Atlantic Coast of Long Island, Fire Island Inlet to Montauk Point

Alternative Screening Report

September, 1998

EXECUTIVE SUMMARY

The US Army Corps of Engineers, New York District (CENAN) is conducting a comprehensive feasibility-level reformulation of the shore protection and storm damage reduction project for the south shore of Long Island, New York, from Fire Island Inlet to Montauk Point. The Federally authorized project area extends west from Montauk Point to Fire Island Inlet along the Atlantic Coast of Suffolk County, Long Island, New York. Commercial, residential, public and other infrastructure in the study area are subject to economic losses (or damages) during severe storms. The principal problems are associated with extreme tides and waves that can cause extensive flooding and erosion both within barrier island and mainland communities. Breaching and/or inundation of the barrier islands also can lead to increased flood damages, especially along the mainland communities bordering Shinnecock, Moriches and Great South Bays.

The purpose of this submission is to identify potential solutions for the reduction of storm damages to economic resources (e.g. residences, commercial properties, and infrastructure) throughout the study area. Alternative storm damage reduction measures are developed to a conceptual level of detail to permit the screening/selection of preliminary features that may used as elements of storm protection alternative plans during future study phases. It is noted that the present screening is preliminary and is primarily intended to winnow the suite of possible solutions to allow more refined evaluation of selected measures. In addition to the detailed design and development of alternative storm protection plans, future study phases will include analyses of economic, environmental, and social and institutional issues to levels of detail consistent with the final plan alternatives.

To ease alternative development, and evaluation and screening procedures, the study area was separated into a series of potential project reaches. The principle factor considered in project reach delineation was the requirement to provide storm protection benefits for a contiguous area (e.g. reducing inundation of all properties along Shinnecock Bay). Storm protection benefits within these reaches are, from a practical point-of-view, independent of actions elsewhere. Project Reaches delineated for the purposes of the present screening are listed in Table 1.

Table 1
Project Reach Designations

Reach	Name	Location
1	Montauk Point	Montauk Point to Hook Pond
2	Ponds	Hook Pond to Agawam Lake
3	Shinnecock	Agawam Lake to Quogue (Quantuck Canal)
4	Moriches	Quogue (Quantuck Canal) to Smith Point
5	Fire Island	Smith Point to Fire Island Inlet

The screening and selection of appropriate storm protection measures required an understanding of the storm damage problems and needs, as well as the opportunities to enhance economic activity through reduction of potential storm damages. Storm damages to property in the study area is primarily the result of the susceptibility of the shoreline between Fire Island Inlet and Montauk Point to extratropical storms (northeasters) and hurricanes. These storms produce tides and waves that may cause extensive flooding and erosion throughout the study area. The principle cause of storm damage along the mainland is inundation. Damages to infrastructure along the barrier islands are due to a combination of mechanisms, including wave attack, erosion and inundation. Severe storms also erode barrier island beaches. This erosion and the attendant risk of barrier island breaching and/or inundation compromises the capacity of the barrier islands to protect against mainland flooding. Storm damages east of Southampton along the mainland coast arise principally from inundation and bluff erosion, which impact nearshore and upland structures. Storm damage problems for delineated project reaches are summarized below.

Project Reach 1 - Montauk Point to Hook Pond - The communities of Ditch Plains, Montauk Beach, East Hampton Beach and Beach Hampton appear to have the greatest need for storm protection. These communities are vulnerable to shorefront structure damage and inundation of low-lying areas. Narrow beaches and relatively low dunes characterize the area along Hither Hills State Park. This area is a concern inasmuch as it fronts the major eastern access route (i.e. Montauk Highway) between Montauk Point and western Long Island. Continued bluff erosion threatens to undermine individual homes throughout the remainder of Project Reach 1. Shoreline erosion is generally mild to moderate, although isolated high erosion areas are present.

Project Reach 2 – Hook Pond to Agawam Lake - Shorefront structures in Project Reach 2 are vulnerable to dune and beach erosion and to a lesser extent inundation and/or wave attack. The principal locations subject to damages arising from dune erosion are at Apaquogue, Wainscott, near Peters Lane in Sagaponack, west of Sagaponack Lake, east/west of Mecox Bay and Wickapogue. Localized flooding of low-lying and more heavily developed areas surrounding Georgica Pond, Sagaponack Lake and Mecox Bay is also a significant concern. These low-lying areas are subject to flooding due to stormwater runoff and overwash, and require frequent letting of accumulated stormwaters to preclude roadway and property flooding.

Project Reach 3 – Agawam Lake to Quogue - The principal problem is the threat of barrier island erosion/breaching, which would lead to inundation of low-lying areas along Shinnecock Bay. The barrier islands, especially those areas west of Shinnecock Inlet and along Tiana Beach, are highly vulnerable to storm erosion, inundation, overwash and breaching. Dune erosion could also lead to oceanfront property damage due to wave attack and erosion. An additional concern along the entire barrier island is the elevation of Dune Road, which is subject to frequent flooding and serves as the only access route along the barrier islands. Long-term erosion (tens of years) is varied throughout this reach, but areas of high erosion are present. Severe erosion is especially evident immediately west of Shinnecock Inlet and along portions of Tiana and Hampton Beaches.

Project Reach 4 – Quogue to Smith Point **-** Low-lying areas along the mainland shore of Moriches Bay are vulnerable to inundation damages associated with storms. This vulnerability would increase with further erosion or breaching/inundation of the fronting barrier islands. Areas susceptible to breaching are Pikes Beach, the area immediately east of Moriches Inlet and isolated segments of Smith Point County Park. Past breaches at Pikes Beach and the area near Moriches Inlet underscore this vulnerability, although breach potential has been reduced at both locations by past construction projects. However, breaching remains a concern for severe storms. Development along the barrier shoreline is subject to damages associated with storm erosion, wave attack and inundation.

Project Reach 5 – Smith Point to Fire Island Inlet **-** Due to the high density of structures along the mainland of Great South Bay, the primary mechanism for economic damage is storm inundation of the mainland that results as storm surge propagates through Fire Island Inlet. Additionally, a number of locations along Fire Island are judged to be susceptible to barrier island breaching and/or inundation that would greatly increase flooding of communities bordering Great South Bay. Storm damages to barrier island structures located behind narrow, low dunes also occur as a result of storm erosion, wave attack, inundation and overwash. Long-term erosion rates are low to moderate, but shoreline undulations increase the likelihood of storm damages by notably narrowing the protective beach.

Storm protection measures examined in this screening were selected to meet the needs for storm protection in the study area and to satisfy, to the maximum extent practicable, environmental, institutional, social and economic constraints on project implementation. In all cases, preliminary storm protection features sought to meet the objectives of reduced storm damages, while avoiding unnecessary, adverse impacts to economic, social and environmental resources. Each of the following features was examined to determine its applicability within the study area, and to select those features for further consideration in the development of plan alternatives during future study phases.

- No Action
- Non-Structural Plans
- Beach Restoration
- Offshore Breakwaters (including Artificial Headlands or T-Groins)
- Seawalls (Rubble-mound)
- Groins
- Beach Restoration With Structures
- Removal/Modification of Groins
- Levees and Floodwalls
- Storm Closure Gates
- Inlet Sand Bypassing (Inlet Modifications)

Based on the conditions in the study area, objectives of and constraints to potential storm protection measures and economic considerations, the following elements were selected as the most promising for consideration in alternative plans.

