Fire Island Inlet to Montauk Point

Coastal Storm Risk Management Simulation Model
Downtown Montauk Shorefront Emergency Stabilization

Economic Reference Documentation

1.0 INTRODUCTION

The Fire Island Inlet to Montauk Point, New York, Combined Beach Erosion Control and Hurricane Protection Project (FIMP) was authorized by the River and Harbor Act of 14 July 1960. The project is being reformulated to identify a comprehensive long-term solution to reduce the risk of coastal storm damages along the south shore of Long Island in a manner which balances the risks to human life and property while maintaining, enhancing, and restoring ecosystem integrity and coastal biodiversity.

The ongoing FIMP reformulation study is evaluating alternatives to reduce the risk of storm damages, determine Federal interest in participating in one or more of these alternatives, and identify a mutually agreeable joint Federal/state/locally supported plan for addressing the storm damage reduction needs in the Study Area. Prior to Hurricane Sandy, the study had identified but not finalized a Tentative Federally Supported Plan.

Following landfall of Hurricane Sandy on 29 October 2012, the protective beach in downtown Montauk has been largely eroded leaving many buildings vulnerable to additional damages from future storms. Figures 1 and 2 in the main report show the eroded beach conditions at downtown Montauk the day after Hurricane Sandy.

Consistent with the Disaster Relief Appropriations Act of 2013 (Public Law. 113-2; herein P.L. 113-2), the USACE has proposed an approach to expedite implementation of a one-time stabilization project within the hamlet of Montauk in advance of the completion of the Reformulation study. It is recognized that the timeframe to complete the FIMP Reformulation Study would leave vulnerable portions of the Village exposed to future damages. This approach is strongly supported by the State of New York, Suffolk County, N.Y., the Town of Easthampton, and the hamlet of Montauk. This approach is also consistent with USACE policy guidance (Memorandum dated 8 January 2014 approval from Steven L. Stockton, P.E., Director of Civil Works, Appendix H – Pertinent Correspondence).

This Stabilization effort is being undertaken in response to the highly vulnerable condition following Hurricane Sandy's erosive forces, where expedited action is needed to stabilize this area. This Downtown Montauk stabilization effort (Reach 5) has been developed as a one-time, initial construction project to repair damages caused by Hurricane Sandy and to stabilize the area. This report utilizes information and data from the ongoing FIMP study to develop a one-time stabilization project and demonstrate that the Stabilization Project has its own independent utility, and as developed, does not limit the options available in the Reformulation Study or pre-suppose the outcome of the Reformulation Study.

1.1 Downtown Montauk Relationship to FIMP

The Fire Island Inlet to Montauk Point, New York, Combined Beach Erosion Control and Hurricane Protection Project (FIMP) was first authorized by the River and Harbor Act of 14 July 1960 in accordance with House Document (HD) 425, 86th Congress, 2d Session, dated 21 June 1960, which established the authorized project. The project is being reformulated by the U.S. Army Corps of Engineers, New York District (USACE) as the lead Federal agency to identify a comprehensive long-term solution to manage the risk of coastal storm damages along the south shore of Long Island in a manner which balances the risks to human life and property while maintaining, enhancing, and restoring ecosystem integrity and coastal biodiversity.

The overall FIMP reformulation study was undertaken to evaluate alternatives to determine Federal interest in participating in one or more of these alternatives, and identify a mutually agreeable joint Federal/state/locally supported plan for addressing the storm risk management needs in the study area. In addition to addressing the USACE's national objectives of storm risk management and environmental sustainability, this collaborative effort identified alternatives for implementation by other Federal, state and local agencies to achieve broader study objectives.

The FIMP Reformulation Study is in the final stages of documenting the process for development of the TFSP. The Reformulation study evaluated several combinations of features to identify the plan that meets the USACE goals and missions and is mutually agreeable to the Department of the Interior, as required by law in the Fire Island National Seashore authorizing act.

The TFSP from the FIMP plan was advanced following economic evaluation consistent with Corps guidelines and will be detailed in the subsequent GRR. The TFSP includes multiple features to achieve CSDR in the study area, including beachfill and renourishment.

1.2 Summary of FIMP Plan Formulation

Evaluation of design and placement of proposed CSDR features in the Study Area identified that a wide range of the individual alternatives are cost effective options for Storm Risk management. The analysis also indicated that no one alternative addresses all the storm risk management problems. Rather, addressing multiple problems requires multiple solutions. In this respect, many of the alternatives considered complement each other, and Alternative Plans benefit from combinations of alternatives. This reformulation process recommended the following features be integrated into overall Plans of improvement:

- Inlet bypassing Plans
- Breach Response Plans (Responsive Plan at +9.5 ft NGVD, Responsive or Proactive Plans at +13 ft NGVD)
- Non-Structural Plans (6-year and 10-year levels of risk management) - defined as those activities to minimize potential damages through elevation, relocation, flood proofing, buyout, etc
- Beachfill (13 ft Dune and 15 ft Dune) - soft structural measures, generally are those constructed of sand and are designed to "augment and/or" mimic the existing natural protective features

Based on the evaluation of the individual alternatives, combined plans were developed. First, Second and Third added plans were developed by incrementally adding Management Alternatives (Plan 1), Non-Structural Alternatives (Plan 2), and Structural Alternatives (Plan 3). The scale of the alternatives selected for inclusion was based on the results of the optimization of individual alternatives and the potential for the combined alternatives to more fully satisfy the project objectives and evaluation criteria.

The authorized project addresses CSDR along five reaches as follows:

Reach 1 – Fire Island Inlet to Moriches Inlet (FIMI)
Reach 2 – Moriches Inlet to Shinnecock Inlet
Reach 3 – Shinnecock Inlet to Southampton (Quogue to Agawam Lake)
Reach 4 – Southampton to Beach Hampton (Agawam Lake to Hook Pond)
Reach 5 – Beach Hampton to Montauk Point (Hook Pond to Montauk Point)

1.3 Montauk Reach and the Hamlet of Montauk

The Montauk Reach is the eastern most of the five designated Reaches within the overall FIMP Study Area. It extends from Hook Pond in East Hampton to Montauk Point, a distance of about 20 miles.

