US Army Corps
of Engineers®
New York District

Integrated Hurricane Sandy General Reevaluation Report and Environmental Impact Statement

Atlantic Coast of New York

East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

Sub Appendix A2-D: Phase 2 Wave Modeling for Design Basis Update

US Army Corps of Engineers

D. SUB-APPENDIX A2-D: PHASE 2 WAVE MODELING FOR DESIGN BASIS UPDATE

D.1 Wave Analysis Background

As part of Phase 1, design wave-heights at the HFFRRF project alignments were specified by applying the wave-height statistics derived from the USACE (2015) North Atlantic Comprehensive Coastal Study (NACCS) database.

The NACCS (2015) was conducted to provide information for computing the joint probability of coastal storm forcing parameters for the U.S. North Atlantic Coast, which is critical for effective flood risk management. As part of the NACCS, estimates of nearshore winds, waves, and water-levels, as well as the associated marginal and joint probabilities were evaluated. This was achieved by simulating a selected suite of tropical and extra-tropical storms to characterize the regional storm hazard. The modeling suite consisted of an offshore wave model (WAM) for simulation of deep-water waves, which were subsequently used to generate boundary conditions for a near-shore steady state wave model STWAVE. The STWAVE model for near-shore waves also allowed for simulation of local wind-generated waves, and was paired with the hydrodynamic circulation model ADCIRC to allow for dynamic interaction between surge and waves. While the ADCIRC model mesh extends across the western North Atlantic with approximately 3.1 million nodes, the nearshore wave model STWAVE is applied over ten domains from coastal Virginia to Maine, including one in the upper New York Bight area. A suite of 1150 storms including 100 extratropical events, and 1,050 synthetic tropical events were simulated for the NACCS production. The high-frequency outputs and statistical products from the modeling are publicly archived for a relatively small number of 18,000 'Save Points'.

The expected significant wave-heights for the 20% AEP (5-year RP) were extracted from NACCS at 137 Save Points along the perimeter of Jamaica Bay shown in Figure 3-1. The data from the save points was applied to all of Jamaica Bay using Natural Neighbor interpolation. Allowances were made for project features that are relatively sheltered or set back from the shoreline, and might thereby be less exposed to the bay, by assigning a minimum design wave-height of one (1) foot for such features.

D.2 Phase 2 Wave Analysis Refinement

As part of Phase 2, the expected wave-heights at the project features were updated to account for the wave transformation that might occur between the NACCS Save Point located within the Bay, and the individual project features located at the shoreline, using a 1-D wave model. In addition, the wave model was also applied to optimize the design of the Natural and Nature-Based Features (NNBFs), which are proposed to accompany select project features. The implementation of these updates is elaborated in the following sections.

Wave Model Setup

The Simulation of Waves Nearshore (SWAN) model (Booij et al, 1996) was used to simulate the transformation of waves along 1-D transects from boundary points within the Bay to the corresponding project alignment features. The bathymetric data for the modeling was derived from high-resolution (1/9 arc seconds or 10 feet) resolution topo-bathy Digital Elevation Models (DEMs) developed by NOAA, post- Hurricane Sandy in 2012. The map of the DEM in the Jamaica Bay Study Area is shown in Figure D-1.