- Non-structural Plans
- Beach Restoration
- Beach Restoration with Structures
- Removal/Modification of Groins
- Levees and Floodwalls
- Closure Gates
- Inlet Sand Bypassing (Inlet Modifications)

These features were designed to a conceptual level of detail to provide a basis for comparison and screening of different storm protection measures at locations throughout the study area. The following factors were considered for each feature to determine their applicability as part of potential plan alternatives.

- Performance – What is the role of the feature in the reduction of storm damages? Where is the feature located?
- Design – What are the specific feature requirements for the study area?
- Costs – What are the costs for feature construction and maintenance?
- Limitations – Does the feature fully address the problem? Can the feature be implemented?
- Impacts – What is the effect of the feature on the environment? Is the feature socially/aesthetically acceptable?

These factors aided in the selection of cost-effective solutions for the reduction of storm damages that also minimize adverse social and environmental impacts. Feature development provided information required for the comparison and selection of various protective measures that will be considered in more detailed evaluations to take place during future study. A brief description each screened feature is presented in the following several paragraphs.

Non-Structural **-** Non-structural measures are applicable to any study area location requiring storm protection. Such measures would be feasible in the event that non-structural actions are less costly than shore protection improvements. These features in concert with shoreline improvements could also be used to augment storm protection. Land use management options may be implemented to avoid exacerbation of future storm damages. Specifically, these land use plans could control development in threatened areas to avoid or minimize future storm damage. Non-structural plans may be effective in reducing storm damages by either preventing water from entering individual structures or by removing structures from flood prone areas. These plans may include a number of different measures, which can be divided into three categories: 1) buyouts, 2) floodproofing and 3) land use regulations.

Beach Restoration **-** Beach restoration is applicable to both barrier island and mainland oceanfront shorelines in areas that are currently subject to erosion, inundation, breaching and wave attack. In those areas where erosion may lead to increased damage vulnerability, beach restoration is a suitable method for abating shoreline erosion and minimizing storm damages. Beach restoration is particularly useful at locations characterized by minor or moderate erosion, where it can be effective in abating shoreline erosion (either long-term or storm-induced) and improving storm protection. Storm-induced property damages include those arising from beach and dune erosion, barrier island breaches and flooding of upland areas. Long-term erosion can also cause property damage and results from longshore sediment transport gradients and/or anomalous offshore bathymetric features. A beachfill normally consists of a design berm that protects the dune from erosion, and a dune that provides a barrier to storm tides and waves. Beachfill alleviates erosion by providing a sacrificial storm barrier. Renourishment operations are required to maintain storm damage protection.

Beach Restoration and Offshore Breakwaters **-** The use of breakwaters in concert with beach restoration is applicable at locations where beachfill alone is vulnerable to significant erosion with an attendant high cost for renourishment/rehabilitation. Breakwaters are classified as beach stabilization structures, serving the following purposes: (1) reduce beach erosion (both long-term and storm-induced), (2) increase beachfill longevity and (3) maintain a protective beach for the reduction of storm damages. Breakwater design concepts were developed to stabilize the beachfill with storm protection primarily provided by the protective beach rather than the structures.

Beach Restoration and Seawalls **-** A seawall can be used to augment the level of protection offered by beach nourishment alone or to reduce the volume of fill required in the design fill section. Unlike breakwaters and headlands, seawalls provide direct storm protection against waves and storm surge. Seawalls do not, however, reduce beach renourishment requirements due to their position landward of the active littoral zone. Nonetheless, long-term beach maintenance is required to ensure structural integrity. Rubble-mound seawalls were examined to augment the protective capacity of and reduce the reliance on beach restoration for storm damage reduction by providing a robust storm barrier. The seawall feature would absorb direct wave impacts, restrict storm erosion and prevent breach formation. The considered seawall design consists of a rubble-mound structure buried in the dune of the design beachfill. Beach restoration ensures the integrity of the seawall prior to severe storms. Because the seawall is placed within the dune, the size of waves that reach the structure is limited even during a severe event. Furthermore, locating the seawall within the dune removes the structure from sight and the active littoral zone during all but the most extreme storms.

Beach Restoration and Groins **-** Beach restoration and groins are applicable to severely eroding shorelines where beach restoration alone is not cost-effective due to high renourishment requirements. Groins can increase the longevity of beachfill by reducing losses due to long-term erosion. Groins are classified as beach stabilization structures. Groins interrupt longshore sediment transport and promote sediment deposition. Groins are often constructed in series to provide protection to a continuous shoreline segment. For the present evaluation, groin compartments would be filled initially to promote sand bypassing, which would limit the adverse impacts often observed downdrift of initially unfilled groin fields.

Removal/Modification of Groins **-** This feature is applicable to locations where existing groins may have adversely impacted the beach and adjacent areas. Existing groins are located in the Towns of Easthampton and Southampton (8), at Westhampton Beach (16) and along Fire Island (2). This feature would examine the removal or modification of groins in the study area to augment the performance of other shore protection features (particularly beachfill). For the present screening groin removal was examined, although future study phases may consider modification of existing groins to lessen possible adverse impacts on the existing littoral environment. Groin modifications could include tapering existing groin fields, lowering and/or shortening groins, or notching groins to enhance sand bypassing to downdrift shorelines. A complete investigation into the feasibility or impacts of this alternative requires careful investigation aimed at quantifying the historic and ongoing impact of the existing groins. It would also be required that existing storm protection in areas where groin removal occurred would not be significantly affected.

Levees and Floodwalls **-** Levees and floodwalls are effective in reducing tidal flooding in coastal areas. The levee or floodwall system provides a barrier against high storm tides that cause flooding. Levees and floodwalls are designed to provide a continuous line of protection around a group of structures or larger development. These features represent a flood barrier not directly exposed to ocean storms. Conceptual design performed for the present analysis describes the development of the levee/floodwall protection alternatives for the mainland of Long Island. These features may be comprised of earthen materials, concrete, rock or a combination of materials. Levees and floodwalls must either be self-enclosed or tie into high ground at each end of a project segment. If a large area is to be protected, rivers or canals draining into the bays will either require closure gates and drainage facilities such as pump stations or will require the line of protection to surround the water course on both sides, extending inland to high ground.

Storm Closure Gates **-** These structures are appropriate as stand alone features at locations where surrounding landmasses are high enough to preclude surge inundation, but may need to be combined with other measures (e.g., beachfill, closure dikes) where surrounding land areas are low. Along the barrier islands in the study area, closure gates would require that storm erosion and inundation of the islands was not a significant contributing factor to estuary flooding. In other words, storm closure gates serve only to reduce flooding through inlets. Storm closure gates can also be used to close off canals or creeks as part of the levee and floodwall feature, and are considered in that analysis. Tidal gates at Fire Island, Moriches and Shinnecock Inlets would provide barriers to flow that could limit the propagation of storm surges into adjoining bays. The present examination also considers a closure gate at Narrow Bay to limit flow between Moriches and Great South Bays. In the event that flow control structures are operated at Moriches and Fire Island Inlets, no structure would be required at Narrow Bay. A flow control structure was not examined between Shinnecock and Moriches Bay, as flows between these estuaries are presently constricted.