The incorporated hamlet of Montauk is in the eastern portion of the Montauk Reach and is a major tourist destination with many hotels, restaurants and shops in the downtown area, many of which suffered significant damages as a result of Sandy. There are 43 buildings in downtown Montauk that fall within the modeled 100-yr floodplain (storm with a 1% probability of occurring in any given year).

This Stabilization Report addresses the immediate actions necessary for the Downtown Montauk portion of the overall FIMP Study Area.

1.4 Stabilization Project Details

The proposed design includes 3,100 feet of reinforced dune extending from South Emery Street to Atlantic Terrace Motel and tapers into high dunes at both ends of the Project Area. The extent of the proposed plan was selected to provide protection to all of the shorefront commercial buildings in Downtown Montauk.

1.5 Effective Project Life

The Stabilization Project has been evaluated over a 15 year period since that is the period of time over which there is a measurable difference between the without project future condition and with-project condition. Erosive conditions on the beach are anticipated to expose the geotextile filled containers (GFCs) to sunlight and waves, and without renourishment, the anticipated duration of CSDR provided by the reinforced dune is 5 years.

1.6 Relevant Benefit Streams

Two benefit streams have been assessed to demonstrate that the Stabilization effort is economically justified. Damage avoided to structure and contents is the largest component of the project benefit for this effort. The structures and contents are largely subjected to undermining from coastal storms. Avoided costs of beach sediment placement by local entities is the second benefit stream captured in this analysis.

1.7 Problem Identification

1.7.1 Without Project Future Conditions

The Without Project Future Conditions (WOPFC) is by definition the projection of the most-likely future conditions in the Study Area in the absence of a proposed project from the current study. The WOPFC serves as the base conditions for all the alternative analyses, including the engineering design, economic evaluation of alternatives, comparison of alternatives, as well as environmental, social and cultural impact assessment.

The WOPFC is a forecast based upon what has actually occurred, is currently occurring or is expected to occur in the Study Area if no actions are taken as a result of this study. As it is impossible to predict specifically what may occur, future activities that impact the without-project condition must be representative of what is most likely to occur, and as such must be based upon historic practice and trends, unless there is definitive evidence of new actions or policies scheduled for implementation that would influence past practices. The goal is to choose the most likely future scenario (not the only future scenario), based upon reasoned, documentable forecasting

In defining the WOPFC, it is assumed that periodic beach fills and beach scraping will continue to be implemented by local governments and home owner associations to maintain some threshold beach condition. This condition is based on a review of historic activities including the extent of local and private activities. Available records indicated that in the years 2010 through 2013 beach and dune repairs of this nature totaling more than $2,200,000 were locally implemented. It is likely that future regulatory requirements may limit the size, scope, and timing of future local projects; but even with these conditions, it is expected that within their available resources, local groups will continue to maintain a minimum beach and dune condition. Since local agencies discourage hard structures to protect shoreline properties, it is not assumed that individual hardening of the shoreline will be allowed.

1.7.2 Structures at Risk

The structure inventory for the Downtown Montauk study area was isolated from the larger FIMP reformulation inventory, and reviewed and updated in cooperation with local officials and property owners. It is summarized and presented in Table 1 and illustrated in Figure 1.

Table 1: Structure Valuation in Downtown Montauk

Structure Usage	**Number**	**Average Footprint (Sq. Ft)**	**Depreciated Structure Replacement Value**	
			Total	**Average**
Hotel	27	9,600	$79,698,400	$2,951,800
Commercial	3	5,900	$2,825,100	$941,700
Single-Family Residential	8	1,300	$1,959,900	$245,000
Multi-Family Residential	5	10,200	$19,350,500	$3,870,100
Totals	*43*		*$103,833,900*	

Depreciated Structure Value: 2005 price level updated to October 2013 via factor of 1.262 (ENR BCI Index)

Figure 1. Downtown Montauk Structures at Risk

2.0 STORM DAMAGE ANALYSIS

2.1 Development of Damages

While BeachFx is the model endorsed for use in Coastal storm damage reduction studies, Beach Fx is not capable of analyzing a reinforced structure as proposed in this scenario. Therefore, the Downtown Montauk Shorefront Emergency Stabilization model was developed to quantify the impact of storms on shorefront development and also to quantify the benefits arising from the construction of an emergency stabilization project to reduce the risk of storm damages in this area.

The immediate shorefront area is potentially subject to storm damage from waves, storm erosion/recession undermining of buildings, and inundation. Prior analyses indicated that the primary damage mechanism affecting shorefront structures in downtown Montauk is undermining by storm erosion/shoreline recession and that most existing models (including the original FIMP shorefront damage model) were not appropriate for this task, either due to limitations in the models themselves, or due to the time and budget required to collate and process the required input data. One limitation of the FIMP shorefront damage model is that it was intended to evaluate with-project scenarios featuring regular beach renourishment as a key component, while renourishment may not be considered for any stabilization project implemented at Downtown Montauk under Public Law 113-2.

The damage model was developed using @Risk for Excel to simulate the damages and losses of shorefront structures to erosion over the 15-year period of analysis permitted within the bounds of Public Law 113-2, both with- and without project. The model randomly generates one storm event in each year of the analysis period, and returns a corresponding water surface elevation, scoured elevation at the toe of the structure, and storm erosion distance, taking into account the effects of sea level rise and shoreline change due to yearly erosion. These are used to determine whether the reinforced structure has failed, and to lookup damages due to subsequent erosion and undermining of shorefront structures.

In accordance with current USACE guidelines the model incorporates risk and uncertainty in that key parameters are defined by probability distributions. These allow the input value to vary independently for the execution of each lifecycle as the @RISK model repetitively recalculates the model and collects the results to report the mean average annual damage value. The parameters currently subject to uncertainty in this model are the setback distances and depreciated replacement value of the shorefront structures in this area.