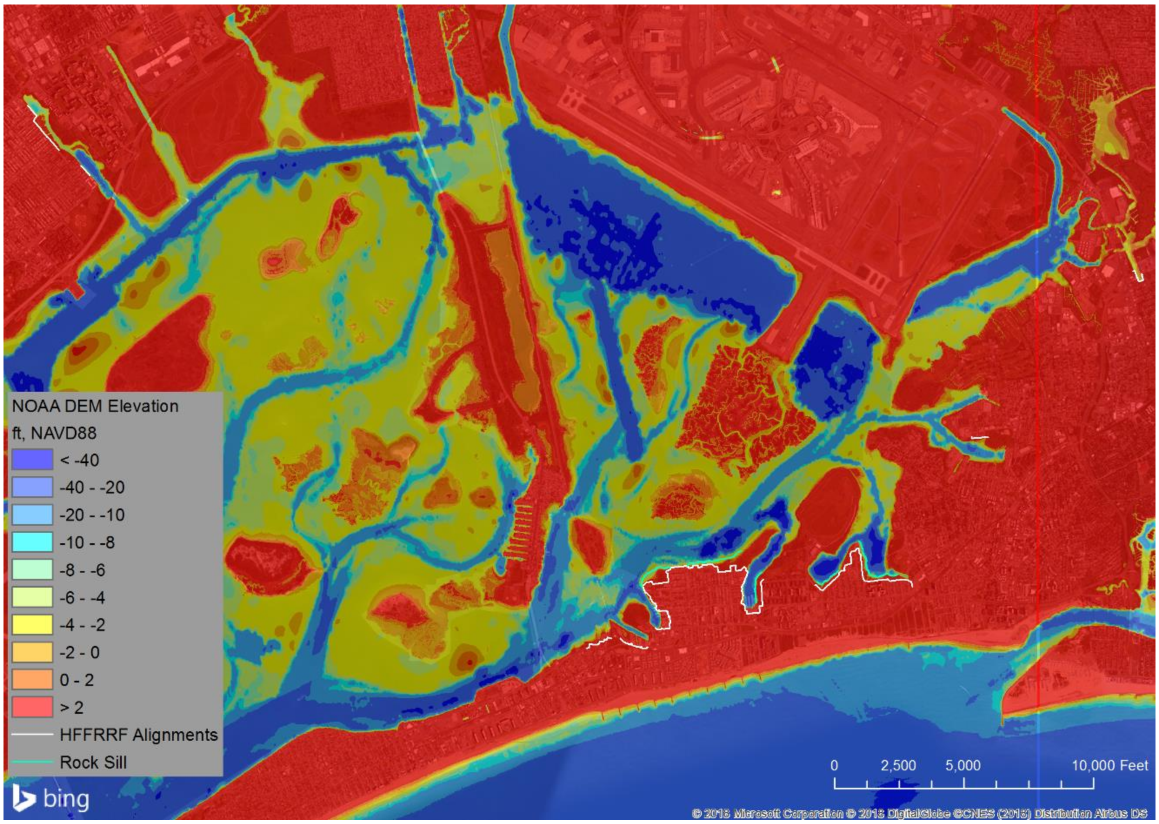

Figure D-1: NOAA High-resolution DEM in Jamaica Bay Study Area

Modeling wave-heights for project features with no NNBF

Based on the available resolution of NACCS wave statistics across the Bay, transects were drawn to model wave-transformation at several HFFRRF locations using the 20% AEP (5-year RP) wave-height as boundary condition. Figure D-2 shows these transect locations with respect to the HFFRRF alignments.


Boundary Point (NACCS)
HFFRRF Alignments
Rock Sill
Wave Model Transect
0 875 1,750 3,500 Feet
bing


Boundary Point (NACCS)
HFFRRF Alignments
Rock Sill
Wave Model Transect
0 875 1,750 3,500 Feet
bing

Figure D-2: 1-D wave model transect locations for refinement of Design Wave condition

At each of these transects, the bottom elevation profile was extracted from the DEM every 6 feet to specify the model bathymetry. A model still-water elevation corresponding to the respective 20% AEP (5-year RP) Still Water-Level plus the Sea Level Rise (SLR) corresponding to the USACE intermediate projection for 2068 was applied. A typical JONSWAP wave spectrum centered on the 5-year NACCS wave-height at the boundary point, and a corresponding peak wave-period according to typical fetch and depth limited wave growth (CERC, 1984) was assumed. The SWAN model was run in stationary mode, which means that the wave conditions within the 1-D model domain were allowed to evolve to a steady-state with the input conditions. Figure D-3 shows an overview of the model outputs with colored transects representing the magnitude of the simulated wave-heights. Profile of bottom elevation, water-level, and predicted wave-height at each of these transects identified in Figure D-2 is shown in Figure D-4 through Figure D-7.