Inlet Modifications – Modifications to Fire Island, Moriches and/or Shinnecock Inlets will be investigated during future study efforts. These modifications would focus on reducing inlet-trapping capacity and could involve modification of inlet dredging practices to enhance sand bypassing and/or construction of sand bypassing plants. Other modifications could include revision of current inlet design cross-sections or other features to limit storm surge propagation through the inlets, and concomitantly bay tidal inundation. These modifications would likely be of limited effectiveness without other shorefront improvements, but could improve the performance of other features by reducing erosion downdrift of the inlets (i.e., enhanced sand bypassing).

Site-specific conditions were evaluated to determine the needs, opportunities and constraints that influence plan development. This evaluation was performed to determine alternative features that will be considered at different locations. Accordingly, matrices were developed to compare the needs, opportunities and constraints for different locations in the study area. Alternative storm protection features were then evaluated to identify potential measures applicable to each reach. Factors considered in selecting features for more detailed study and possible application to different reaches included:

- Problems and Opportunities – performance of specific measures in combating inundation, shoreline erosion, bluff/dune erosion, breach formation, overwash and wave attack; comprises the capability of different measures in meeting storm protection objectives;

- Economic Resources – damage history, barrier island development, mainland development and coastal structure presence; describes possible locations for implementation of different measures and summarizes economic resources to be protected;

- Environmental Constraints - Coastal Barrier Resource System and Significant Fish & Wildlife Habitats; indicates environmental sensitivity of potential locations for implementation of different measures; and

- Institutional Constraints - Coastal Barrier Resources Act (CBRA); New York State Coastal Zone Management Policies; Coastal Erosion Hazard Areas; public access, Fire Island National Seashore (FINS), local regulation, wilderness designation, historical constraints; identifies possible constraints to storm protection plans.

These factors were used to determine whether a particular measure is practicable and should be considered in future study phases. The purpose of the screening is to select only those measures that are technically, economically, environmentally, socially and institutionally practicable. Based on these considerations, features were selected for more detailed evaluation for each reach delineated in the study area.

Table 2 reflects the results of this screening process. No ranking was assigned to these measures at the present time, although cost comparisons indicated that non-structural and beach restoration measures were the least costly options in Project Reaches 1 and 2. Other measures selected in Project Reaches 1 and 2 (beach restoration and groins/seawalls) were selected to evaluate the cost effectiveness of these measures in response to the highly localized nature of storm damage problems. Cost comparisons in Project Reaches 3 to 5 indicated that beach restoration is the least costly alternative, although non-structural measures will be examined in concert with or in lieu of shorefront improvements in these areas. Other measures (beach restoration and seawalls/groins/breakwaters) were selected for further evaluation in response to several localized areas where severe erosion or the localized nature of the storm damage problems may preclude cost-effective use of other features. Levees and floodwalls, because of their applicability to localized flooding problems, may be further evaluated in Project Reaches 3 to 5, but do not provide cost-effective, regional storm protection. Inlet modifications will be examined at Shinnecock, Moriches and Fire Island Inlet to determine whether enhanced sand bypassing or modified inlet designs could potentially limit future storm damages and/or enhance the performance of plan alternatives. All other features (i.e., storm closure gates, coastal structures only) were eliminated from further consideration due to their failure to meet the objectives of the Reformulation Study.

Table 2

Storm Protection Feature Screening Summary

Project Reach	**Non-Structural**	**Beach Restoration**	**Beach Restoration**						
			Breakwaters	**Seawalls**	**Groins**	**Groin Modification**	**Levees and Floodwalls**	**Storm Closure Gates**	**Inlet Modifications**
1	✓	✓		✓	✓				
2	✓	✓		✓	✓				
3	✓	✓		✓	✓				✓
4	✓	✓		✓	✓	✓			✓
5	✓	✓	✓	✓					✓

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1. INTRODUCTION

The US Army Corps of Engineers, New York District (CENAN) is conducting a comprehensive feasibility-level reformulation of the shore protection and storm damage reduction project for the south shore of Long Island, New York, from Fire Island Inlet to Montauk Point. Numerous study tasks are involved in the planning of storm damage reduction projects for the approximately 83-mile study area length. The Reformulation Study is a multi-year and multi-task effort, involving project planning and engineering, economic analyses and environmental studies.

1.1 Study Location

The Federally authorized project area extends west from Montauk Point to Fire Island Inlet along the Atlantic Coast of Suffolk County, Long Island, New York (see Figure 1.1). The study area includes the mainland of Long Island extending from Montauk Point to Southampton, the barrier island chain from Southampton to Fire Island Inlet, the Atlantic Ocean shorelines and adjacent back-bay areas along Shinnecock, Moriches and Great South Bays. Total study length encompasses approximately 83 miles along the Atlantic Ocean and comprises approximately 70 percent of the total ocean frontage of Long Island, as well as hundreds of miles of bay shoreline.

1.2 Purpose

The study area is subject to economic damages during severe storms due to extreme tides and waves that can cause extensive flooding and erosion, both of which can be exacerbated by breaching and overwashing of the barrier islands. Normal site condition changes (e.g., shoreline movements) may also increase the likelihood of economic losses, as the protective capacity of the barrier islands are lessened in association with decreasing beach widths and dune erosion. The purpose of this submission is to identify potential solutions for the reduction of storm damages to economic resources (e.g., residences, commercial properties, and infrastructure) throughout the study area. Alternative storm damage reduction measures are developed to a conceptual level of detail to permit the screening/selection of those features that may used as elements of storm protection alternative plans during future study phases. The present submission builds upon earlier study results that included the identification of a series of reaches to ease the development and screening of potential project alternatives.

1.3 Reformulation Study Authority

The Fire Island Inlet to Montauk Point, New York, Combined Beach Erosion Control and Hurricane Protection Project was authorized by the River and Harbor Act of 14 July 1960 in accordance with House Document 425, 85th Congress, 2nd Session, dated 21 June 1960. The authorization was modified for the cost sharing of the beach erosion portion of the project in accordance with Section 103 of the River and Harbor Act of 12 October 1962. The project authorization was modified again by Section 31 of the Water Resources Development Act of 1986 (P.L. 99-662), which directed the Secretary of the Army to apply the cost sharing provisions of Section 31(1) of the Water Resources Development Act of 1974 (P.L. 93-251) to include periodic nourishment of the construction project at Westhampton Beach, New York, for a period of 20 years after the date of enactment of P.L. 99-662. The Water Resources Development Act of 1992 further modified the project to extend the period of renourishment for 30 years from the date of project completion for Westhampton Beach with the non-Federal share not to exceed 35 percent of the total project cost.

The authorized project provided for the dual purposes of beach erosion control and hurricane protection. Stated purposes of the authorized project, as described in House Document 425, were as follows: (1) the beach erosion control phase was to determine the most practicable economic method of restoring adequate recreational and protective beaches and to provide continued stability to the ocean shore from Fire Island Inlet to Montauk Point and (2) the hurricane study phase was to develop an adequate plan of protection against hurricane flooding for the same study area.

