APPENDIX B
PHYSICAL CONDITONS

Physical Conditions

A general description of the coastal processes that characterize the study area and provide the basis for design and evaluation of storm protection measures are provided in this section.

Winds

Predominant wind directions in the Study Area are from the southwest, west and northwest. Although winds from the southeast are not predominate (less than 25% of all wind occurrences), due to the study area shoreline orientation (159 degrees from north) and the almost unlimited fetch distances to generate waves, they do have a marked influence on the study area coastal processes. Wind speeds are typically less than 27 knots, accounting for approximately 95 percent of all observations. The dominant wind speed range is from 7 to 16 knots, which occurs nearly 49 percent of the time. Wind speeds exceeding 27 knots (strong breeze) are less frequent with a total occurrence of approximately 5 percent (USACE-NAN, DRAFT, 2000).

Astronomical Tides

Astronomical tides on the south shore of Long Island are semi-diurnal, rising and falling twice daily. The tidal range along the ocean shoreline increases from east to west. For example, the average range in the vicinity of Montauk Point is approximately 2 feet (most easterly); while near Fire Island Inlet the range is over 4 feet (most westerly).

Storm Surge

Storm surge is water that is pushed toward the shore by the force of the winds and the decrease in astronomical area pressure during major storms. Water levels rise at the shoreline when the motion of wind driven waters is arrested by the coastal landmass. Two types of storms are of primary significance along the south shore of Long Island: (1) tropical storms which typically impact the New York area from July to October, and (2) extratropical storms which are primarily winter storms occurring from October to March. These storms are often referred to as “nor’easters” due to the predominate direction from which the winds originate.

Hurricanes are the most powerful tropical storms to reach the study area with wind speeds in excess of 74 mph (by NOAA definition). Records indicate 26 hurricanes have impacted the study area in the past century. Nor’easters are less intense than hurricanes, with sustained wind speeds generally less than 57 mph. However, the durations of elevated water levels and waves during nor’easters are generally longer, enhancing the ability of nor’easters to cause coastal damage. Approximately 68 moderate to severe nor’easters have impacted the New York coastal region since 1865.

As a part of the Reformulation Study, the USACE has undertaken a comprehensive evaluation of storm-induced water levels for FIMP. Estimates of storm surge were made using a combination of models including the finite element hydrodynamic model ADCIRC (Advanced CIRCulation model) (Scheffner et al., 1994), the beach, berm, and dune erosion model SBEACH (Larson and Kraus ,1989), and the waves, currents, sediment transport, and morphological evolution modeling system Delft3D (WL | Delft Hydraulics, 2004). The models allow for the simulation of dune erosion, barrier island inundation, and breaching in order to identify the water surface elevations for different storm events and barrier island configurations. The output of these models led to the development of storm surge stage-frequency curves that identify the probability of these storm-induced water elevations occurring throughout the study area. The impact of open breaches on storm stages was quantified with the hydrodynamic model described above. Modeling results indicate that open breaches result in measurable changes in storm water levels and cause relative increase in the stage frequency curves of 6 to 18 inches.

Sea Level Rise

By definition, sea level rise (SLR) is an increase in the mean level of the ocean. Eustatic sea level rise is a change in global average sea level brought about by an alteration to the volume of the world's oceans. Relative sea level rise takes into consideration the eustatic increases in sea level as well as local land movements of subsidence or lifting. The historic sea level rise rate at NOAA Tidal Station at Sandy Hook, NJ is approximately 0.0126 feet/year or about 1.3 feet/century.

Recent climate research has documented observed global warming for the 20th century and has predicted either continued or accelerated global warming for the 21st century and possibly beyond (IPCC 2013). One impact of continued or accelerated climate warming is continued or accelerated rise of eustatic sea level due to continued thermal expansion of ocean waters and increased volume due to the melting of the Greenland and Antarctic ice masses (IPCC 2013). There are various projections of accelerated sea level rise, from 2.6 feet/century up to almost 5.4 feet/century. A significant increase in relative sea level could result in extensive shoreline erosion and inundation. Higher relative sea level elevates flood levels, and as a result, smaller, more frequent storms could result in flooding equivalent to larger less frequent storms. The more frequent flood events on top of higher sea level may affect more property, resulting in greater damages as sea level increases.

The current guidance (ER 1100-2-8162) from the USACE states that proposed alternatives should be formulated and evaluated for a range of possible future eustatic rates of SLR. Three possible eustatic SLR rates, low, intermediate, and high, are provided in the guidance. These rates of rise correspond to 0.7 ft, 1.3 ft, and 2.7 ft over the 50 year period of analysis for the low, medium and high rates of relative sea level rise.

Currents

The rise and fall of tides is accompanied by the horizontal movement of the water called tidal current. When these waters are channeled through narrow passages such as inlets, the currents can become quite strong, first in one direction as the tide comes in (the flood) and then reversing as the tide falls (the ebb). For the inlets in the study area, the flood and ebb tidal currents generate ebb and flood shoals, which impact sediment bypassing across an inlet (see Inlets, below).

Waves

Waves are the dominant forcing mechanism for most coastal processes along the south shore of Long Island. During storm events, wave impact on beaches that cause erosion of the beach are combined with the increased water level from wave setup, which can lead to overwashing or breach formation. In the study area, significant wave heights, exceeding 3.3 feet occur approximately 25 to 30 percent of the time (USACE-NAN, DRAFT, 2000). Significant wave heights during extreme storm events may exceed 18 feet. The predominant wave period (time between successive wave crests) is between 5 and 9 seconds, which accounts for more than 60 percent of all waves.

Beach Characteristics

Along the study area the grain size distribution of the beach material varies. Typically, grain size increases from west to east, with mean grain size ranging from 0.39 mm to 0.52 mm.

Offshore Sediment Characteristics

The inner continental shelf south and offshore of the study area is characterized by ridge and swale morphology. Surficial sediments are predominantly fine to medium grained sands. Fine-grained sediment outcrops exist in isolated areas of the inner shelf and shoreface. The geology of this area is complex and is characterized by Holocene sediments of variable thickness. These sediments generally consist of either organic-rich muds (backbarrier deposits typically found in the sheltered waters leeward of a barrier island) or modern marine and inlet-filling sands. The area west of Moriches Inlet is typified by a seaward-sloping wedge-shaped deposit of backbarrier sediments underlying marine sand. The maximum thickness of these Holocene sediments is 10 feet along the western portion of Fire Island thinning towards Moriches Inlet.