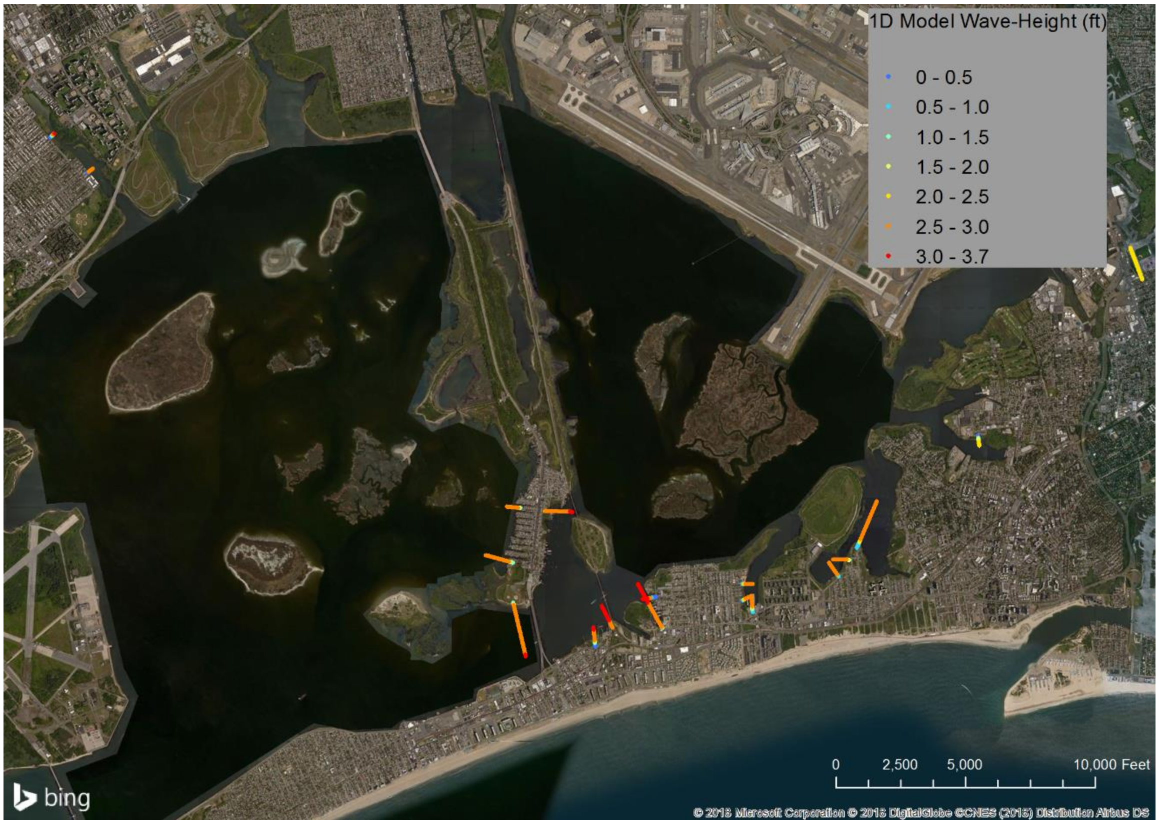

Figure D-3: Overview of wave model output showing predicted wave-heights

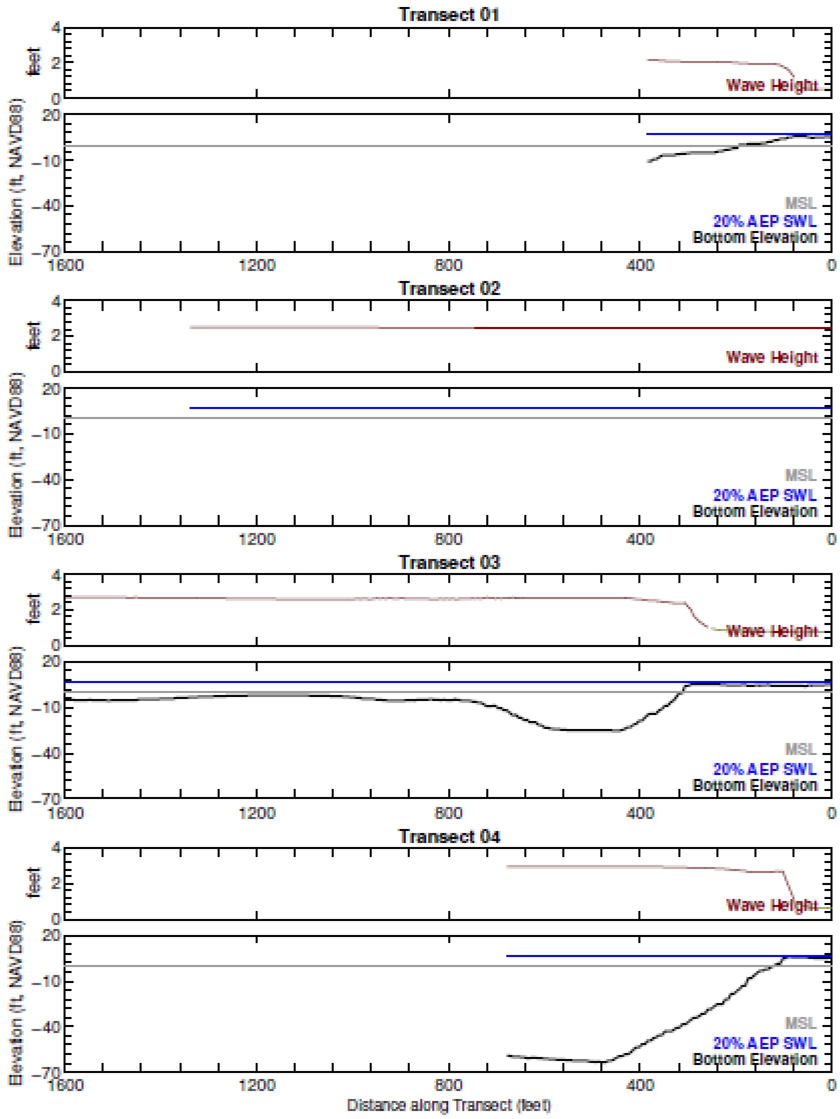

Figure D-4: Transect elevation profiles showing 1-D model wave-height transformation