Elements of the authorized project included widening the beaches along the developed areas between Kismet and Mecox Bay to a minimum width of 100 feet at an elevation of 14 feet above Mean Sea Level (MSL). Dunes were to be raised to an elevation of 20 feet above MSL from Fire Island Inlet to Hither Hills State Park, and at Montauk and opposite Lake Montauk Harbor by artificial placement of suitable sand. Other elements of the authorized project included dune grass planting and interior drainage structures at Mecox Bay, Sagaponack Lake and Georgica Pond. The project authorized construction of up to 50 groins subject to future determination of the actual need based on experience.

1.4 Study Process

The Reformulation Study will comprise a comprehensive evaluation of storm damage reduction alternatives, as well as the examination of environmental, institutional and regional impacts arising from potential project construction and/or implementation. Planned milestones in the continuing Reformulation Study are summarized in Table 1.1.

Table 1.1

Reformulation Study Milestones

Milestone	Completion Date	Description
Reach Delineation	April 1998	Identifies the approach for considering alternative measures, based upon study area characteristics.
Screening of Storm Damage Reduction Alternatives	January 1999	Investigation of typical alternative solutions for general project areas; documents the basis for alternatives to be further considered in future study phases.
Identification of Mitigation Alternatives	February 1999	For each alternative addressed in the screening report, a qualitative discussion of impacts is included, with the identification of mitigation measures for each alternative. Report documents basis for measures to be further developed, and identifies the necessary development steps (e.g., quantification of impacts, siting).
Detailed Development of Storm Damage Reduction Alternatives	December 1999	Detailed development of alternatives identified in the screening report, including, including site specific development of up to four alternative types, and three scales. Report documents solutions to be modeled for with-project consideration, in order to evaluate project performance and economics impacts.
Screening of Mitigation Alternatives	January 2000	For each of the specific alternatives identified in the above analysis, further analyses of site specific impacts will be performed, including design of possible mitigation measures. The report will include the methods to be used for final quantification, and selection of mitigation measures.
Design Optimization	September 2000	Incorporates modifications to project plans based upon with-project simulation, economic analysis based upon with-project simulations, and project costs for storm damage reduction measures, including required mitigation costs. Will include comparison of all plans, throughout project location, and identify the NED plan, and the selected plan, if different than the NED.
Final Feasibility Design	February 2001	Based upon Design Optimization, final feasibility level design of the selected plan(s).
Alternative Formulation Briefing	June 2001	Presentation of formulation analysis, selected design, and economic and environmental considerations to USACE higher authorities. Will serve as precursor to information to be presented in the Reformulation Report and Environmental Impact Statement.
Draft Report and EIS (HQUSACE/Agency Review)	September 2001	
Draft Report (Public Review)	January 2002	
Final Report	May 2002	

1.5 Report Format

The remainder of this submission describes the procedures used in the conceptual design and screening of storm damage reduction measures. The present submission is limited to engineering and/or technical analyses of storm protection measures, and is divided into the following sections.

- ***Section 2 – Site Conditions***

- ***Section 3 – Problem Identification, Needs and Opportunities***
- ***Section 4 – Preliminary Project Feature Screening***
- ***Section 5 – Conceptual Features Design***
- ***Section 6 – Features Selection***

2. SITE CONDITIONS

2.1 Introduction

Physical processes and economic and coastal resources of the study area have been identified to provide the basis for examining storm protection problems and opportunities. These processes/resources represent the baseline conditions used to evaluate the storm protection needs of the study area. This information is important in the screening/selection of appropriate storm protection measures that are consistent with the identified problems and conditions. Concurrent to the formulation of plans, the information presented below is being developed to a higher level of detail that will be consistent with the final design of storm protection alternative measures.

2.2 Site Characteristics

The study area is shown in Figures 2.1 to 2.8. The eastern project segment includes the south fork of the mainland coast of Long Island, and extends from Montauk Point to the Town of Southampton (approximately 33 miles). Extending west from Montauk Point for a distance of approximately about 15 miles, the south shore of Long Island is backed by Block Island Sound (to the east) and Napeague Bay (to the west). Island widths in this segment range from about 15,000 feet at Montauk to 4,500 feet at Napeague. The eastern 10-mile segment of the study area is characterized by a series of bluffs or headlands with elevations ranging up to 100 feet. For the next 23 miles to the west, the shore is characterized by lower bluffs and/or dunes fronted by beaches of varying width. Beach widths in the eastern project area range from approximately 50 to 200 feet and are characterized by berm elevations from 6 to 10 feet. Several bodies of water are situated just landward of the shorefront, within the boundaries of the Towns of East Hampton and Southampton. The largest of these water bodies include Hook Pond, Georgica Pond, Sagaponack Lake, Mecox Bay and Agawam Lake (see Figures 2.3 and 2.4).

A series of barrier islands is located within the western portion of the study area extending from Southampton to Fire Island Inlet for a distance of approximately 50 miles. The island chain includes the 4-mile long barrier island extending from Southampton to Shinnecock Inlet; the 15-mile barrier island from Shinnecock Inlet to Moriches Inlet; and the 30-mile long Fire Island that extends from Moriches Inlet to Fire Island Inlet. Beaches along the barrier island chain are generally characterized by a well-defined dune system with crest elevations ranging from 6 to 40 feet relative to the National Geodetic Vertical Datum (NGVD).

The barrier island chain is separated from the Long Island mainland by Shinnecock, Moriches and Great South Bays. Shinnecock Bay is a relatively small estuarial system located between the Villages of Southampton and Quogue, where it connects with Moriches Bay through the Quantuck and Quogue

Canals. Moriches Bay, like Shinnecock Bay, is a relatively small estuary that is comprised of an ocean entrance, eastern and western connections to Shinnecock Bay and Great South Bay, respectively, and a number of tidal rivers and creeks. Moriches Bay extends from Westhampton Beach to Smith Point (inclusive of Narrow Bay) where it adjoins Great South Bay. Great South Bay is the largest of the study area estuaries extending about 30 miles from Smith Point to South Oyster Bay. Inlets connecting Shinnecock, Moriches and Great South Bays with the Atlantic Ocean include Shinnecock, Moriches and Fire Island Inlets which are located approximately 96, 80 and 50 miles east of The Battery, New York City, respectively. Federal navigation projects have been established at each of these inlets.

2.3 Study Area Reaches

To ease alternative development, evaluation and screening procedures, the study area was separated into a series of reaches, namely: (1) potential project reaches and (2) physical reaches. These reaches were delineated from Fire Island Inlet to Montauk Point and represent the oceanfront areas where oceanfront storm protection measures may be undertaken. An addition set of economic reaches was also delineated for evaluation of storm damage reduction benefits and analysis of bay shoreline storm protection alternatives. Economic reaches were specified from Fire Island Inlet to Montauk Point and along the bay shorelines surrounding Great South, Moriches and Shinnecock Bays. The following two paragraphs describe physical and project reaches and their relationship to the development of storm damage reduction plans. Reach delineation procedures were presented in Interim Submission No. 1 (dated April 1998) and results are shown in Figures 2.2 to 2.8. These figures also show economic reach locations to be used for project economic evaluation, but these reaches are not used in the present report. It is noted that physical reach numbering has been modified from Interim Submission No. 1, although locations are unchanged.