2.1.1 Model Description

The purpose of this model is to quantify the impact of storms on development along East Hampton, NY, in the study area. The immediate shorefront area is subject to storm damage from waves, storm erosion and inundation.

The study area is also vulnerable to wave and inundation damages. Analysis of these impacts was conducted under the larger FIMP effort with a different model. These damages were found to be a small percentage of the overall damages and were primarily incurred only at very low frequency events. For this stabilization effort, the PDT limited the analysis to erosion damage only, quantified by the spreadsheet model described below.

This is a spreadsheet model using @Risk (Palisade Corporation) add in to Microsoft Excel to simulate the damages and losses to shorefront structures over a fifteen year period of analysis, with and without project. The model randomly generates one storm event in each year of the analysis period and returns a corresponding water surface elevation, scoured elevation at the toe of the structure, and storm erosion distance, taking into account the effects of sea level rise and shoreline change due to yearly erosion. These are used to determine whether the reinforced structure has failed, and to lookup damages due to subsequent erosion and undermining of shorefront structures.

The model currently assumes that the reinforced dune alternative will fail when impacted by a wave height of three feet or more, or id the toe elevation is reduced to scour to +1 foot NGVD. In accordance with current USACE guidelines, the model incorporates risk and uncertainty in that key parameters are defined by probability distributions. These allow the input value to vary independently for the execution of each lifecycle as the @RISK model repetitively recalculates the model and collects the results to report the mean average annual damage value. The parameters currently subject to uncertainty in this model are the setback distances and depreciated replacement value of the shorefront structures in this area.

@Risk is a Monte Carlo simulation risk analysis tool available from the Palisade Corporation. It is used as an add-on to Excel to generate a range of outcomes from which probabilities can be derived. @Risk was developed by Palisade Corp. in 1987 and continues to be updated and supported. It supports decision-making throughout a wide range of industry sectors. More information on @Risk is available through the company's website at: http://www.palisade.com/risk/. The Planning and Policy Division of Headquarters, USACE has approved @Risk for use in Corps studies.

2.1.2 Without Project Damages

The calculation of without project damages was based on the assumption that the selected plan is not constructed and that the shorefront structures are vulnerable to damage from erosion in any year of the period of analysis. The set of vulnerable structures contributing to the damage analysis was taken from the structure inventory compiled for the original FIMP shorefront damage analyses, with their depreciated structure replacement values revised to a 2013 price level via an update factor of 1.26, which was derived from the historic building cost index published monthly by the *Engineering News-Record*. This update factor has been used for other components of the current FIMP study.

The model records damages due to erosion in any given year by means of a lookup table of aggregated structure damage versus erosion distance. The model currently assumes that as a building is undermined, the damage incurred increases linearly from zero at zero undermining to 100% when the mid-point of the structure has been passed. Content damages were incorporated by adding 50% to the value of each structure. The aggregate damage/erosion distance function resulting from this approach which has been incorporated in the model is presented. The model currently assumes that structures damaged to 100% of their value are not rebuilt within the same lifecycle.

The model has been executed using an interest rate of 3.5% and 25,000 iterations to give without project equivalent annual damages of $1,378,000. It should be noted that if this analysis were to be conducted for the evaluation of a long-term solution for the Downtown Montauk area, i.e. one using a period of analysis of 50 years, significantly higher without project equivalent annual damages would be expected, due to the increased vulnerability of structures to erosion in the latter part of the analysis period.

It should be noted that additional damages to reflect land loss and cost of demolition of structures could be included in the without project analysis. For the purposes of the Stabilization effort, these values were not quantified.

Without Project conditions are presented in Figure 2.

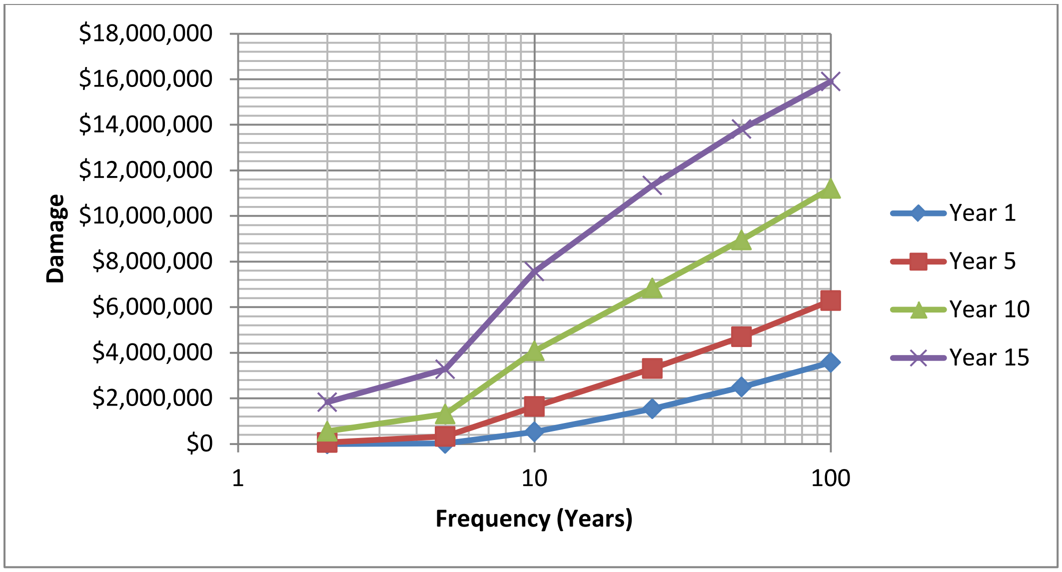

Figure 2: Without-Project Damage-Frequency Curve

2.1.3 Damage Sensitivity and Uncertainty

As described above, annual damages represent the expected average or mean results. The actual amount of future damages is highly sensitive to the timing and sequence of storms, future events that cannot be predicted. The life cycle simulation has incorporated the uncertainty of these parameters by allowing the values to vary in each simulation. In order to account for uncertainties in the timing and impacts of various storms, calculations are performed for a large number of lifecycles and mean or average value is reported.