Since the 1960's, efforts have been undertaken in the study area to identify locations offshore which contain sediment (sand) that would be a suitable source for beach nourishment. This includes considerations for compatibility to native beach grain size, the amount of volume available, environmental considerations, and distance to the project site. Twelve potential offshore sites and seven potential upland source sites were identified as possible sources for the beach nourishment measures.

Shoreline Changes

Historic Shoreline Rate-of-Change (SRC) values in the FIMP study are documented in Gravens et al. (1999), which examined three non-overlapping time intervals using available shoreline data sets. The first period, representative of the epoch prior to significant human influence on the barriers, is 63 years long (1870 to 1933). The second period, representative of initial development on the barriers and the initiation of human intervention with natural processes including inlet stabilization and significant beach fill placements, is approximately 46 years long (1933 to 1979). The third period, representative of modern times and reflecting the most recent beach nourishment practices, is approximately 15 years long (1979 to 1995).

Downtown Montauk is eroding. Observed shoreline changes from 1979 to 1995 (Figure 1) indicate that within the Downtown Montauk Project Area the shoreline is eroding on average by approximately 3 ft/yr (0.9 m/yr).
A separate study by Buonaiuto & Bokuniewicz (2005) evaluated bluff erosion east of Downtown Montauk based on profile surveys collected between 1995 and 2001. The study found that the average rate of bluff recession rate was -1 feet/year over this time period

Recent shoreline changes were evaluated based on LIDAR collected in 2000 and on November 16, 2012 (Post-Hurricane Sandy). A quantitative analysis of the shoreline and dune migration was performed by analyzing the change in the +3 feet NGVD and +11 feet NGVD contours. These contours were selected to characterize the recession of the shoreline and dune. Figure 2 shows the change in position in the +3 feet NGVD and +11 feet NVD contour over the 12 year period. The shoreline experienced an average landward migration of 44 feet or -3.7 feet/year.

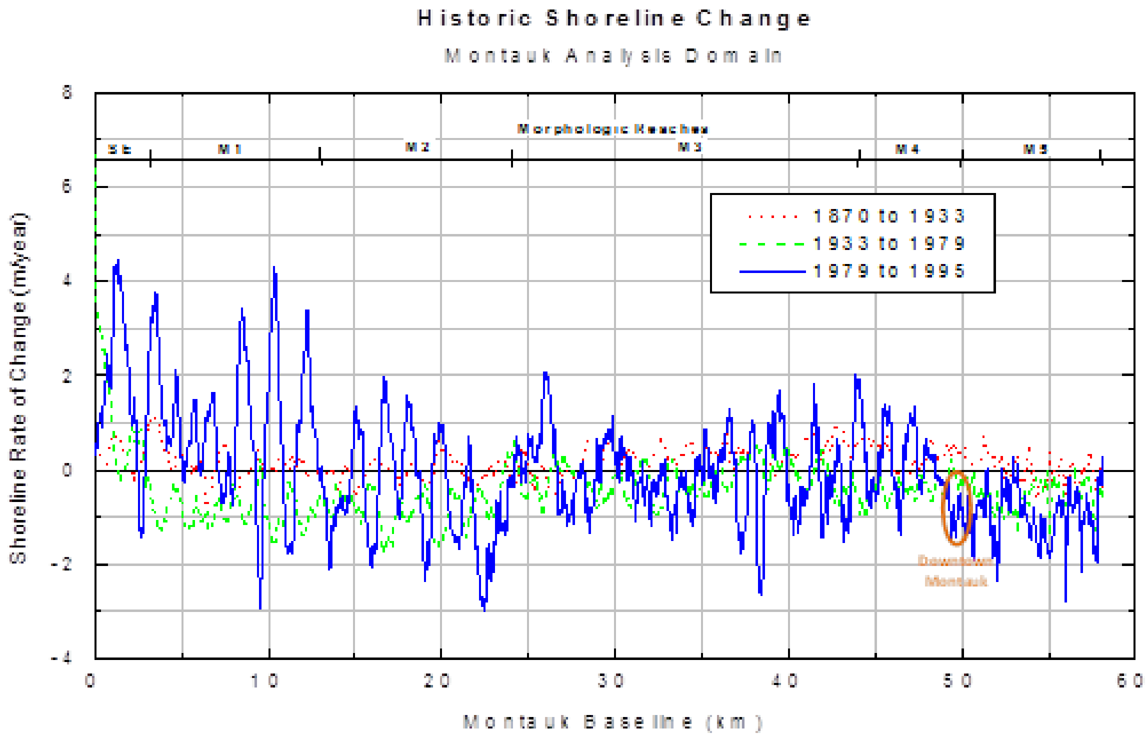

Figure 1: Historic Shoreline Change in Montauk (Gravens et al. 1999)

Based on these observations a background erosion rate of -3 feet/year was selected to characterize the future without-project conditions and applied in the economic analysis.

Existing Shore Protection Activities

There is no history of federal beach nourishment activities at Downtown Montauk. However, local governments and home owners have periodically trucked in sand to stabilized dunes in response to storm events. Available records indicated that in the years 2010 through 2013 beach and dune repairs of this nature were conducted totaling more than $2,200,000.

Sediment Budget

A sediment budget refers to the balance between sediment added to or removed from the coastal system, and is used to reflect the trends in alongshore sediment transport. Coastal erosion is a physical expression of a deficit in the sediment budget where nearshore processes remove more material from the shore than is added.

An existing (c. 2001) conditions sediment budget presenting estimates of volume changes and alongshore sediment transport rates within the FIMP study area were developed. The budget incorporates, to the extent possible, relevant long-term trends identified in previous studies as well as recent changes, including relatively new inlet and shoreline management practices at Shinnecock Inlet and the Westhampton Interim Project.

Overall, this budget shows that there is a gradient in the alongshore sediment transport rates from Montauk Point to Fire Island Inlet. In the Montauk Cell, sediment transport rates increase from 0 to 205,000 cy/yr from Montauk Point to Shinnecock Inlet. This alongshore sediment transport gradient causes a deficit in the sediment budget that is offset by coastal erosion since there is no other source of sediment to the cell.