2.3.1 Project Reaches

Project reaches are defined as shore segments where separate storm protection measures may be implemented generally independent of actions elsewhere. The principle factor considered in project reach delineation was the requirement to provide storm protection benefits for a contiguous area (e.g. all of Shinnecock Bay). Storm damage reduction benefits within these reaches are, from a practical point-of-view, separate of actions elsewhere. While the influence of alternatives for a single project reach must be considered in the context of the entire study area, separation of these segments permits evaluation of incremental project benefits. Project reaches may be characterized by varying physical characteristics that influence the development of storm protection measures. Therefore, project reaches were subdivided into physical reaches to reflect changes in physical conditions important to project element design.

2.3.2 Physical Reaches

These reaches were defined as continuous shore segments having similar geomorphic features and environmental constraints, and serve as the preliminary basis for determining appropriate storm protection solutions. As stated above, physical reaches are subreaches of project reaches. Project features would be consistent for a physical reach due to similar site conditions, but may differ between neighboring physical reaches due to varying conditions. Consequently, alternatives for a given project reach include the design features of each physical reach. Physical reaches are akin to design reaches. The latter will be delineated either by combining or restructuring physical reaches based on the outcome of more detail analyses during future study stages.

2.4 Social and Economic Resources

The importance and severity of storm damages and, consequently, the economic feasibility of storm damage reduction plans are dependent on the social and economic resources at risk. This section provides a brief description of these factors for use in the screening and selection of appropriate storm protection measures.

2.4.1 Institutional Boundaries

The entire study area is located in Suffolk County, including portions of five towns, namely: (1) Town of East Hampton, (2) Town of Southampton, (3) Town of Brookhaven, (4) Town of Islip and (5) Town of Babylon. Town locations are shown in Figures 2.1 and 2.9. Each of these towns is comprised of incorporated villages and unincorporated hamlets. The town in which a hamlet is located governs that hamlet, whereas incorporated villages have local governments. The boundaries of the five towns and the incorporated villages located within these towns are important to plan formulation performed for the Reformulation Study. In addition to Suffolk County and local jurisdictions, the Fire Island National Seashore and several state parks are present in the study area. Since state, federal and local jurisdictions will have input to the planning process, their needs regarding development of storm protection plans must be considered. More detailed information on the social and economic criteria is being developed concurrently with the development of alternatives to identify the benefits associated with storm protection measures.

2.4.2 Land Use

A summary of land uses in the study area is presented in Table 2.1, which shows that the study area is more developed to the west and that development decreases to the east. Aside from the more developed mainland communities, Fire Island National Seashore, Robert Moses State Park and Smith Point County Park comprise the vast majority of Fire Island. The eastern towns, including Southampton and East Hampton, have a significant portion of land use devoted to agriculture and a relatively small portion devoted to commercial/industrial use. To the west, near the Nassau County border, there is very little agricultural use and more commercial/industrial use. There are currently about 35,000 acres of active farmland in Suffolk County, but this amount is decreasing by approximately 1,400 acres/year.

2.4.3 Development

Table 2.2 shows that the study area contains over 47,000 structures located along the south shore in Suffolk County. These structures are generally located within a swath that extends from the shoreline to an area where the ground elevations rise above 16 feet NGVD. Over 22,000 of these structures are located in the 100-year floodplain and the majority of these structures are located at the western end of the study area. There are relatively few structures located in the 100-year flood plain east of Southampton in Project Reaches 1 and 2 relative to Project Reaches 3, 4 and 5 (Shinnecock, Moriches and Great South Bays, respectively). The majority of the structures are residential, whereas commercial, municipal and industrial structures represent approximately 8 percent of the total.

Just over 10 percent of the buildings in the study area are located on the barrier islands. These barrier island structures are spaced sporadically with the majority of development adjacent to Great South Bay between Fire Island Inlet and Watch Hill and east of Cupsogue County Park along Moriches and Shinnecock Bays. The barrier islands between these two developed areas have few structures and contain the Fire Island Wilderness Area, Smith Point County Park and Cupsogue County Park.

2.4.4 Accessibility

The study area has a large network of roadways (see Figure 2.1). A number of highways provide east-west access including the Long Island Expressway (Interstate 495), the Northern State Parkway, the Southern State Parkway, Sunrise Highway (Route 27) and the Montauk Highway (route 27A/27). At the western end of the study area on Jones Island, Ocean Parkway provides east-west access along Long Island and connects at its western end with the Wantaugh and Meadowbrook Parkways. Both of these parkways are major north-south thoroughfares. The east end of Ocean Parkway connects to the Robert Moses Parkway and the Sagitos State Parkway providing additional north-south routes. The William Floyd Parkway at the center of the study area provides a major north-south route across Long Island.

There are no roadways on Fire Island except at its eastern end where the William Floyd Parkway connects at Smith Point County Park, and at its western end where the Robert Moses Causeway connects the mainland to Robert Moses State Park. The Robert Moses Causeway is the only access route to the Fire

Island Lighthouse and vicinity. Further access to Fire Island is limited to (1) ferry service from Bay Shore, Sayville and Patchogue and (2) private boat access. Travel on Fire Island is limited to rough trails and footpaths, and motorized vehicle use is restricted.

East of Shinnecock Inlet, Dune Road provides east-west access from the barrier island to the village of Southampton via Halsey Neck Road, Cooper Neck Lane, First Neck Lane and South Main Street. Dune Road continues west of Shinnecock Inlet providing east-west access along the barrier island from Shinnecock Inlet west to Cupsogue County Park near Moriches Inlet. Dune Road is connected to the mainland via Jessup Lane and Beach Lane in Westhampton Beach, by Post Lane in Quogue and by the Ponquogue Bridge in Ponquogue.

East of the Village of Southampton, the Montauk Highway (Route 27) provides the only major east-west roadway, and is, therefore, a crucial roadway in terms of its potential for flooding. Other large north-south thoroughfares include those listed below.

- Moriches-Riverhead Road (Route 51) extends from Riverhead southwest to East Moriches and connects the Sunrise Highway and Montauk Highway.
- Route 112 connects Part Jefferson and Patchogue.
- Westhampton Road (Route 111) connects the Long Island Expressway to the Sunrise Highway.
- Nicholls Road (Route 97) connects the Long Island Expressway, Sunrise Highway and Montauk Highway.
- Veterans Memorial Highway (Route 454) provides access from the Long Island Expressway to the Sunrise Highway.
- Route 110 connects the Long Island Expressway, Southern State Parkway and Montauk Highway.

In addition to these thoroughfares, the Montauk Branch of the Long Island Railroad (LIRR) provides passenger railroad service from Montauk Point to New York City via Jamaica, New York. Bus services are also available throughout Long Island.

Traffic congestion on Long Island has increased over the last 20 years due to increases in population and the number of drivers. For example, from 1980 to 1990 the population of Nassau and Suffolk Counties grew by approximately 37,750 but the number of licensed drivers grew by 321,000. As Suffolk County’s population is spread out, transportation via mass transit is difficult (87 percent of Suffolk County’s work force works on Long Island) and traffic congestion is a problem. Furthermore, despite major transportation corridors along the south shore of Long Island, a number of the villages are only connected to major roadways via roadways of smaller capacity. If these roadways become flooded and/or washed out, access to these communities is interrupted.