The model has been developed to evaluate the non-shorefront erosion conditions unique to the project site, and is not intended for direct application to evaluate shorefront damages at other locations.

Table 2: Description of Simulation Model Spreadsheet Component Tabs

Tab	Tab name	Contents and Description
1	Simulation	Input of key data and the lifecycle simulation mechanism by which storm events are generated and erosion damages to structures are realized, depending on the existence and integrity of the reinforced dune structure on the shorefront. A storm event probability is randomly generated for each lifecycle year, for which erosion distances and ocean water levels are retrieved from Tab 2, enabling total erosion distances and wave heights to be calculated. If the without-project condition is specified, erosion beyond the 5 foot contour and subsequent building damage is possible from the first year in the lifecycle. If the with-project condition is specified, erosion beyond the 5 foot contour is only possible following failure of the structure due to toe scour or wave action. Once it has failed by either mechanism, the structure is assumed to be not repaired or replaced. Erosion damages associated with the total erosion distance (storm erosion plus long term shoreline change) are looked up in Tab 4, and are refined by linear interpolation between low/high damages when the erosion distance falls between the 10 foot increments in the erosion-damage curve. Erosion damages are adjusted to reflect the user-defined probability that destroyed structures will be rebuilt. The adjusted damages in each lifecycle year are converted to present values, and their total is amortized to produce the EAD for each lifecycle.
2	Lookup	Interpolated stage- and erosion-frequency data from Tab 3 formatted into a lookup table to be referenced by Tab 1.
3	Interpolation	Input of local Stage-Frequency and Erosion-Frequency curves, plus interpolation of stage and erosion values for all intermediate frequencies for which data has not been provided.
4	Damages Lookup	Provides lookup tables of the aggregated erosion-distance relationships generated by Tabs 5 and 6, to be referenced by Tab 1.
5	Building Inventory	Calculates the damage experienced by each structure due to erosion as the structure is undermined in increments of 10 feet, based on the depreciated replacement value and setback distance of each structure. Erosion damage is assumed to increase linearly from zero at the point immediately before undermining occurs to 100% when 50% of the structure footprint has been undermined. Uncertainty has been incorporated by allowing the setback distance and total value of the structures to vary via normal distributions with standard deviation input by the user.

Tab	Tab name	Contents and Description
6	No Rebuild Adjustment	Calculates the damage experienced by each structure due to erosion as the structure is undermined as per Tab 5, except that in this case only the erosion distance at which 100% damage is realized is captured for each structure. This data is used to adjust erosion damages generated in Tab 1 to reflect the probability that previously destroyed structures are rebuilt to their original condition before subsequent storms.
7, 8	Results	Example results output generated by executing the model for without- and with-project conditions.

Upon a successful execution, results are written to a new spreadsheet tab which is automatically appended to the existing tabs in the spreadsheet, provided the user has chosen the appropriate settings in the Utilities\Reports menus in the @RISK application.

2.2 Model overview in Planning Effort

The model is critical to the planning effort in that it is considered to be the only appropriate tool currently available to evaluate the benefits of the proposed reinforced dune structure and hence is vital to facilitating the selection of the NED plan for the emergency stabilization of the downtown Montauk shorefront area.

2.3 Description of Input Data

The model requires several types of input data as described above in the "Model Description" Section and in Table 1. All data in the current version of the model

The key inputs to the model are the externally-generated ocean stage-frequency and erosion frequency relationships unique to this location, and the physical characteristics of the vulnerable shorefront structures, notably their depreciated replacement value and shorefront setback distances. Other inputs to be entered by the user are the base year, project life in years, Federal interest rate, rate of sea level rise, long-term shoreline change rate, shorefront profile geometry (structure elevation, berm elevation/width, profile slope), structure failure thresholds, standard deviations of uncertain variables, and the probability that structures destroyed by erosion will be rebuilt.

2.4 Description of Output Data

The model has flexible output capabilities and the principal output generated by each execution of the model is the EAD. In the version provided for certification, the model also includes outputs which enable annual and cumulative reinforced dune failure probabilities to be plotted. In addition, any cell in the model may be included as an output of the simulation model in order to track other variables such as patterns of damage or shoreline change over time.

2.5 Assumptions

The model makes numerous assumptions described in the sections above regarding the relationship between ocean water levels, shorefront conditions and the exposure to erosion of the shorefront structures. Among the key assumptions are the following:

- Wave action and toe scour are the only potential mechanisms by which the reinforced dune may fail and leave the shorefront structures exposed to erosion.
- Erosion damage is assumed to increase linearly from zero at the point immediately before undermining occurs to 100% when 50% of the structure footprint has been undermined.

Other assumptions such as the probability of rebuilding and the actual failure thresholds for the reinforced dune due to wave and scour are not fixed and may be chosen by the user.

2.6 Conformance with Corps policies and procedures

The model complies with policies and procedures regarding treatment of economic parameters, including considerations of base year and present worth analysis, and the application of sea level rise. The model incorporates Risk and Uncertainty concepts through the application of a lifecycle approach and the application of uncertainty distributions to key input variables such as structure value and setback distance.

2.7 Identification of formulas used in the model and proof that the computations are appropriate and done correctly

The formulas used in the model are simple mathematical functions, which were verified as part of the standard checking and QC process. The most complex formulas are the interpolation of water levels and the calculation of building damage based on erosion distances. The generation of the random storm events has been tracked and verified to produce sampled stage probability distributions that reproduce closely the input stage frequency curves. In addition, the modeled failure of the reinforced dune structure has been examined to demonstrate that it does initially provide the intended level of protection against erosion.