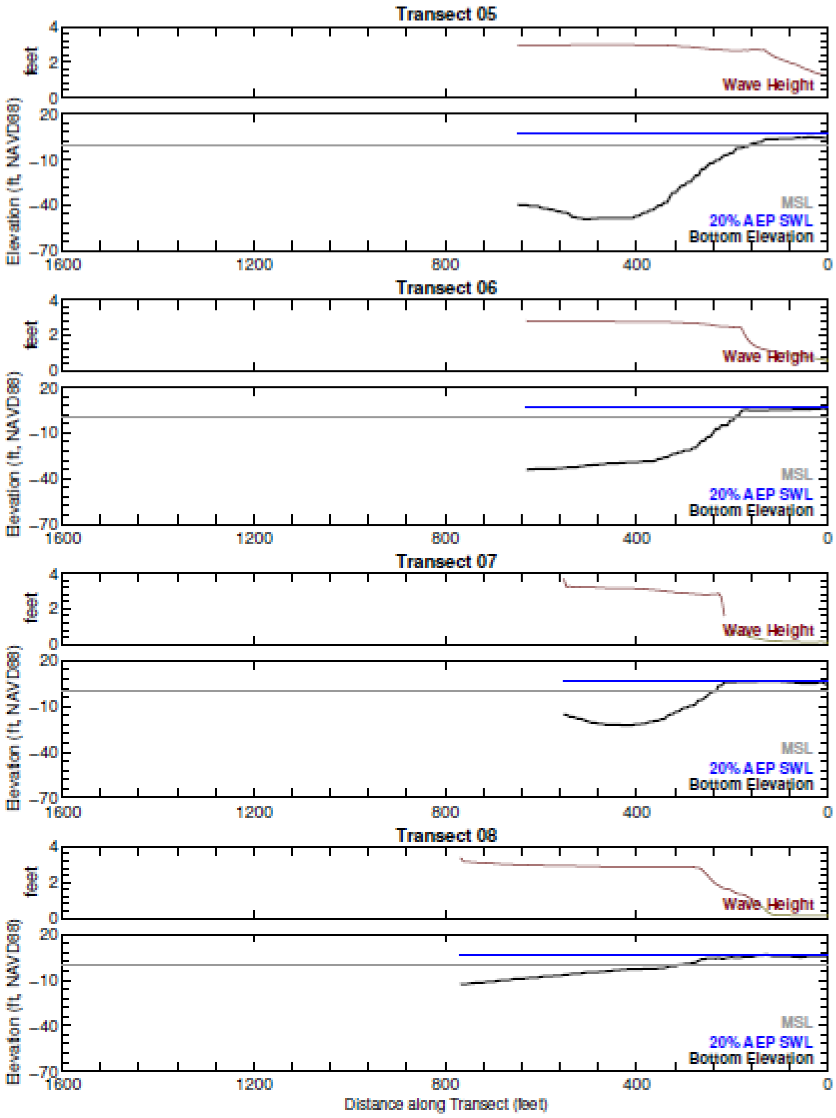

Figure D-5: Transect elevation profiles showing 1-D model wave-height transformation

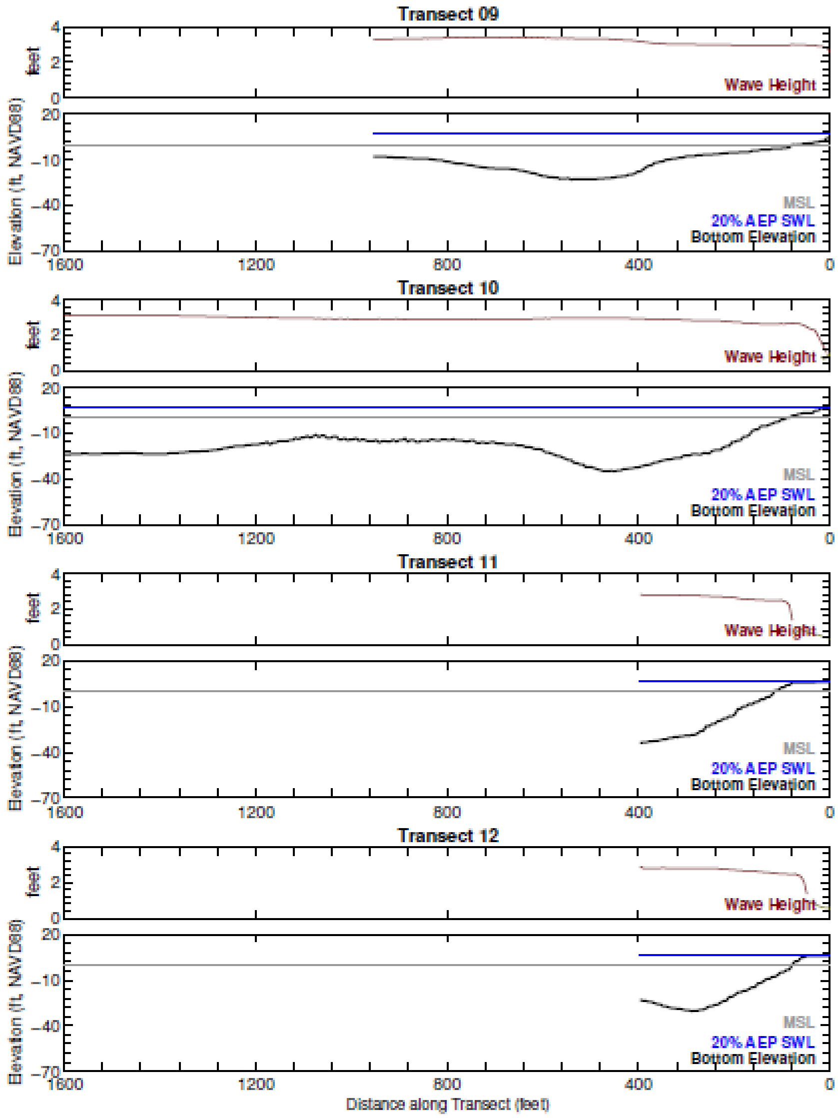

Figure D-6: Transect elevation profiles showing 1-D model wave-height transformation