TABLE 2.1
LAND USE SUMMARY

Location	Total Acres	Percent Residential			Percent Commercial/ Industrial/ Institutional	Percent Recreation	Percent Agriculture	Percent Vacant
		Low to Medium Density	Intermediate to High Density	Total				
Town of Babylon	32,664	20.3	26.6	46.8	17.2	29.3	0.2	6.3
Incorporated Villages:								
Amityville	1,340	21.0	38.2	59.3	26.0	10.6	0.0	4.2
Babylon	1,557	10.6	52.2	62.8	18.7	8.4	0.0	9.9
Lindenhurst	2,322	14.3	59.6	74.0	18.2	4.3	0.0	3.7
Town of Islip	58,823	31.6	2.8	34.4	25.5	19.9	0.3	19.9
Incorporated Villages:								
Brightwaters	652	78.5	7.6	86.2	3.8	6.9	0.0	3.2
Ocean Beach	90	0.0	64.4	64.4	0.0	25.6	0.0	10.0
Saltaire	209	12.0	0.0	12.0	0.0	23.9	0.0	64.1
Town of Brookhaven	148,919	18.9	3.4	22.4	22.0	11.6	5.4	38.7
Incorporated Villages:								
Patchogue	1,485	62.6	3.5	66.1	18.7	5.0	0.0	10.0
Bellport	893	58.5	0.0	58.5	5.6	19.0	0.0	16.8
Town of Southampton	140.2	13.4	1.9	15.3	10.7	9.1	16.2	48.7
Incorporated Villages:								
Quogue	2,681	23.6	0.0	23.6	4.4	2.8	0.1	69.0
Southampton	4,237	51.6	2.0	53.6	6.3	1.2	8.2	30.6
Westhampton Beach	1,942	37.0	0.6	37.5	22.0	1.8	0.3	38.5
Town of Easthampton	43,629	10.5	1.7	12.2	10.2	19.0	6.9	51.6
Incorporated Villages:								
Easthampton	3,017	34.8	0.3	35.2	6.1	8.8	9.9	40.0

Source: Quantification and Analysis of Land Use for Nassau and Suffolk Counties, Long Island Regional Planning Board, December 1982

TABLE 2.2
APPROXIMATE NUMBER OF STRUCTURES IN 100-YEAR FLOODPLAIN

Project Reach	Structures In 100-Year Floodplain	Structures Between 100-Year Floodplain and 16' NGVD	Total Structures (Mainland Study Area)
1	85	989	1,074
2	112	937	1,049
3	1,641	2,258	3,899
4	4,335	2,906	7,246
5	15,845	18,408	34,255
Total	22,018	25,498	47,516

3. PROBLEM IDENTIFICATION, NEEDS AND OPPORTUNITIES

3.1 Introduction

The screening and selection of appropriate storm protection measures requires an understanding of the coastal processes and storm damage problems and needs, as well as opportunities to enhance economic and recreational activity through reduction of potential storm damages. The identification of storm damage problems in the study area have been summarized based on recent storm experiences and current study area conditions to provide a basis for the preliminary assessment of storm protection methods.

3.2 Problem Overview

Storm damages to property in the study area are primarily the result of the susceptibility of the shoreline between Fire Island Inlet and Montauk Point to extratropical storms, northeasters and hurricanes. These storms produce tides and waves that may cause extensive flooding and erosion throughout the study area. Severe storms have historically overwashed and even broken through the barrier islands at various places between Fire Island Inlet and Southampton inundating developed areas on the barrier islands and mainland. The mainland shoreline from Southampton to Montauk Point has also been impacted by historic storms that have narrowed the protective beaches and resulted in significant bluff/dune erosion. Severe storms during recent years have exacerbated these conditions resulting in more widespread vulnerability to economic losses during future storms. Damages to existing development and infrastructure arising from continued shoreline movements, increased bluff/dune erosion and barrier island breaching/inundation include flooding along the ocean and bay shorelines and damages to oceanfront structures arising from erosion, tidal inundation and direct ocean wave attack. Infrastructure vulnerable to damage include homes, commercial properties, transportation routes, utility lines and sewers. Storm damages have resulted in extensive financial losses to upland properties and numerous storm evacuations.

The principle cause of storm damage along the mainland is tidal inundation. As the water level rises due to storm tides, the low-lying areas of the mainland become flooded. Damages to infrastructure along the barrier islands are due to a combination of mechanisms, including wave attack, erosion and tidal inundation. Severe storms also erode barrier island beaches and dunes. This erosion and the attendant risk of barrier island breaching/inundation compromises the capacity of the barrier islands to protect against mainland flooding. Storm damages east of Southampton along the mainland coast arise principally from tidal inundation and bluff erosion, which can adversely impact nearshore and upland structures.

Recent storms that have resulted in economic losses between Fire Island Inlet and Montauk Point include (1) Hurricane Bob in 1991, (2) the 1991 Halloween Northeaster, (3) the December 1992 Northeaster and (4) the March 1993 Northeaster. Additionally, numerous lesser storms have caused tidal inundation and property damages along the barrier islands, and bluff/dune erosion and tidal inundation of mainland structures.

3.2.1 Coastal Flooding

Flooding resulting from storm tides has been a recurring problem for numerous communities along the south shore of Long Island. Flood-related problems are magnified along the western portion of the study area where storm tide elevations are higher, development density is greater and land area elevations can be low (see Photograph 3.1). The severity of the flooding problem is decreased along the eastern portion of the study area where land elevations are relatively high. Several isolated, low-lying communities in the eastern portion of the study area are, however, subject to storm flooding.

Continued growth in Suffolk County has led to intensive development of low-lying areas around Great South, Moriches and Shinnecock Bays. During storms, the presence of the barrier islands limits or prevents widespread tidal inundation of these low-lying areas, although flooding during severe storms can be extensive. Fire Island, Moriches and Shinnecock Inlets, as well as Narrow Bay, act as constrictions that significantly control storm surge propagation into study area estuaries.

3.2.2 Erosion

Erosion may be classified as either short-term (storm-induced) or long-term erosion. The former is associated with cross-shore sediment transport during storms while the latter is associated with gradients of longshore sediment transport under normal conditions. Storm driven waves may cause severe, short-term recession of beaches, dunes and bluffs, while long-term shoreline processes may result in significant shoreline movement over a period of years. Both phenomena are responsible for erosion related problems (e.g., property and infrastructure damages) along the study area.

Long-term shoreline erosion due to longshore sediment transport gradients and/or overall sediment deficits has resulted in the reduction of the protective capabilities of numerous barrier island and mainland beaches. Long-term shoreline movements throughout the study area are characterized by erosion on the order of 1 to 2 feet per year. Extreme long-term shoreline erosion is reported at several locations, most notably west of Shinnecock Inlet, Pikes Beach and Smith Point County Park. The influence of severe long-term erosion west of Shinnecock Inlet is shown in Photograph 3.2. This photograph shows a narrow, low beach that has been rendered susceptible to increased overtopping, storm erosion and breaching by long-term processes. Several factors can influence long-term erosion, including the effects of inlets (both stabilized and unstabilized), coastal structures or natural sediment deficits. It is also recognized that long-term erosion includes the accumulation of short-term erosion events (i.e., storms).

