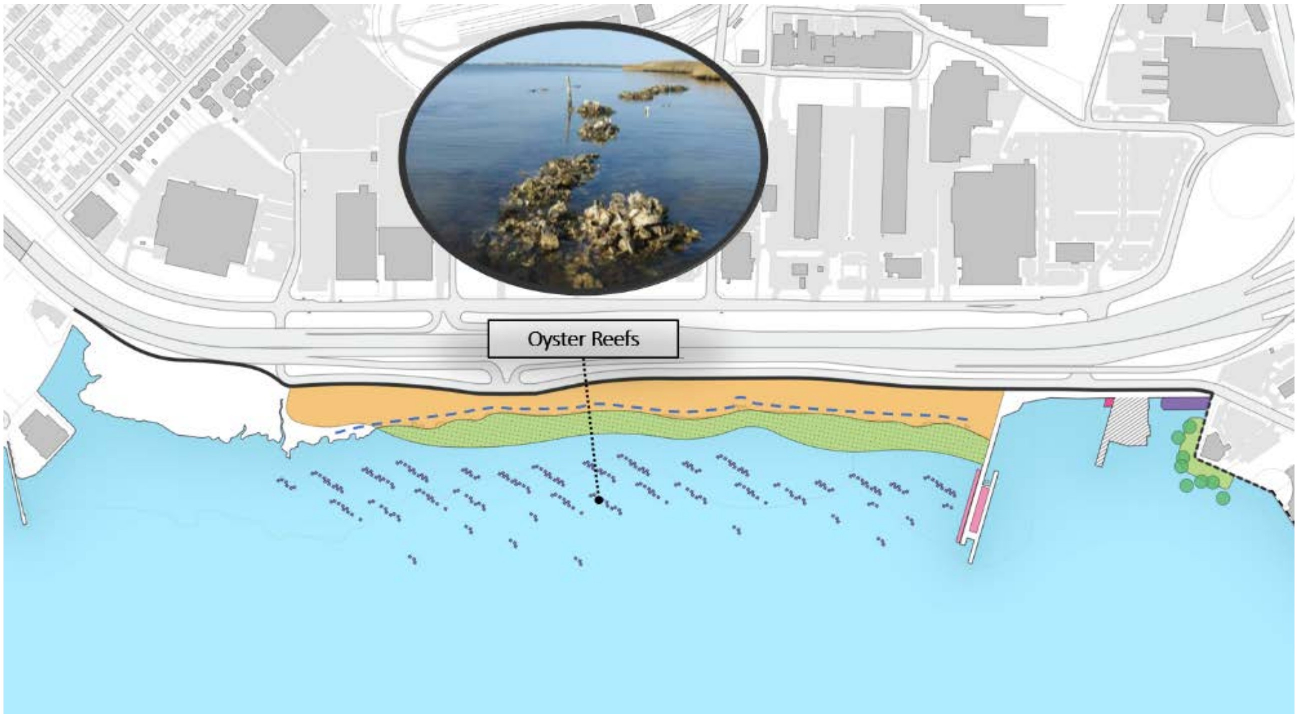


Figure 16– Schematic Representation of Using Oyster Reefs for Shoreline Stabilization

The Hybrid Park alternative concept plan presents reefs along the groins, almost perpendicular to the shoreline. Placement starts on the dry beach and extends nearshore approximately to the tip of the shorter size groins. With the layout presented in the conceptual design drawings, oyster reefs would not provide additional shoreline protection to the Site. Repositioning the reefs should be considered if shoreline protection is one of the goals of including oyster reefs in the design. With their layout in the conceptual design documents, oyster reefs would not impact water elevation, wave, or sediment transport processes. Additionally, oysters feed from planktons and particles from the water making salty or brackish water necessary for their survival. It is GZA's recommendation to redesign the proposed oyster reef features to remove them from the dry beach.

Another consideration for placing oyster reefs at the Site should be human health. Oysters have a popularity as a delicacy. Oysters harvested for human consumption are raised in waters with certain water quality requirements. Placing oysters at a location accessible to park visitors should either be restricted or be done in accordance with regulatory guidelines and protocols. GZA recommends contacting the U.S. Fish and Wildlife Service regarding oyster reefs during the design and permitting stage of the Project, if this alternative is selected.

One other feature included in this alternative is the fishing pier. A discussion about the impacts of the fishing pier is provided under the Destination Park alternative discussion.

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