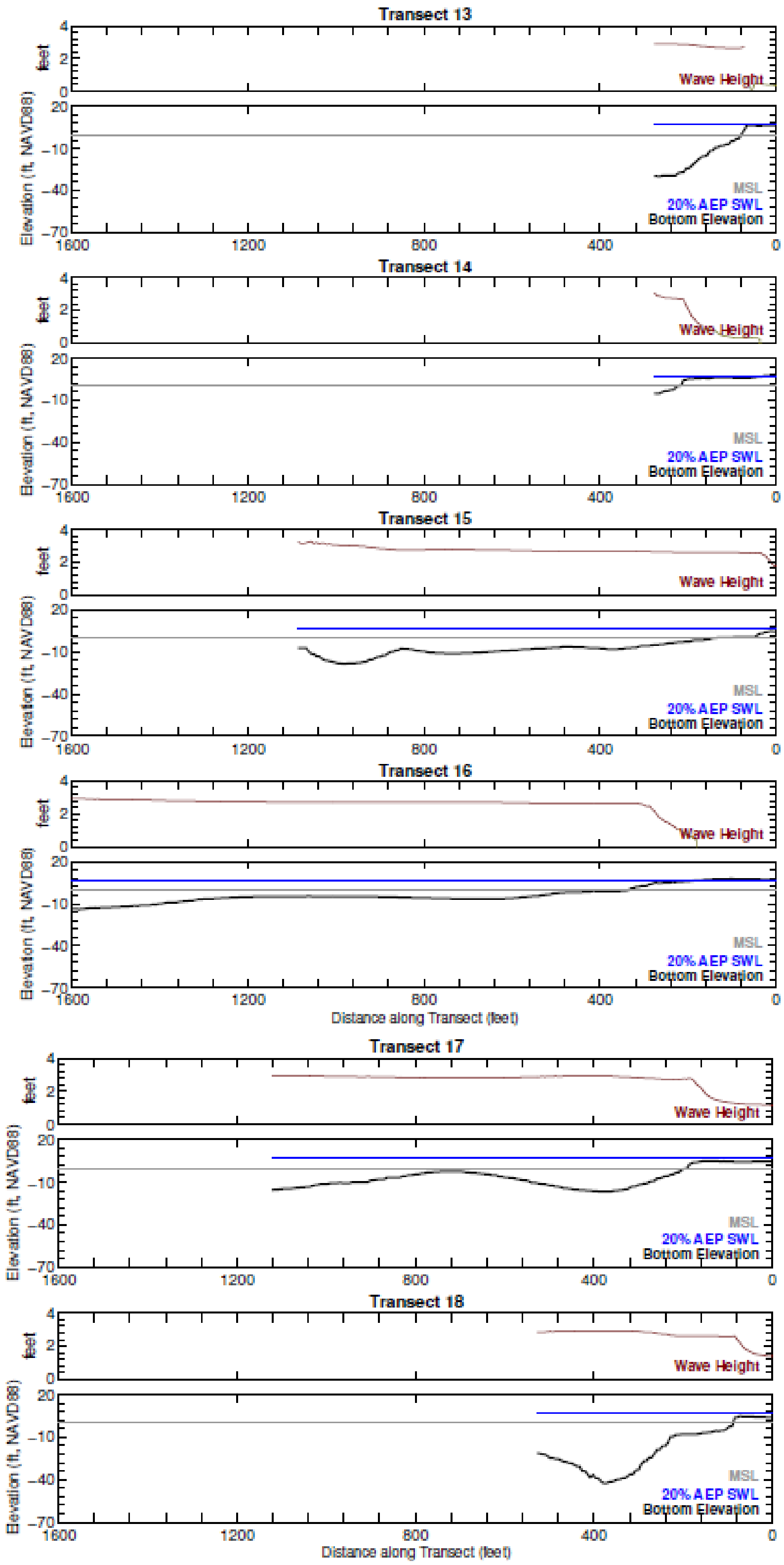

Figure D-7: Transect elevation profiles showing 1-D model wave-height transformation

The design wave-height at each HFFRRF alignment was subsequently updated using the simulated wave-height at the feature from the nearest model transect. A map of the features denoting the updated wave-heights is shown in Figure D-8. The corresponding required freeboards for the features developed during Phase 2 of the HFFRRF screening were set using the overtopping criterion of one liter per second per meter.