Storm-induced shoreline, dune and bluff erosion has greatly impacted the study area. Dune and bluff erosion during a single storm may exceed long-term erosion that occurs over a period of years. The impact of storm events on dune erosion is typified by Photograph 3.3. Dunes and bluffs erode during storms and may be a critical source of sediments to the study area littoral environment. This source of sediments is vital to the ability of study area beaches to renourish and sustain themselves. Bluffs are a predominant coastal feature along the eastern portion of the study area, and unlike beach erosion that may recover after storm passage, storm-induced dune and bluff erosion does not recover quickly and in some cases may never recover. The erosion of dunes and/or bluffs during storms introduces beach sediments to the shoreface as the beach profile adjusts to elevated storm tides and waves. Once moved to the shoreface, these sediments provide a degree of protection to dunes and bluffs during subsequent storms. Shorefront infrastructure may, however, become threatened as coastal dunes and bluffs recede. Furthermore, the threat of erosion often leads property owners to construct stabilization measures, which can, in some cases, exacerbate erosion in adjacent areas.

An additional factor relevant to long-term shoreline movements is the persistence of large-scale shoreline undulations about the average shoreline position. These undulations may dwarf long-term erosion, and can increase the potential for storm damage and breaching. These undulations can impact several miles of shoreline with landward indentures from the average shoreline position that average between 50 and 100 feet.

3.2.3 Barrier Island Breaching and Overtopping

Breaching and overtopping has occurred at various times and locations in the study area. Historically, breaches have occurred during several major storms, including in 1938, 1954, 1962, 1980 and 1992 (see Photograph 3.4). Most of these breaches have either closed naturally or were closed mechanically, with the exception being the breach that formed the present Shinnecock Inlet during a storm in 1938. Most recently, in December 1992, two breaches formed at Pikes Beach between Westhampton and Moriches Inlet, and overwash occurred west of Shinnecock Inlet and at Tiana Beach, Atlantique, Old Inlet and Smith Point County Park. Additionally, dune overtopping and overwash has occurred at numerous locations during recent years.

The impacts of barrier island breaching and overwash can be immediate. Immediate impacts that persist during the course of the causal storm include increased normal and storm tides in the adjoining embayment, displacement of barrier island sediments, burial of tidal wetlands, interruption of littoral drift, modification of bay circulation and destruction of structures proximate to breach/overwash areas.

Impacts that can occur subsequent to breach formation and are exacerbated should the breach increase in size include:

- breach vulnerability to migrate with the attendant destruction of structures;
- provision of an additional opening to an embayment, which can alter bay flushing and circulation characteristics, bay salinities, and increase normal astronomical and storm tides within the bay;
- increased shoaling and/or closure of the existing bay inlet opening;
- increased wave activity in formerly quiescent areas, possibly leading to shoreline/marsh erosion;
- shoaling of bay navigation channels; and
- trapping of significant portions of barrier beach sediments leading to downdrift erosion of adjacent beaches.

The impacts described pertain to periods that span from breach formation to closure, and generally comprise the adverse impacts that the Reformulation Study proposes to address. These adverse impacts are significant factors influencing the need for storm protection in the study area. Over the course of several decades, numerous storms causing overwashing and breaching will occur. Attending these events can be marked storm damages that are exacerbated should the protection provided by the barrier island be compromised by overwashing or breaching. On the other hand, overwashing and breaching are pivotal in the development of the barrier island system, but generally produce major change over periods of hundreds to thousands of years. However, these breaching and overwash effects represent the cumulating of short-term episodes (i.e., storms). In general, overwashing is a principal source of sediments for the vertical construction of the barrier islands in response to rising sea levels, whereas breaching (or new inlets) provide the backbarrier sediments that accommodate barrier island migration and salt marsh establishment.

It is acknowledged that the storm damage reduction measures being considered may adversely impact the benefits associated with barrier island breaching and overwash. These benefits include barrier island migration, wetland creation/stabilization and other geologic and environmental factors in the evolution of the barrier island system. Conversely, considered measures would also reduce possible adverse economic, social and environmental impacts associated with breaching and overwash. It must be recognized that the planning horizon of the Reformulation Study (50 years) may be relatively insignificant in light of the time-frame of barrier island development that is commonly believed to be on the order of hundreds or thousands of years. As the present report provides an engineering evaluation of storm protection features, geologic factors are not addressed herein. Nonetheless, ongoing and future Reformulation Study efforts will examine geologic and environmental impacts of potential construction by quantifying the reduction of breaching and overwash due to possible plans. These future investigations will examine the cumulative geomorphic and environmental impacts of potential construction on the barrier island and estuarial system.

3.3 Storm History

Two storm types are important along the south shore of Long Island: (1) tropical storms which typically impact the New York area from July to October, and (2) extratropical occurring from October to March. Extratropical storms (northeasters) are usually less intense than tropical storms (hurricanes), but tend to have a much longer duration. These storms often cause high water levels and intense waves, and are responsible for significant damages and flooding throughout the Long Island coastal region.

Historically, New York has been subjected to a number of severe hurricanes and northeasters. Several of these storms are listed in Table 3.1. Northeasters are generally less intense than hurricanes, but may have localized winds that reach hurricane strength. Because of their longer duration, however, northeasters often cause damages that equal or exceed those of hurricanes. USACE (1969) states that 65 moderate to severe northeasters have impacted the New York coastal region over the 100 year period preceding 1965. More recently, a series of severe northeasters has impacted the New York coastal region in October 1991, December 1992, and March 1993. The two most severe northeasters occurred on 6 to 8 March 1962 and 11 to 12 December 1992.

TABLE 3.1
SIGNIFICANT PROJECT AREA HISTORICAL STORMS

Date	Storm Type	Date	Storm Type
14 September 1904	Hurricane	3 March 1931	Extratropical
8 September 1934	Hurricane	17 November 1935	Extratropical
21 September 1938	Hurricane	25 November 1950	Extratropical
14 September 1944	Hurricane	6 November 1953	Extratropical
31 August 1954	Hurricane Carol	6 March 1962	Extratropical
12 September 1960	Hurricane Donna	6 February 1978	Extratropical
6 August 1976	Hurricane Belle	28 March 1984	Extratropical
27 September 1985	Hurricane Gloria	30 October 1991	Extratropical
19 August 1991	Hurricane Bob	11 December 1992	Extratropical

3.4 Project Reach Problem Identification

While the entire south shore of Long Island is subject to generally similar storm problems, separation of the study area into reaches allows for a refined assessment of site-specific problems and needs. This section describes the conditions and associated problems specific to each project reach. Project and physical reaches locations were shown in Figures 2.2 to 2.8. These reaches extend the entire study area length, and reflect the need to examine storm protection for contiguous areas that include varying site conditions influencing feature selection. On the other hand, storm damage problems are variable and non-continuous, and may be limited to isolated locations. Consequently, design subreaches were identified that represent those areas within which different storm protection features may be applicable. These subreaches were selected based on economic considerations, such as past storm damages and development that indicate likely economic justification for inclusion in the planning process. Furthermore, subreaches were identified based on existing conditions that provide or lack adequate storm protection. Design subreaches are referenced in the following paragraphs and are shown in Figures 3.1 to 3.5 for each project reach, and are identified relative to project and physical reaches in Table 3.2. Future study phases will examine/modify design reaches based on more comprehensive investigations of localized storm problems and needs. For the purposes of the present discussions, design subreach locations shown in Figures 3.1 to 3.5 are utilized in the screening process to allow the identification of solutions appropriate to local conditions.