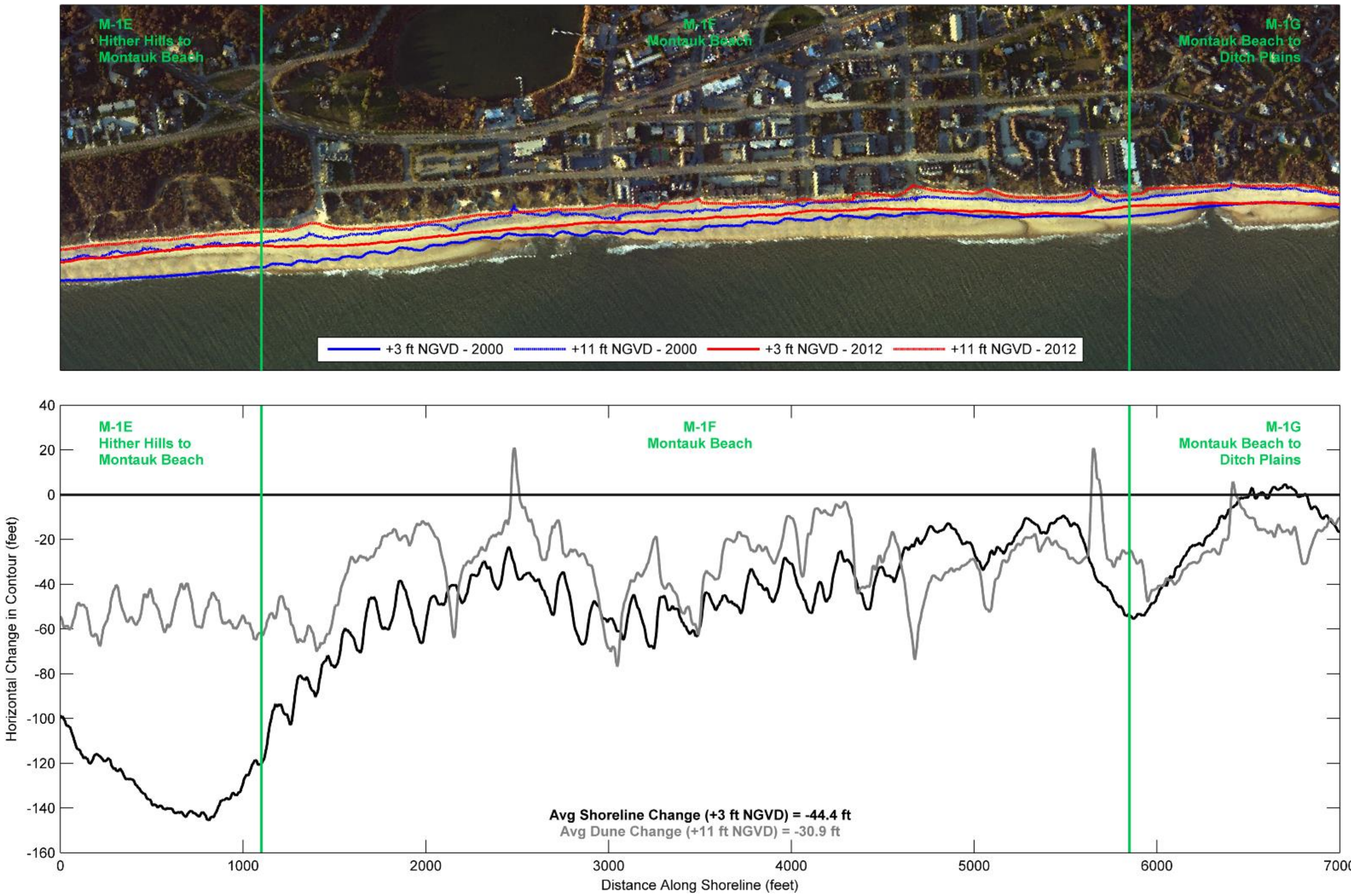

Figure 2: Observed Shoreline Changes at downtown Montauk

Socio-Economic Conditions

According to the U.S. Census Bureau, average for 2008-2012, median household income for the Town of East Hampton was $74,894 compared with $87,778 in Suffolk County. This was not evenly distributed across the Town; median income was $71,312 in Montauk and $112,371 in Northwest Harbor. The census distinguishes for all households and income for various types of family households, and income for non-family households. It is noted that while the median household and family income is more than $10,000 lower in East Hampton than in Suffolk County, the per capita income is higher. The higher per capita income is likely the result of the higher wages earned by a smaller segment the East Hampton population that skews the average per capita income as well as the fact that children under 18 make up a smaller percent of the population in East Hampton than in Suffolk County.

In Montauk Village, the occupation category with the highest percentage of workers was management, professional and related occupations; 31.1 percent of the employed population, 24.0 percent of the Montauk workforce occupied sales and office positions, 26.5 percent worked in service occupations and 14.6 percent had natural resources, construction, and maintenance occupations. Production, transportation and material moving occupations accounted for 3.7 percent of the employed population. As in Montauk, Countywide the management, professional and related occupations (37.8%); sales and office occupations (26.4%), and service occupations (17.1%) had the highest percentage of workers.

Table 1: Per Capita and Family Income

Place	Median Household Income ($)	Median Family Income ($)	Per Capita Income ($)	Percent of Households With Income $200,000 +	Percent of Families Below Poverty Level
East Hampton Town	74,894	90,990	50,377	12.5	4.7
Amagansett CDP	76,346	121,607	60,743	20.2	2.8
East Hampton Village	79,542	88,207	96,189	23.7	6.8
East Hampton North CDP	50,325	70,952	42,005	8.5	11.2
Montauk CDP	71,312	79,495	44,905	7.8	3.9
Napeague CDP	78,958	79,792	40,463	13.0	0.0
Northwest Harbor CDP	94,216	112,371	64,236	16.6	0.0
Sag Harbor Village	91,004	129,432	66,847	15.6	1.9
Springs CDP	72,557	88,667	39,348	15.1	6.3
Wainscott CDP	81,875	81,667	51,428	13.3	6.0
Suffolk County	87,778	100,179	36,819	10.5	4.1

Montauk residents are generally well educated; 48.5 percent of the population 25 years old and older have an Associate's degree or higher and another 15.7 percent have some college education. Countywide, 41.7 percent of this segment of the population have an Associate's degree or higher.