Figure D-8: Updated wave-heights at HFFRRF alignments using 1-D wave model to transform NACCS data

D.3 Wave Model application to NNBF locations

Wave Analysis set-up and Schematization

The wave model was further applied to optimize the elevation of rock-sills that are part of the Natural and Nature Base Features with the goal of minimizing wave impacts on the wetland vegetation. Following the guidance in Miller et al, 2016, a target transmitted wave-height across the feature sills of half a foot or less under operational conditions was deemed necessary to protect the habitat on the leeward side of the sill. Figure D-9 shows a typical NNBF profile for the Jamaica Bay Study Area.

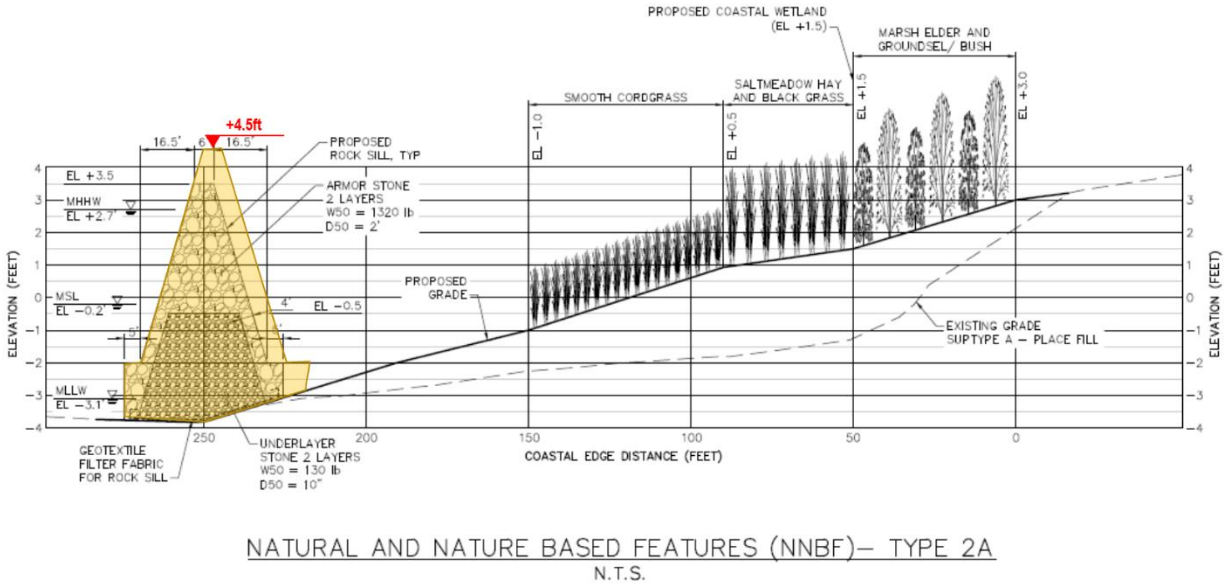

Figure D-9: Typical NNBF section

The simulated model transects for the NNBF locations are shown in Figure D-10. The model bathymetry for each of these transects was specified at 1 foot resolution based on the NOAA DEM. The existing bottom profile from the DEM was adapted to include a rock sill at a base elevation of -2’ NAVD88, a sill slope of 1 in 3, and a crest width of 6’. The NNBF area behind the sill was set at a 1 in 40 slope. Although it is recognized that the actual configuration of the NNBF rock sill and leeward wetlands and berm will vary once preliminary designs are completed, the focus of this analysis was on the transmitted wave-height. The transmitted wave-height is mainly a function of the incoming wave-height, the bay-side bathymetric profile and the crest geometry of the rock sill. As such the schematic representation of the landward profile was deemed acceptable for the feasibility study.