2.8 Process used to test and validate model

The model drew on previous simulation models originally initially developed for other US Army Corps of Engineers coastal storm damage reduction projects in 2003 and 2006 and shared several concepts and techniques. Alpha or Beta testing was not undertaken since the model components are not intended for use outside the development team.

However, results and spreadsheet computations were checked at multiple stages in the development, and reproduction of the stage frequency data by the storm simulation approach was verified by comparing input stage frequency data to @RISK output statistics.

2.9 Availability of input data necessary to support the model

The hydrologic/geomorphic model input data may be developed using standard coastal engineering tools, while the building inventory data necessary to evaluate erosion damages must be sourced either from field surveys or local tax assessment data.

2.10 Formatting of output in an understandable manner

The primary output from the model is the single value of EAD resulting from the @RISK simulation which is written to a simple table in a new spreadsheet tab generated by every execution of the model. This table also includes all other secondary outputs as selected by the user.

The model results provide the necessary information to determine storm damage reduction benefits. The detailed statistics can be reviewed to identify associated uncertainty and confidence bands.

3.0 FORMULATION OF ALTERNATIVE PLANS

Prior to Hurricane Sandy, storm damage reduction measures for the downtown Montauk area were considered as part of the ongoing FIMP Reformulation Study. Consistent with both P.L. 113-2 and the Reformulation Study itself, requirements in formulating any stabilization project formulated for downtown Montauk in the aftermath of Hurricane Sandy is required to include:

a. Compatible with the likely outcome of the Reformulation process;

b. Economically justified with no adverse environmental impacts

c. Reversible should the stabilization project be subsequently determined to be NOT compatible with the finding and recommendations of the overall Reformulation study.

3.1 Pre-Sandy Alternative Plan Comparison

The FIMP Reformulation Study considered the downtown Montauk area in the alternative analysis. The initial screening considered non-structural measures, beachfill with structures, and beachfill. Each of these measures were analyzed considering general design requirements, costs, and local acceptability.

Non-structural measures (relocation and acquisition) were eliminated from further consideration based on high costs to relocate or acquire the large ocean front structures, and the lack of local support for an alternative that would largely eliminate a significant component of the local economy. Similarly, beachfill with structures was eliminated from further consideration based on cost considerations. Beachfill was the only measure considered for further evaluation.

The performance of the following three beachfill design templates was evaluated during the Reformulation Study: 1) +13 ft dune, 90 ft berm; 2) +15 ft dune, 90 ft berm; 3) +17 ft dune, 120 ft berm. The +15 ft (NGVD) dune and 90 ft berm was identified as the optimal design template for reducing storm damages and minimizing costs. However, an economic analysis of the beachfill alternative showed that it had a low Benefit-Cost Ratio (BCR). Consequently, the beachfill alternative was removed from further consideration in the Reformulation Study.

Downtown Montauk has one of the highest cost damages per foot of shoreline in the Study Area; however, unlike other reaches in the Study Area, the Project Area is not susceptible to barrier island breaching, which is a major driver of economic benefits in the FIMP Study Area. The cost of beachfill at downtown Montauk is also significantly higher than at other locations because of the relatively high volume of sand required for initial construction and renourishment, and relatively high unit costs for sand.

The Reformulation study identified downtown Montauk as an area of high damage where sediment management measures should be evaluated as a possible alternative. Sediment management features are small-scale beach nourishment projects that are designed to offset long-term erosion trends in a location, which also act as a feeder beach for downdrift areas.

The sediment management measure for downtown Montauk recommended the placement of 120,000 cy of sediment every 4 years. The feeder beach would contribute an additional 30,000 cy/yr to the sediment budget. This supplemental sediment source would provide a constant supply of sediment to the beaches at downtown Montauk and farther west and, therefore, provide erosion control benefits to this region. The feeder beach would be constructed once every four years in concert with future renourishment operations at other locations in the Study Area.

An important distinction between the feeder beach and the beachfill alternatives is that a specific design section (i.e. 90 ft berm), and thus, a specific level of protection, is not being provided and maintained in the feeder beach. The primary objective of the feeder beach is to offset long-term erosion and ensure long-term continuity of longshore sediment transport. An economic analysis of the feeder beach indicated that the alternative had an acceptable BCR (greater than 1.0) and it was incorporated in the TFSP plan.

3.1 Post-Sandy Alternative Plan Comparison

In the aftermath of Hurricane Sandy, it was recognized that there was a need to revisit the TFSP and determine if the eroded beach conditions and updated costs and benefits warranted selection of a larger alternative plan at downtown Montauk. This analysis is presently underway as part of the Reformulation Study to consider a wider array of alternatives, and to aid in identifying a stabilization plan. An evaluation of five alternatives is underway, taking into consideration the severely eroded beach conditions following Sandy. This includes reevaluation of the cost assumptions and other sources of potential economic benefits.

3.1.1 Alternative Development

Based on the prior screening of alternatives, and coordination with State and local officials, five conceptual alternatives were considered for evaluation:

- Alternative 1: Beach Restoration,
- Alternative 2: Beach Restoration and Buried Seawall,
- Alternative 3: Feeder Beach,
- Alternative 4: Dune Reinforcement,
- Alternative 5: Dune Reinforcement and Feeder Beach.

These five alternatives represent a range of measures providing different levels of protection and design project lives. Alternatives 1, 2, and 3 are similar to the pre-Sandy alternatives, and are designed to provide a 44 year level of protection and have a design project life of 50 years. The post-Sandy analysis also considered two alternatives that provided a lower level of protection, and a shorter design life to stabilize the project area immediately and effectively. Alternative 4 is a geotextile reinforced dune alternative that could be constructed as a one-time action to offset the loss of dune function from Hurricane Sandy. Alternative 5 is an update to the plan previously recommended in the TFSP, which would repair the dune function at downtown Montauk and provide beach nourishment to maintain a consistent level of functioning.