Some people in Montauk have a very low income, a fact that is not necessarily obvious from looking only at median income figures. Approximately 3.9 percent of families in Montauk live below the poverty level, as compared to 4.1 percent Countywide. The poverty level is defined according to the number of people per household, the number of children per household and other factors; the weighted average poverty threshold for a 4-person family (including two infer the age of 18) in 2013 was an income of $23,624. About 9 percent of the total population of Montauk have an income below poverty level, compared to 6 percent in Suffolk County. The percent of households with incomes over $200,000 is comparatively less in Montauk than Countywide, reflecting less affluence Montauk than in the County in general. Living on a low income in Montauk is particularly difficult as there is limited public transportation and the cost of housing is extremely high.

Downtown Montauk is the major business area in the Study Area. The town is divided by Montauk Highway and extends south to the Atlantic Ocean. There are wide variety of year-round commercial establishments in addition to the seasonal motels and resort units. The business district includes supermarkets, banks, clothing stores, gas stations, restaurants, bars, pharmacies, repair shops and other establishments traditionally found in business centers. Institutional facilities, including churches and a library, are located along Montauk Highway in the eastern portion of the business district. A municipal ball field complex borders the northern portion of the downtown area. The downtown area is laid out in a grid of 40 foot by 100 foot lots separated by wide public roads and alleyways.

Problem Identification

This section describes the shorefront and back bay conditions in greater detail to more effectively characterize the relative risk to storm damages that have been accounted for in the project modeling. It is noted here that the back bay conditions were not considered in the Downtown Montauk Stabilization Project since the Project Area does not include any of the three major bays (Great South Bay, Moriches Bay, and Shinnecock Bay). However, the overall FIMP study does consider back bay conditions.

<u>1. Topography.</u> Extensive information is available to characterize the existing topography along the Atlantic Ocean shoreline and along the back bay area. The topography of the shorefront can be characterized by the dune conditions (dune height, width, and volume), and the beach conditions (beach berm height, width, and slope), The back bay environment is more characterized by the overall elevation within the floodplain.

The shorefront conditions along the study area are quite variable. Changes in the beach and dune are reflected in seasonal changes, storm induced changes, human induced changes, and changes that can occur due to shoreline undulations linked to very site specific variations in the nearshore conditions.

To account for this variability over time, the study considers a range of conditions, from a baseline condition to a future vulnerable condition. A September 2000 topographic survey was used to establish a baseline condition. This topography served as the basis for the various modeling efforts undertaken to characterize the response to storm events. This September 2000 condition, however, only represents one condition that could exist within the project area. In fact, the September 2000 conditions represent a beach which is relatively wide and a dune condition which is relatively high and wide. In order to characterize the storm response under a range of future conditions, another topographic condition was established, which is called a “future vulnerable condition”. The future vulnerable condition is a condition derived from past survey information and a projection of future trends. It is intended to represent a more vulnerable condition. The future vulnerable condition was developed to be similar in nature to conditions that existed in the mid-90’s, except that ongoing fill actions which are identified as likely to occur in the future, such as the Westhampton Interim Project. The post-Sandy condition in many instances is now equal to this future vulnerable condition.

Along the backbay shoreline, the topography is more stable. Since the area is gently sloping, it is difficult to characterize the area relative to its topography. Instead, the relative heights of the backbay area are described in the next section which provides a description of the floodplain.

2. Existing Coastal Structures and Expected Future Response. As discussed in the existing conditions and w/o project conditions section, there are a number of beachfill projects and coastal structures in the study area. There is also a history of local beachfill efforts, which is expected to continue in the future. These existing projects and expected future activities significantly affect conditions that are likely to occur in the future. In areas where fill projects have occurred and are likely to occur in the future, it is expected that there is a limit to how degraded the shoreline conditions will become. It is also necessary to consider the long-term erosional trends that would likely occur with these projects in place and whether or not there is an existing coastal structure, or beachfill project that would likely occur in the future.

3. Long-Term Erosional Trends. Long-term erosional trends are those conditions which are due to differences in long-shore transport rates, physical conditions, or constructed features which impact long-shore transport. The long-term erosional trends are essential when assessing the long-term changes that are likely to occur in a given area, and whether the area is erosional, stable, or accreting.

4. Shoreline Undulations. Shoreline undulations, in contrast to long-term erosion trends, are an erosional signature apparent to different degrees along the study area that are short-term in nature and somewhat ephemeral. Shoreline undulations are also referred to as “circulation cells”, and “erosional hot spots”. The exact cause of these shoreline undulations is unknown, but it is assumed that there is a correlation between the condition of the nearshore bar, and the localized erosion. Analysis has been undertaken to evaluate historic shorelines to identify locations where these undulations are likely to occur, and the likely magnitude of these shoreline undulations.

These analyses show that the undulations tend to form and migrate alongshore for a distance before disappearing. Although it appears that some areas are more prone to these undulations, analysis of the undulations indicates that they could occur anywhere along the shoreline. For purposes of analyses, it has been assumed that the undulations can occur anywhere, and are likely to range in size between 1 and 2 km in length (0.6 miles to 1.2 miles). The landward and seaward amplitude of the undulations were quantified as 16 meters (52 feet). It is important to note that in the analyses, it is assumed that locations which are experiencing accelerated erosion due to the presence of existing coastal structures are not subject to erosional undulations.

5. Sea Level Rise. Sea level rise is a critical factor when evaluating future impacts. For purposes of this analysis, an estimate for future sea level rise based upon the historical rate of change for the gage at Sandy Hook has been used. To reflect the fact that a significant degree of uncertainty surrounds the selection of a rate of sea level rise for use in this analysis, all modeling exercises allow variation of the rate of sea level rise from simulation to simulation, with the final results incorporating the average affects of sea level rise over many simulations. Based on the Sandy Hook gage, the most likely rate of sea level rise in the study area is estimated to be 0.127 feet per year, and that the sea level rise follows a log-normal probability distribution with a standard deviation of 0.0006 feet per year. It is acknowledged that the assumed most likely rate is a conservative estimate for purposes of alternative analysis, and may understate without-project damages and with-project benefits.