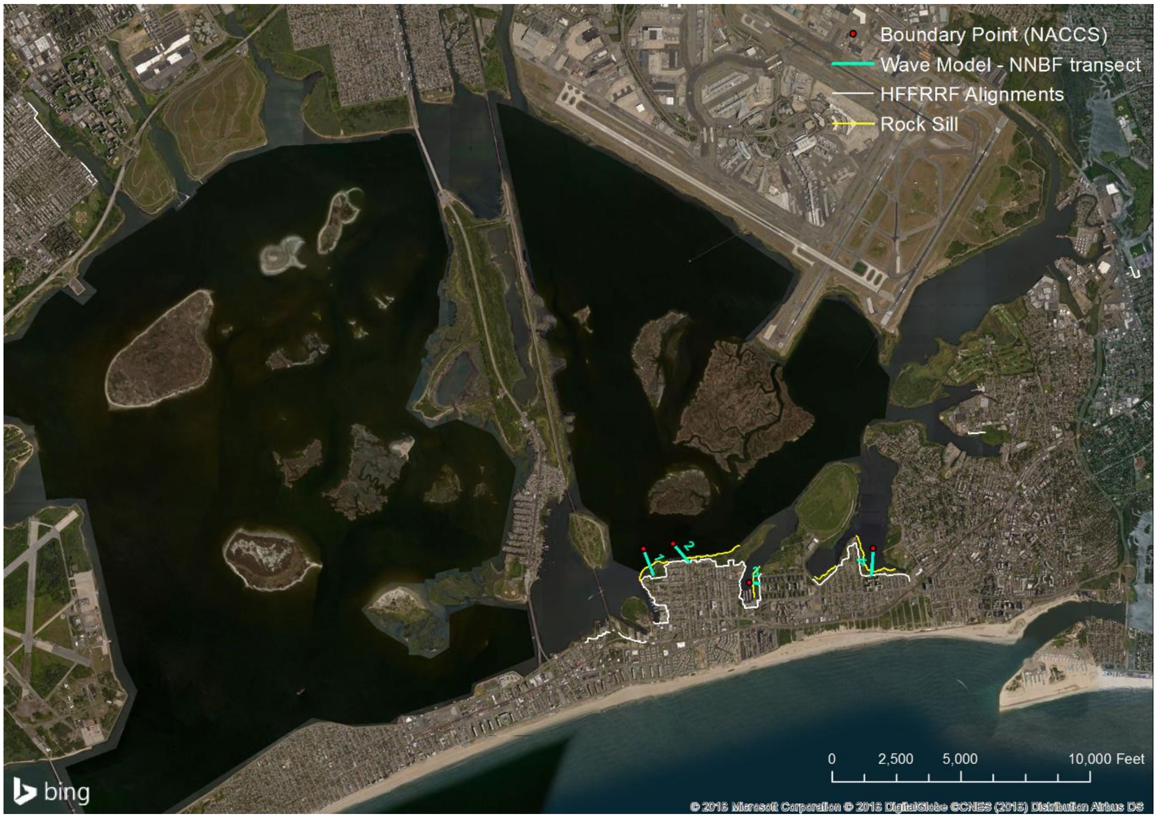

Figure D-10: Location of NNBF wave model transects

Several possible sill elevations as part of each NNBF were simulated in the wave model, using a 1, 2, and 5 year return period wave-height as boundary condition, to identify the lowest possible sill elevation providing the necessary sheltering from waves on the leeward side of the sill for each condition. A still water elevation with the same probability of occurrence as the wave-height was assumed for each scenario. Inclusion of expected future sea-level-rise scenarios was omitted since the created NNBFs were deemed most vulnerable to erosion in the near-term timeframe, following construction. For each scenario, the lowest sill crest elevation at which the predicted transmitted wave-height did not exceed the target height of 0.5 foot was identified.

Wave Modeling Results for NNBF Rock Sills

Table D-2 shows the modeled sill crest elevations meeting that requirement for each scenario at a typical transect location (Transect 1 at Arverne). The cumulative probability of occurrence of each scenario over a 1 or 2 year period is also shown. Applying the target wave-height of half a foot to a 2 year return period event yields a minimum sill-crest elevation of 4.5 feet. The 2 year return period scenario corresponds to a 39% chance of occurrence over 1 year, and 63% chance over 2 years. Using the same target transmitted wave-height on a 5 year return period event would yield a minimum sill-crest elevation of 5.5 feet. The 5 year return period scenario corresponds to an 18% chance of occurrence over 1 year, and 33% chance over 2 years.

Table D-2: Summary of required sill-crest elevation to meet transmitted wave-height target for NNBFs under different scenarios

Inputs / Scenario			**Sill-Crest Elevation with target Transmitted Wave Ht. of 0.5 ft**		**Cumulative Likelihood of Exceedance (%)**	
Return Period (years)	Wave-Height at Boundary (ft)	Still Water Level (ft, NAVD88)	w.r.t NAVD88	w.r.t MHHW	Over 1 year	Over 2 years
1	2.53	3.61	3.5	0.8	63	86
2	2.72	4.56	4.5	1.8	39	63
5	2.90	5.74	5.5	2.8	18	33
10	3.04	6.83	6.5	3.8	10	18
20	3.18	7.77	7.5	4.8	5	10

Synopsis

Part of the wave analysis was to provide guidance on the elevation of the rock sill such that it is capable of protecting existing and newly established marsh during normal operational events and to minimize the cumulative impact of storms for a 1-2 year period. Following the guidance in Miller et al, 2016, this appendix describes sill height estimates using wave modeling analysis to protect the habitat during normal operational periods, keeping the transmitted wave-height at 0.5 feet or less except during extreme storms. Table D-2 shows sill height options for the wave climate in Jamaica Bay expressed in AEP terms. The higher the sill, the greater the protection, however, higher sills translate into greater costs and could increase visual nuisance.

It should further be stressed that the rock sill in combination with a healthy wetland habitat on the landward side will also provide wave protection (wave-height reduction) during the design conditions (20% AEP water level and waves) for the berm feature. I.e. the rock sill allows for a reduction in freeboard and lower crest elevation for the upland situated berm feature. Compared to the “without rock sill scenario” the freeboard reduction is approximately 1.5 feet for a rock sill with a 4.5 foot crest elevation.

The analyses documented herein demonstrates a 4.5 to 5.5 foot sill will be sufficient to achieve the target wave conditions for the NNBFs, which may only be expected to be exceeded at an acceptable average rate of once in two years.