Due to the large quantities of sand fill required for construction of Alternatives 1, 2, 3, and 5, dredging of an offshore borrow area would be required. Dune Reinforcement (Alternative 4) requires significantly less sand, approximately 51,000 cy, than other four alternatives. Therefore, it is feasible and expected to be less costly to obtain the necessary sand fill material from upland sediment sources.

The final analysis and comparison of alternatives for the long-term Reformulation Study are still underway, but the above information has been used as the basis for developing the stabilization plan for downtown Montauk.

<u>Stabilization Plan Selection</u>

As presented previously, a stabilization project for downtown Montauk is required to be each of the following:

a. Compatible with the likely outcome of the Reformulation process;
b. Economically justified as a separate, independent project;
c. Limited in duration to provide stabilization prior to implementation of the FIMP Reformulation.

In reviewing the alternatives under consideration, Alternative 4 was identified as the only alternative that meets the criteria for a stabilization project. Alternatives 1, 2, 3, and 5 all have very high costs, and can only perform as designed if done in conjunction with a long-term plan for renourishment. Given that the stabilization project for downtown Montauk is intended as a 1 time project in advance of the implementation of the overall FIMP reformulation, these 4 alternatives were not considered further, and Alternative 4 was selected as a viable stabilization alternative.

<u>Alternative 4 - Dune Reinforcement</u>

Alternative 4, Dune Reinforcement, consists of stabilizing and reinforcing the existing dune along 3,100 ft of the shoreline in downtown Montauk. The core of the dune consists of hydraulically-filled Geotextile Sand Containers (GSCs). GSCs have increasingly been used to provide low cost, soft, environmentally acceptable solution for shore protection structures (Pilarzyk, 2002, Dassanayake and Oumeraci, 2012). Coastal structures built with GSCs are obtained by substituting rocks with containers made of geotextile and filled with locally available sand.

The core of a typical proposed Reinforced Dune consists of approximately 14,171 GSCs with filled dimensions of approximately 5.5 ft long, 3.5 ft wide, and 1.5 ft tall, each weighing approximately 1.7 tons. For greater stability, the GSCs are aligned with the long side perpendicular to the shoreline with an overlap of 50% of the filled width. The proposed design is to provide reinforcement by stacking the bags along the existing dune at a 1V:2H slope. The Dune Reinforcement extends from a toe elevation of +3 ft to a crest elevation of +13.5 ft NGVD. In order to increase the resiliency of the design and reduce the potential for undermining, the proposed design includes a 45 foot wide berm cap at +9.5 ft NGVD. The additional sediment, estimated at approximately 20,000 cubic yards (6 cy/ft), will provide additional protection to the toe of the structure from undermining and decrease the likelihood of exposure of the GSCs during small storm events.

Dune reinforcement with GSCs may provide a relatively soft, flexible, easily installed, and easily removed solution. However, there are some disadvantages to using GSCs in the place of traditional armor stone units. The level of protection and longevity offered by the GSCs is considerably less than armor stone. GSCs have a lower specific gravity and are more susceptible to sliding and being pulled out when exposed to large waves. The longevity offered by GSCs is also limited by deterioration from UIV exposure, vandalism, and contact with debris. To maximize the longevity of the GSCs the proposed design calls for the GSCs to be covered by a layer of sand to decrease the likelihood of the geobags being exposed for long periods of time.

It is estimated that the reinforced dune provides a level of protection of approximately 25 years (4% annual chance of design exceedance). The effective life of this type of structure would be approximately 15 years (50% probability of failure). A fifteen year effective project life was determined as a result of two factors: 1) 5 years is the approximate point in the future in which the cumulative failure probability of the reinforced dune exceeded 50%; and 2) the durability and longevity of the GSCsis limited and will eventually break down due to UV radiation, abrasion, and contact with debris.

3.2.2 Stabilization Constraints

- The Stabilization Plan must have independent utility.
- The Stabilization Plan cannot foreclose on alternatives under evaluation in the overall FIMP Reformulation Study.
- The Stabilization Plan must be within the current FIMP authorities as authorized in the River and Harbor Act of 14 July 1960 in accordance with House Document (HD) 425, 86th Congress, 2d Session, dated 21 June 1960, which established the authorized project. The FIMP authorization precedes authorization of P.L. 113-2 in 2013; thus providing the authority for the Stabilization Plan as an HSLRR.

The Main Report summarizes the alternatives which were investigated for inclusion in the GRR. Due to the requirements of PL 113-2, only one alternative was appropriate for recommendation within the Stabilization plan.

Dune reinforcement with GSCs may provide a relatively soft, flexible, easily installed, and easily removed solution. However, there are some disadvantages to using GSCs in the place of traditional armor stone units. The level of protection and longevity offered by the GSCs is considerably less than armor stone. GSCs have a lower specific gravity and are more susceptible to sliding and being pulled out when exposed to large waves. The longevity offered by GSCs is also limited by deterioration from UIV exposure, vandalism, and debris. To maximize the longevity of the GSCs the proposed design calls for the GSCs to be covered by a layer of sand to decrease the likelihood of the geobags from being exposed.

Not only are the GSCs less resilient than an armor stone, but the absence of a wide maintained berm width increases the potential for undermining and exposure to larger wave heights. It is estimated that the reinforced dune provides a level of protection of approximately 25 years (4% annual chance of design exceedance). The effective life of this type of structure would be approximately 15 years (50% probability of failure).

3.2.3 Plan Comparison

A summary of the annualized costs for the five conceptual alternatives are provided in Table 3. As described in the Main report, the five alternatives represent a range of measures offering different levels of protection and different design project life. The annualized costs of alternatives 1, 2, 3, and 5 are based on a 50 year period of performance and assumed a periodic nourishment requirement every 4 years, while alternative 4 are based on a 15 year period of performance with no periodic nourishment. The 15 year period of performance is based on the expected life of the GSCs that are used to construct the reinforced dune. Due to the high annualized costs of alternatives 1, 2, 3, and 5 and also given that the stabilization project for downtown Montauk is intended as a 1 time project in advance of the implementation of the overall FIMP reformulation, these 4 alternatives will not be considered further.