Overview of the Modeling Approach

This section provides an overview of the specific hydrodynamics of the study area. To orient the reader, the following paragraphs summarize the modeling efforts undertaken for this study, including an overview of the hydrodynamic modeling and the estimation of frequency relationships.

Storm-surge numerical modeling

Storm-surge numerical modeling was performed to produce peak storm water levels at 49 locations across the entire FIMP study area. These 49 locations were selected to capture the variability in storm water levels along the open coast and within the three bays. The storm-surge numerical modeling strategy for FIMP addressed a comprehensive list of physical processes (wind conditions, barometric pressure, astronomic tide, wave conditions, morphologic response, [namely barrier island overwash and breaching], and localized wind and wave setup) by merging hydrodynamic, wave, and sediment transport models. The integration of these modeling efforts is shown below. Each component shown is described below in Figure 3.

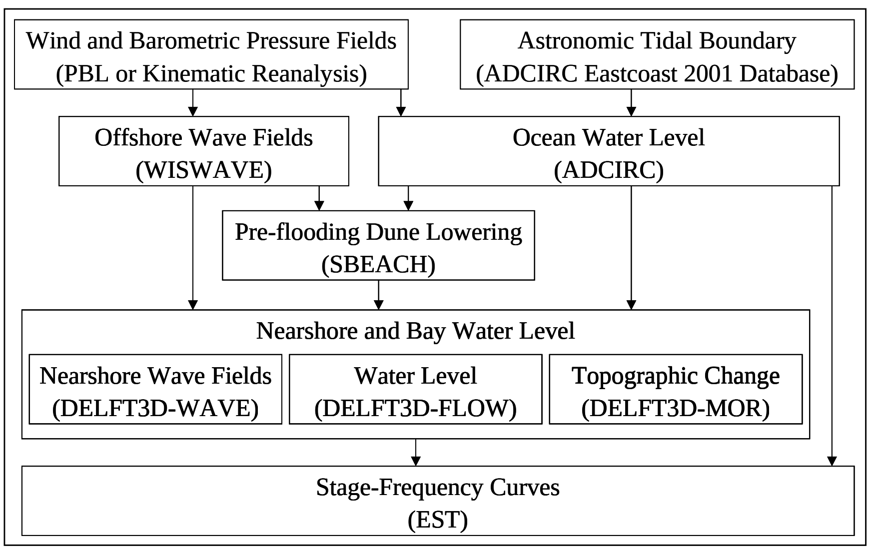

Figure 3. FIMP storm water level modeling and stage-frequency methodology

The six numerical models were applied to accomplish specific requirements for the study, as described below:

1. A Planetary Boundary Layer (PBL) model for wind field simulation was used to develop wind and pressure fields for tropical storms. (Thompson and Cardone, 1996).

2. An Interactive Kinematic Objective Analysis (IKOA) for wind field simulation was used to develop extratropical wind fields through data assimilation, based upon the National Center for Environmental Prediction (NCEP) database.

3. The offshore extreme storm wave conditions were generated using WISWAVE (also WAVAD) (Resio, 1981) a second generation, directional spectral wave model. WISWAVE output was used as input for the DELFT3D modeling and for SBEACH.

4. ADCIRC was used to simulate the ocean and nearshore (outside the surf zone) storm water levels (Luettich et al., 1992). ADCIRC is a long-wave hydrodynamic finite-element model that simulates water surface elevations and currents from astronomic tides, wind, and barometric pressure by solving the two-dimensional, depth-integrated momentum and continuity equations. The grid resolution varies from very coarse at the open ocean boundaries to 50-m in some nearshore locations. ADCIRC was forced with the winds and barometric pressure fields from 1 and 2 above, to capture meteorological effects on water levels, in conjunction with astronomic tidal constituents from the ADCIRC East Coast 2001 Tidal Constituent Database.

5. SBEACH was used for the hydrodynamic modeling, and separately to evaluate the shorefront response for the design and evaluation of beachfill alternatives. In the context of the hydrodynamic modeling, SBEACH was applied to estimate dune lowering that occurred prior to a dune being overtopped. SBEACH (Larson and Kraus 1989a; Larson, Kraus, and Byrnes 1990) is a numerical model for predicting beach, berm, and dune erosion due to storm waves and water levels. SBEACH is an empirically-based model of beach profile change developed to replicate dynamics of dune and berm erosion using standard data (topography, beach profiles, etc.) available in most engineering applications. In model simulations, the beach profile progresses to an equilibrium state as a function of the initial profile condition (including median grain size and shoreward boundary conditions) and storm conditions (wave height, period, and direction; wind speed and direction; and water level). The model predicts profile response to storms including wave overtopping and dune lowering (Kraus and Wise 1993, Wise and Kraus 1993). For storm surge modeling, SBEACH storm simulations were performed for more than 200 beach profiles cut from the 2000 lidar topography. Dune crest elevation change just prior to inundation was extracted from the SBEACH simulation results and put into the DELFT3D topography grid to improve estimates of potential breaching and overwash processes.

6. The DELFT3D Modeling Suite (FLOW, WAVE, MOR) was used to compute the bay water levels under storm conditions, taking into account the contribution of storm surge, waves, winds and the contribution of overwash and/or breaching.

a. The DELFT3D-FLOW applied for this study simulates water level and currents from tidal, meteorological, and wave forcing by solving a two-dimensional depth-integrated flow and transport phenomena. The grid for this study extended from East Rockaway Inlet eastward to the east side of Shinnecock Bay. The model grid includes Great South, Moriches, and Shinnecock Bays, and their inlets, and extends up to 5 km from across the nearshore, with variable resolution. DELFT3D-FLOW was forced along its offshore boundary with water level time series from ADCIRC, throughout its domain with the storm wind and pressure fields, and with wave radiation stress fields.

b. The stationary wave model HISWA (DELFT3D-WAVE) was used to compute nearshore wave climate and resulting surf-zone radiation stresses (Holthuijsen et al., 1989). HISWA is a second generation wave model that computes wave propagation; wave generation by wind; non-linear wave-wave interactions and dissipation for a given bottom topography; and stationary wind, water level, and current field in waters of deep, intermediate and finite depth.