If higher risk can be justified, for example by accepting some maintenance schedule for habitat repair, the sill height can be further optimized in PED. However for feasibility level design and screening purposes it is recommended to set the rock sill crest elevation at an elevation of +4.5 feet NAVD88.

The predicted wave-heights across each model transect at the NNBF locations under future 20% AEP design conditions is shown in Figure D-11.

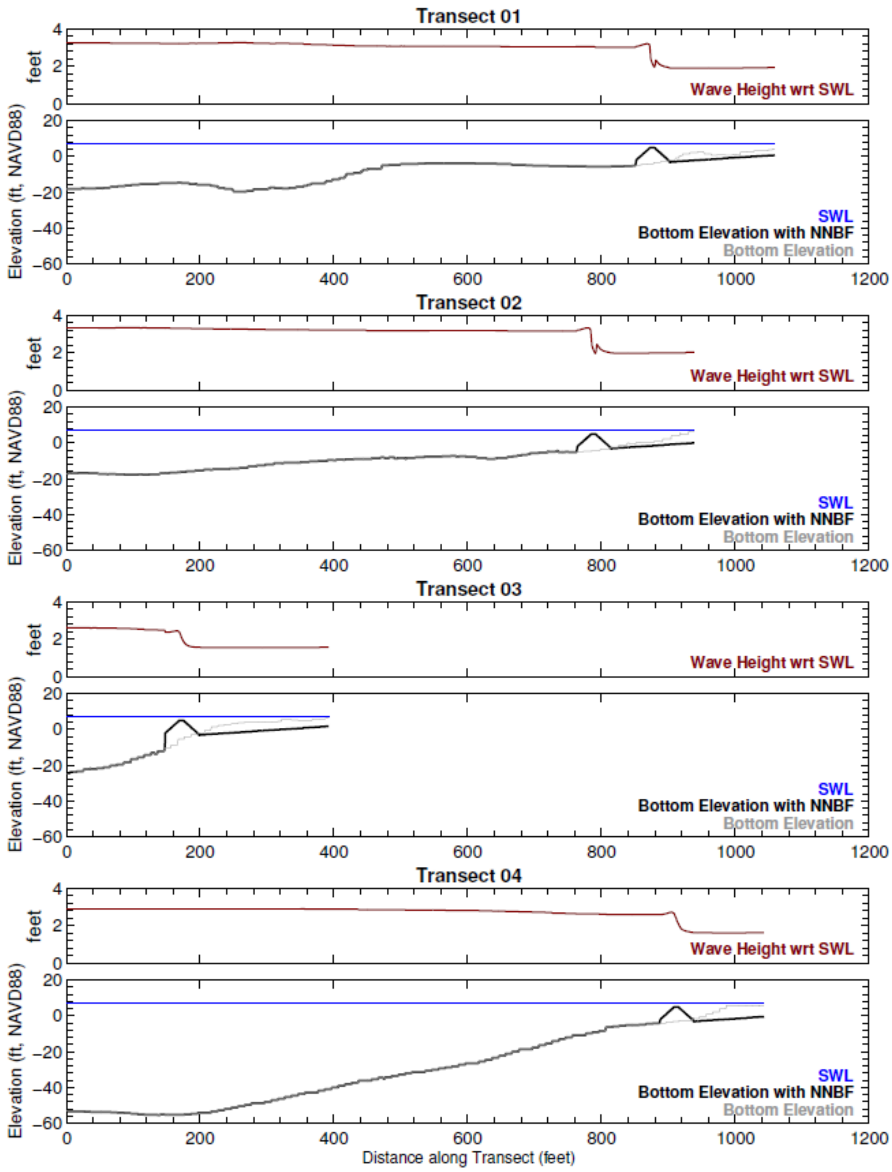

Figure D-11: 1-D model wave-height transformation across NNBFs

D.4 Conclusion

Assumptions and limitations of the modeling approach

The NACCS analysis forms the basis of the current study, as it is used to provide boundary conditions for the 1-D wave transformation to the shoreline features. The expected annual exceedance probabilities for different wave conditions within Jamaica Bay are therefore based on the NACCS analysis. However, the 1-D wave transformation model parameters were not calibrated or validated for lack of wave data at the shoreline. Additional sensitivity analysis to model parameters or more detailed analysis using a 2-D wave model could help further improve confidence in the model results.

Recommendations for PED phase

The wave transect modeling analysis was based on the bathymetric DEM from NOAA, which is a compilation of several data sources including some historical data. Since the estimated expected wave at the location of a feature depends on the bottom profile, additional data collection for the bay-side cross-shore profiles at the locations of the constructed features is recommended as part of any analysis during the PED phase. Other assumptions of lesser consequence on the estimated wave-height at feature or sill were made as part of the 1-D model. The model did not consider the friction effects due to any vegetation, especially as part of the NNBFs. A schematized representation of the NNBFs was used at this stage of analysis, which can be refined based on actual design during the PED phase.