Table 3: Annualized Costs of Alternatives

Annual Costs	Beach Restoration[1]	Beach Restoration & Seawall[1]	Feeder Beach[1]	Dune Reinforcement[2]	Feeder Beach & Dune Reinforcement[1]
First Construction	$1,248,000	$1,390,000	$466,000	$761,000[3]	$680,000
Renourishment	$3,837,000	$2,417,000	$2,337,000	n/a	$2,422,000
O&M	$292,000	$326,000	$109,000	$157,000	$160,000
Total	$5,377,000	$4,133,000	$2,912,000	$918,000	$3,262,000

Notes: FY14 price level, 3.5% Discount rate;

[1] Based on 50 yr. Period of Performance (POA) with periodic nourishment every 4 years;

[2] Based on 15 yr. POA with no renourishment.

[3] Includes Interest During Construction (IDC) based on a four-month construction schedule.

3.2 Economic Evaluation

3.2.1 With-Project Storm Damages and Benefits

In compliance with Public Law 113-2 and the associated constraints described in previous sections, current efforts are limited to the implementation of a stabilization project with a 15 year life and no requirement for periodic renourishment. Therefore at this stage in the study only

Alternative 4, the reinforced dune structure has been subject to analyses for damages and benefits.

To model the damages with the Stabilization Project in place showing the benefits of the project, the model described in Section 3.3 was configured to allow erosion beyond the +5 foot NGVD contour only after the reinforced dune structure has failed due to either wave action or scour. In the first year of the project life, the dune provides approximately a 1 in 25 year level of protection (4% annual chance of failure immediately following construction) with the annual failure probability rising to approximately 8% (1 in 13 year) by the end of the project life. The increase in annual failure probability of the project over time is presented in Figure 3. The cumulative failure probability of the project is presented in Figure 3, which indicates that the probability that the project will have failed by the end of the period of analysis is almost 60%.

The model has been executed using a project life of 15 years, an interest rate of 3.5% and 12,500 iterations to compute with-project equivalent annual damages of $326,000. Hence the annual storm damage reduction benefits of the project are estimated to be $1,052,000.