HISWA wave computations are carried out on a rectangular grid. A nested grid approach was also used for nearshore wave modeling and spans from East Rockaway Inlet to Montauk Point. The offshore grid was forced on its offshore boundary with significant wave height, peak period, and mean wave direction, input from the WISWAVE simulations, for each hourly input condition. The HISWA model has a dynamic interaction with DELFT3D-FLOW (i.e. two way wave-current interaction), which accounts for the effect of waves on currents and the effect of flow on waves, including wave setup, which allows for direct simulation of the impacts of wave setup on hydrodynamics, specifically water level at the coastline and in the estuarial bays.

c. The morphological changes, namely barrier island overwash and breaching, were simulated using DELFT3D-MOR. Three-dimensional transport of suspended sediment is calculated in DELFT3D by solving the three-dimensional advection-diffusion (mass-balance) equation for the suspended sediment. The local flow velocities and eddy diffusivities are based on the results of the hydrodynamic computations. Computationally, the three-dimensional transport of sediment is computed in exactly the same way as the transport of any other conservative constituent, such as salinity and heat. For the transport of non-cohesive sediment the Van Rijn (1993) formulation is used, which accounts for the effect of waves. Based on these sediment transport calculations, the elevation of the bed is dynamically updated at each computational time-step.

Collectively, these models simulate the impact that each modeled storm has on ocean and bay water elevations, lowering of the dune during the storm, and the morphological response due to a storm. The outputs from these models were input into a statistical modeling tool to estimate the likelihood of storm occurrence. The output from this analysis is presented in this report to represent the likelihood of various storm effects.

Stage Frequency Methodology

The Empirical Simulation Techniques (EST) was applied to generate stage frequency curves. EST are a group of nonparametric methods for proceeding directly from hydrometeorological storm data to simulations of future storm activity and coastal impact, without introducing parametric assumptions concerning the probability law formulas and related parameters of the data (Scheffner *et al.*, 1999).

Two EST procedures, one univariate (1-D) and the other multivariate, were used in the FIMP studies. The 1-D EST methodology, using water level as the one dimension, was employed for stage-frequency development for the FIMP study. The multivariate EST was used in conjunction with SBEACH for modeling of beach profile response and estimation of storm-induced coastal changes, which is used to evaluate the beach and dune impacts for purpose of design and evaluation. (see Gravens *et al.*, 1999).

For the FIMP study, the 1-D EST methodology was applied in a manner to account for the likelihood that historic storms could impact the areas at any tide condition. In order to apply this approach, 21 additional alternate tide events were run, to provide an improved estimate of the storm effects under different tide conditions. Along the open coast, the total surge generally can be added to the various tide conditions to develop the total surge effect, however, due to the complicated hydrodynamics of flows through the inlets and over the barrier island ,this approach does not work well within the bays,. With the inclusion of these alternate tide scenarios, final stage-frequency curves were generated to represent stage frequency relationships for the study area, at the 49 locations output from the model.

Storms and Ocean Storm Induced Water Level

Storms are the major drivers for storm damage within the study area. The modeling efforts have been undertaken to characterize likely storm activity in the future, and the storm response that can be expected in the future, under different topographic conditions. The basis for our modeling effort in this study assumes that storms will occur in a manner similar to what has occurred in the past. Historic storms (as shown in Table 2) were used to develop statistics on storm recurrence, and the corresponding estimates of storm frequency, and the estimates of stage frequency. Table 3 shows stage-frequency relationships along the Atlantic Ocean illustrative of downtown Montauk project area. Two sets of elevations are shown on the table: the storm water level alone, and the water elevation including the storm water level plus wave setup. The storm water level value is an elevation which is determined based upon procedures described above. This storm water level value is not representative of what an observer would see if standing on the beach.

In addition to the storm water level, there is an additional increase in water elevation due to wave setup, where the breaking of waves results in a localized increase in the water surface elevation along the coast. This value of storm water level, plus setup is what is shown as the higher elevation on this curve. Wave setup is a component of the water elevation which is difficult to quantify, and which can be variable depending upon the specific site conditions. As shown in the figure, wave setup adds an additional 2 to 3 feet of water to the storm water height under the conditions evaluated. It is important to note that the combination of surge plus setup is intended to be representative of the still water elevation along the shoreline.

Table 2: Historic Storms Modeled for FIMP

Tropical Events (1930 – 2001)			Extratropical Events (1950 – 1998)	
Name	**Start Date**	**Duration (hrs)**	**Start Date**	**Duration (hrs)**
not named	10-Sep-1938	15	22-Nov-1950	34
not named	9-Sep-1944	10	04-Nov-1953	26
Carol	25-Aug-1954	5	11-Oct-1955	43
Edna	2-Sep-1954	7	25-Sep-1956	34
Hazel	5-Oct-1954	6	03-Mar-1962	56
Connie	3-Aug-1955	0	05-Nov-1977	28
Donna	29-Aug-1960	13	17-Jan-1978	16
Esther	10-Sep-1961	14	04-Feb-1978	27
Doria	20-Aug-1971	2	22-Jan-1979	19
Agnes	14-Jun-1972	18	22-Oct-1980	17
Belle	6-Aug-1976	7	26-Mar-1984	31
Gloria	16-Sep-1985	5	09-Feb-1985	17
Bob	16-Aug-1991	4	28-Oct-1991	50
Floyd	7-Sep-1999	3	01-Jan-1992	18
			08-Dec-1992	78
			02-Mar-1993	12
			10-Mar-1993	25
			28-Feb-1994	22
			21-Dec-1994	23
			05-Jan-1996	25
			6-Oct-1996	12
			02-Feb-1998	24

Table 3: Stage-frequency relationships with and without wave setup for downtown Montauk

Return Period (years)	Without Wave Setup[1] Feet (NGVD)	With Wave Setup[2] Feet (NGVD)
2	3.8	4.5

10	5.4	7.5
25	6.6	9.4
50	7.8	11.4
100	9.4	14.2
500	12.1	19.1

Notes: [1]Stage frequency relationships derived from ADCIRC Modeling Results and 1-D EST (Station 39, Ditch Plains)
[2]Includes wave setup from Multivariate EST

Erosion Response

The storm parameters were used as input in a variety of coastal engineering models to characterize the erosion response for various topographic conditions. The Corps model SBEACH was applied to characterize the erosional response along the ocean shoreline. Characterization of the erosional response of a dune and beach and the impacts to existing development requires consideration of several important factors. These factors include These factors include:

- Erosion Distance – distance from the shoreline (+) NGVD) on the in initial beach profile to the landward-most point of 1 foot of vertical accretion or erosion that occurs during a storm.
- Vertical Erosion of Dune Crest - amount of dune lowering that occurs during a storm.
- Recession of 0 ft NGVD - landward translation of the 0 ft NGVD contour that occurs during a storm.
- Recession of 10 ft NGVD - landward translation of the 10 ft contour that occurs during a storm.