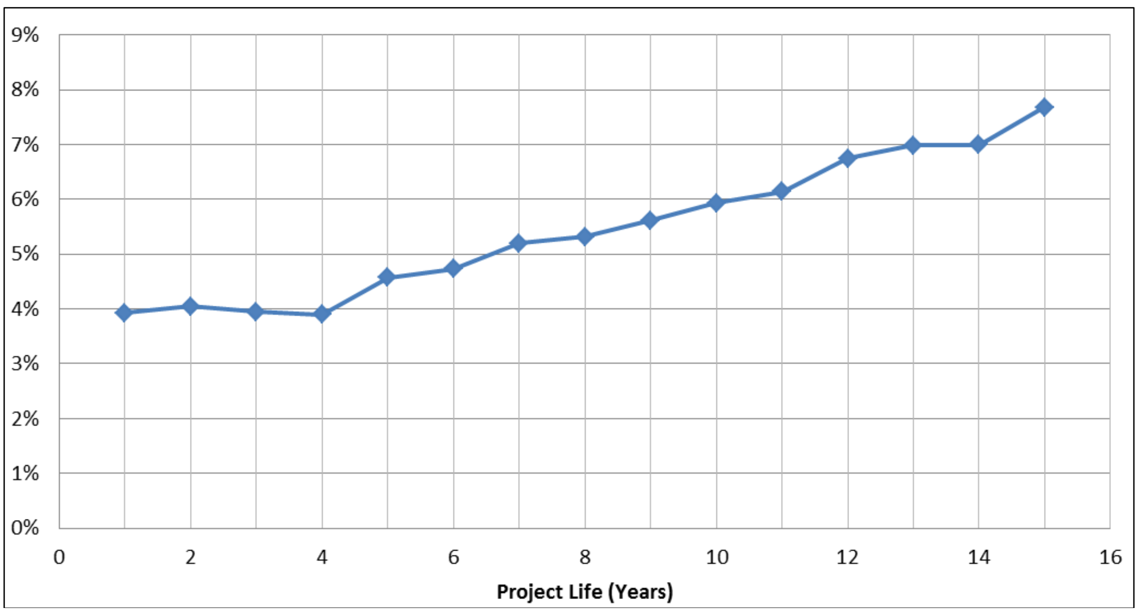

Figure 3a: Annual Failure Probability of Reinforced Dune

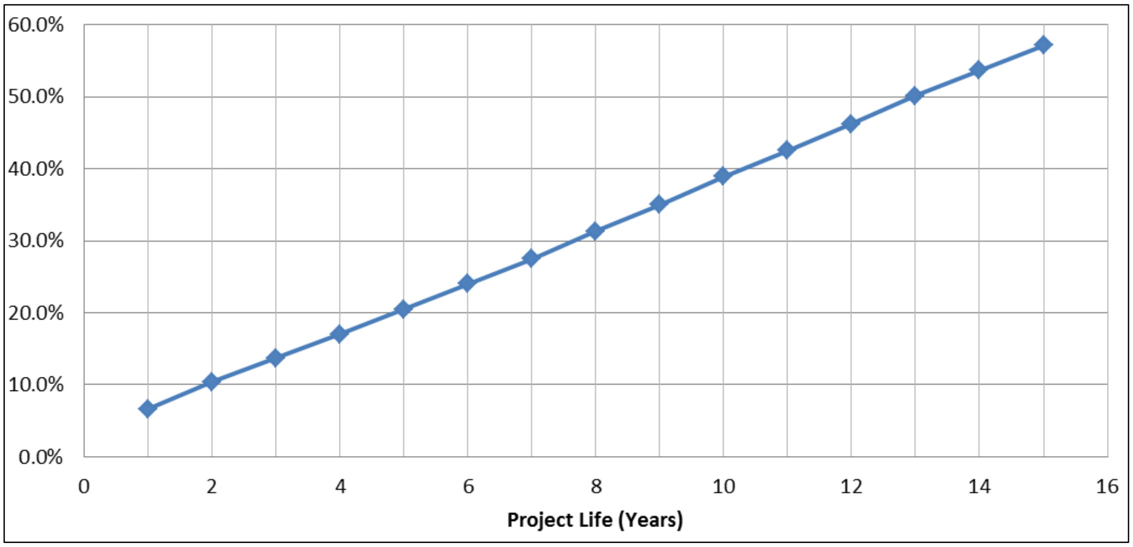

Figure 3b: **Cumulative Failure Probability of Reinforced Dune**

The with-project model outputs were post-processed to derive damage frequency plots for years 1, 5, 10, and 15 in the analysis period, and these plots are presented in Figure 4 for comparison with Figure 2. It is evident that while the vulnerability to erosion still increases over time with the project in place, the expected damages are greatly reduced. For example; for the 10% annual chance exceedance event, expected damages in years 1 and 10 are expected to be reduced from $1 million and $3.8 million to zero and $1.3 million, respectively.

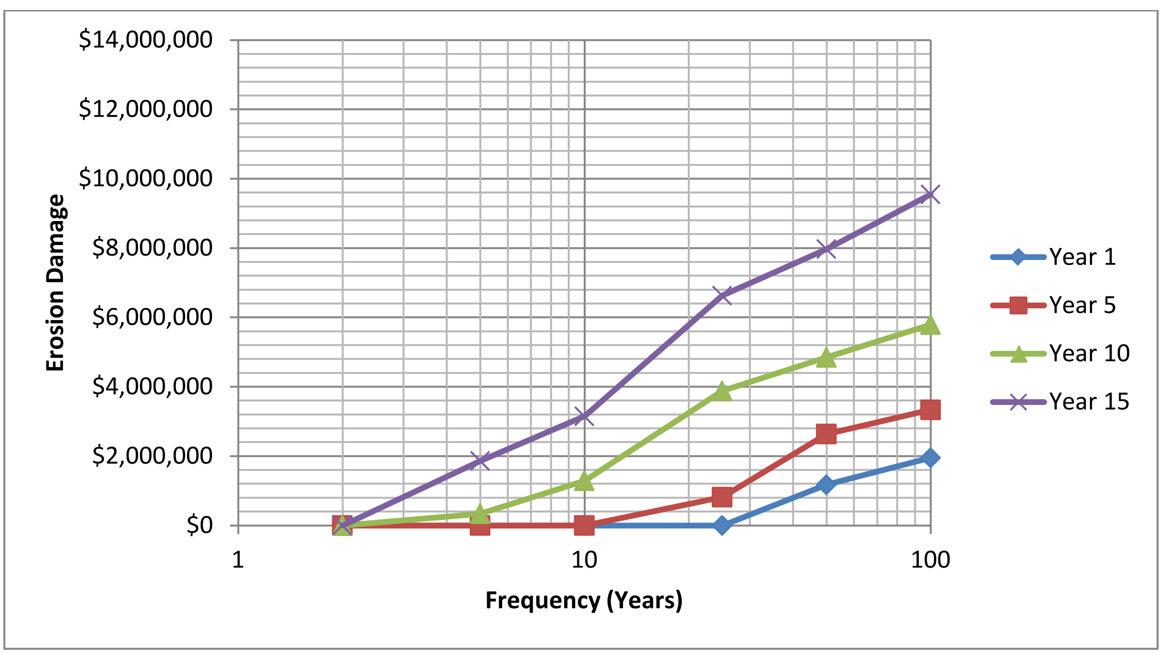

Figure 4: **With-Project Damage-Frequency Curve**

3.2.2 Additional Benefits

The cost of locally implemented beach and dune repairs mentioned in Section 3.2 would assumed to be avoided following the construction of the selected plan, and therefore can be considered a project benefit. The annual cost avoided has been derived by assigning frequencies of occurrence to the recorded local repair costs for the years 2011 – 2013, based on the return periods of the most significant storms in those years. A cost/frequency curve was subsequently constructed which was used to compute a probability-weighted annual average cost avoided of $185,000.

Table 4: Summary of Cost Avoided Frequency Generation

Date of Actions[1]	Estimated Frequency[2]	Cost[3]
August 2011	20% (5-year)	$555,600
October 2012	5% (20-year)	$1,340,000
March 2013	33% (3-year)	$136,800
December 2013	25% (4-year)	$182,300
Annual Average Cost		*$185,340*

1. Approximate date of storm event that triggered actions.
2. Estimated from comparison of measured storm tide levels and the local stage vs frequency relationship.
3. Derived from data collated by First Coastal Corporation, Westhampton Beach, NY

3.2.3 Summary of Economic Evaluation

The annual damages and benefits resulting from the model analyses for the reinforced dune are summarized in Table 5, along with annualized project costs estimated separately (See Appendix G), and the resulting benefit-cost ratio.

Table 5: Summary of Stabilization Project Damages, Costs, and Benefits

Without Project Annual Damages	**$1,378,000**
With Project Annual Damages	$326,000
Storm Damage Reduction Benefits	$1,052,000
Local Costs Avoided	$185,000
Total Annual Project Benefits	$1,237,000
Annual Cost	$918,000
Net Benefits	$319,000
Benefit-Cost Ratio	1.35

Interest rate 3.5%, Project Life 15 years, Benefits in FY14 Price Level, Model reflects base year of 2016

To illustrate the potential variance of the model results, 25th and 75th percentile storm damage reduction benefits have been extracted from the @Risk model results. The 25th percentile benefits are $1,118,000 and the 75th percentile damage reduction benefits are $1,108,000, giving a range of benefit-cost ratios of 1.21 to 1.12.

As demonstrated in the analysis, the recommended Stabilization Plan is economically justified as a one time, stand alone action.