Figures 4 to 7 illustrate the erosional response for a typical location along the project area in downtown Montauk.

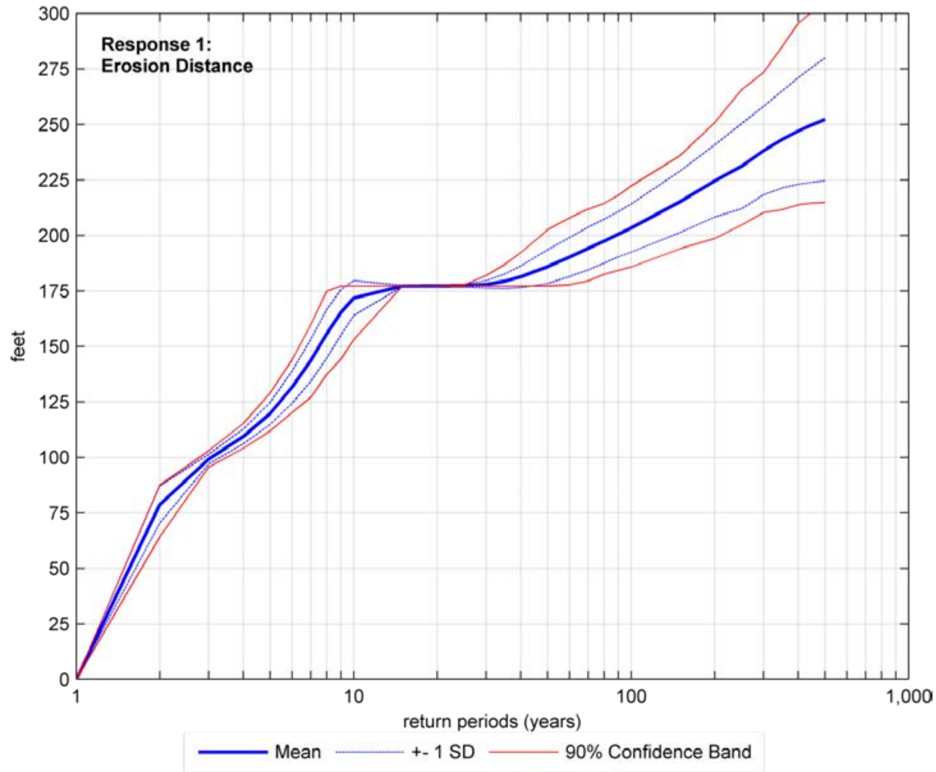

Figure 4: Erosion distance vs. frequency for downtown Montauk

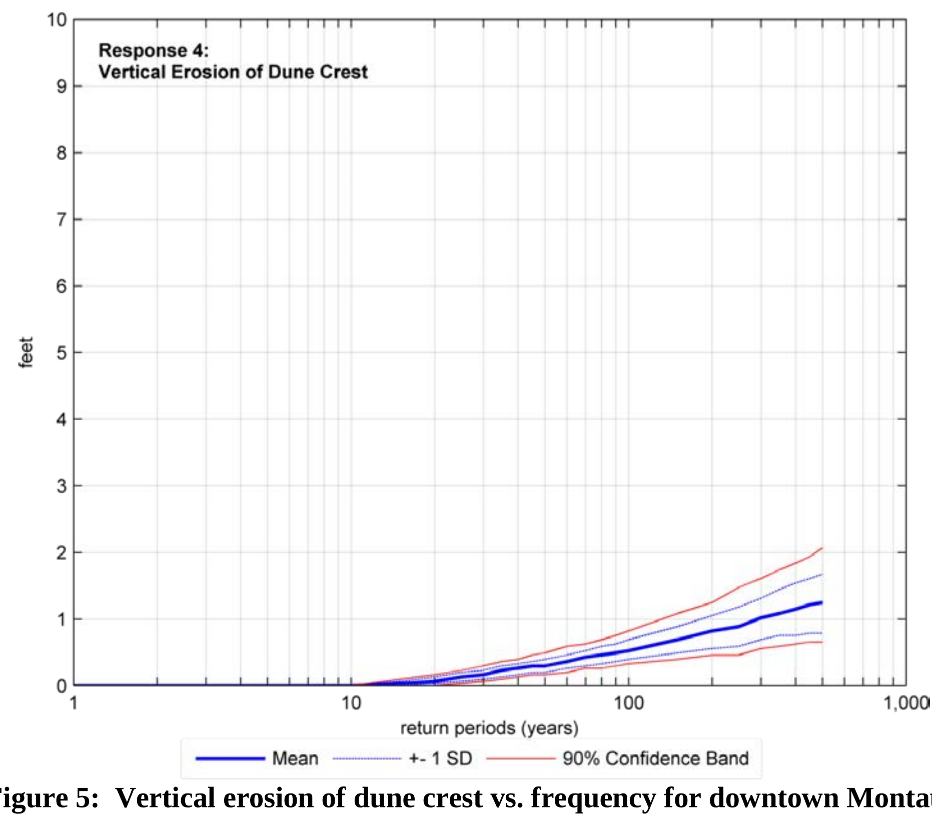

Figure 5: Vertical erosion of dune crest vs. frequency for downtown Montauk

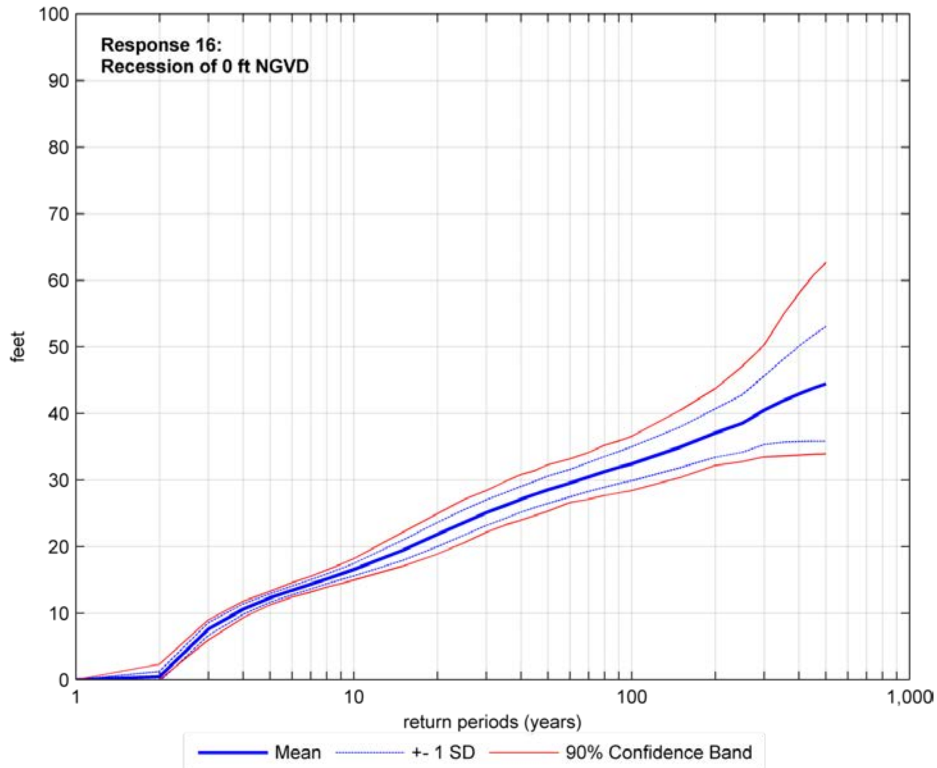

Figure 6: Recession of 0-ft NGVD29 elevation vs. frequency for downtown Montauk

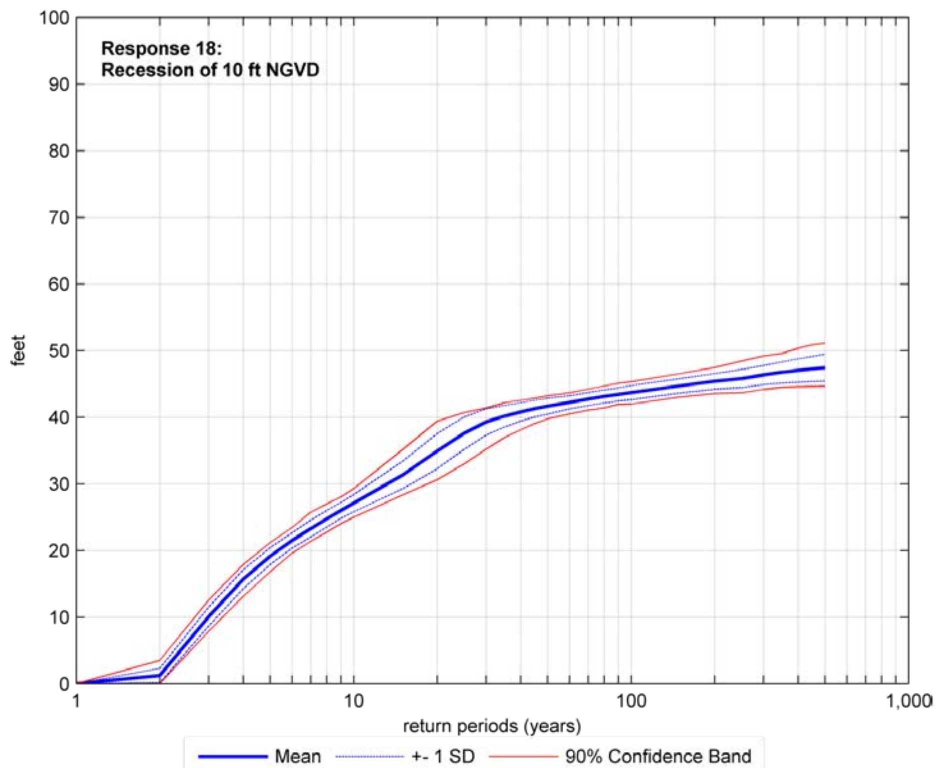

Figure 7: Recession of 10-ft NGVD29 elevation vs. frequency for downtown Montauk

Post-Storm Recovery

It is important to note that the SBEACH modeling, described above captures the erosion which occurs during a storm event. What has been observed to occur is, immediately after a storm event, beaches tend to begin to recover when long-period waves move the sand from the nearshore back onto the beach. When determining how the study area evolves over time, it is important to estimate the amount of recovery expected in an area. The amount of recovery, expressed as a percentage of the volume lost, depends upon a number of factors, including the sediment budget.

The estimated amount of beach recovery has been established for various shoreline locations. These recovery amounts have been developed in order to match the long-term erosional trends for each location, and establish whether the area is erosional, stable or accreting in the long-term.

Lifecycle Considerations

The information summarized above has been used as key inputs into a lifecycle model, which has been developed specifically to estimate the shorefront storm damages that are likely to occur in downtown Montauk in the future. Because the damage may change over time in response to shoreline change, sea level rise, and storm impacts, the analysis of damage considers various sequences of storms over the period of analysis.

The lifecycle model uses the stage-frequency relationship (with setup) presented in Table 3 and the recession-frequency relationship in Figure 7 to simulate the increasing vulnerability of the shorefront structures during a series of lifecycles. Key variables are subject to uncertainty, in compliance with current USACE guidelines. In addition to the stage- and erosion-frequency relationships above, the baseline model also incorporates the historic sea level rise rate of 0.0126 feet/year and a background (non-storm) shoreline change rate of -3 feet/year.

The results of this model indicate that the risk of storm damages to structures in the shorefront area of downtown Montauk will increase in the future due to the combined impacts of sea level rise, storms, and shoreline erosion.