The primary problems described below are based on site inspection and recent topographic mapping, for each project reach. Problem severity was judged on the basis of prior storm damage and the extent and estimated frequency of future occurrences. This evaluation considered the level of development in each reach.

3.4.1 Project Reach 1 - Montauk Point to Hook Pond

Description. Project reach 1 is located within the Town of East Hampton, and extends from Montauk Point to Hook Pond (see Figure 3.1). This reach covers approximately 19.5 miles of mainland, oceanfront shoreline. Elevated coastal bluffs fronted by narrow beaches are predominant throughout the area, but several low-lying areas fronted by high, narrow dunes also exist. Development in Project Reach 1 is sparse, notwithstanding the fact that the communities of Ditch Plains, Montauk Beach, Hither Hills State Park, East Hampton Beach and Beach Hampton lie within the reach. Interestingly, these communities are generally located in low-lying land areas fronted by narrow beaches and dunes (see Photograph 3.5). The remainder of Project Reach 1 is characterized by individual or small groups of homes located along high dunes and bluffs (see Photograph 3.6). Approximately eighty-five structures are located within the 100-year floodplain. Coastal protection structures along this reach are limited and widely spaced.

Problem Identification. The communities of Ditch Plains, Montauk Beach, East Hampton Beach and Beach Hampton appear to have the greatest need for storm protection. These communities are vulnerable to shorefront structure damage and tidal inundation of low-lying areas. The area along Hither Hills State Park is characterized by narrow beaches and relatively low dunes. This area is a concern inasmuch as it fronts the major eastern access route (i.e. Montauk Highway) between Montauk Point and western Long Island. Elevations of that roadway are as low as 4 feet NGVD. As a result, dune erosion and tidal inundation are a concern. Continued bluff erosion threatens to undermine individual homes throughout the remainder of Project Reach 1.

3.4.2 Project Reach 2 – Hook Pond to Agawam Lake

Description. This reach extends from Hook Pond west to Agawam Lake (see Figure 3.2) and includes portions of the Towns of East Hampton and Southampton. The reach extends approximately 11.5 miles along the Atlantic Ocean, and includes the communities of Apaquogue, Wainscott, Sagaponack, Mecox, Wickapogue and Southampton. The mainland shoreline within this reach is characterized by segments of narrow beaches backed by dunes of varying elevations, although the area is generally characterized by high dunes. There are, however, low-lying areas fronting a series of landlocked ponds that are subject to flooding and barrier beach washover during extreme storm or rainfall events. Development in this reach is relative sparse with a total of approximately 112 structures located in the 100-year floodplain. Shoreline conditions are generally characterized by individual and/or groups of structures located landward of the existing dunes (see Photograph 3.7). Coastal protection measures have been constructed along much of the shorefront (see Photograph 3.8).

Problem Identification. Shorefront structures in Project Reach 2 are vulnerable to dune and beach erosion and to a lesser extent tidal inundation and/or wave attack (see Photographs 3.9 and 3.10). The principal locations subject to damages arising from dune erosion are at Apaquogue, Wainscott, near Peters Lane in Sagaponack, west of Sagaponack Lake, east/west of Mecox Bay and Wickapogue. Localized flooding of low-lying and more heavily developed areas surrounding Georgica Pond, Sagaponack Lake and Mecox Bay is also a significant concern. These low-lying areas are subject to flooding due to stormwater runoff and overwash, and require frequent letting of accumulated stormwaters to preclude roadway and property flooding.

3.4.3 Project Reach 3 – Agawam Lake to Quogue

Description. This reach is entirely within the Town of Southampton and includes the mainland oceanfront shoreline west of Agawam Lake, the shoreline along Shinnecock Bay and the barrier island extending west to the easternmost groin at Westhampton Beach (see Figure 3.3). Project Reach 3 also includes Shinnecock Bay and Shinnecock Inlet. The total length of this reach is approximately 14.0 miles, and includes the communities of Southampton, Southampton Beach, Tiana Beach and Hampton Beach, as well as all communities adjoining Shinnecock Bay. Mainland development is heavy along Shinnecock Bay and the Atlantic Ocean. A total of approximately 1,641 structures are within the 100-year floodplain. Variable beach widths and dune elevations characterize the shoreline. Numerous structures are located just landward of the dune (see Photograph 3.11), and along the mainland oceanfront are backed by relatively heavy and low-lying development. Along the barrier island east of Shinnecock

Inlet, private residences are situated landward of high dunes. Low-lying, sparsely developed areas leeward of narrow dunes prevail from Shinnecock Inlet to Hampton Beach (see Photograph 3.12). Barrier island development increases within Hampton Beach, where dunes have been eroded (see Photograph 3.13). The mainland areas around Shinnecock Bay are generally low-lying and heavily developed.

Problem Identification. The principal problem is the threat of barrier island erosion and breaching/inundation, which would lead to tidal inundation of low-lying areas along Shinnecock Bay. The barrier islands, especially those areas west of Shinnecock Inlet and along Tiana Beach (see Photograph 3.14), are highly vulnerable to storm erosion, tidal inundation, overwash and breaching. Increased shoaling of Shinnecock Inlet would likely occur should a breach form through the barrier island. Dune and beach erosion is the primary problem along Hampton Beach due to the proximity of structures located in low-lying areas behind the dunes. Dune erosion could also lead to oceanfront property damage due to wave attack and erosion. An additional concern along the entire barrier island is the elevation of Dune Road, which is subject to frequent flooding and serves as the only access route along the barrier islands.

3.4.4 Project Reach 4 – Quogue to Smith Point

Description. Extending from the easternmost groin in Westhampton Beach to the eastern boundary of the Fire Island Wilderness Area, this reach spans approximately 13.0 miles (see Figure 3.4) and is located in the Towns of Southampton and Brookhaven. Project Reach 4 fronts all of Moriches Bay and includes Moriches Inlet. Mainland development around Moriches Bay is heavy and generally low-lying. A total of approximately 4,335 structures currently are located in the 100-year floodplain. The barrier island shoreline is comprised of widely varied dune and beach conditions. The easternmost 3.5-mile segment comprises the groin field at Westhampton Beach where high dunes and wide beaches predominate (see Photograph 3.15). Barrier island development along Westhampton Beach is dense relative to other barrier island segments. From the Westhampton groin field west for a distance of about 5,000 feet along Pikes Beach, barrier island development is generally absent due to the breaches in 1992. Home reconstruction has been ongoing in the area since completion of the Westhampton Interim Project. Shoreline conditions in this area reflect the Westhampton Interim Project (see Photograph 3.16). Shoreline erosion will be abated by renourishment operations that will continue for a minimum period of thirty years absent a new decision or outcome of the Reformulation Study. Site conditions from 5,000 to 9,000 feet west of the Westhampton groin field are comparable to those along Pikes Beach, although existing development is heavier. There is no residential development in Cupsogue County Park from Pikes Beach to Moriches Inlet, although park facilities are present. The eastern 4,000 feet of this barrier island section is wide with high dunes. The 3,000-ft segment immediately east of Moriches Inlet is narrow with narrow beaches and dunes. An existing revetment is present along the barrier bay shoreline extending about 1,500 feet east of the inlet. No development exists west from Moriches Inlet to the Wilderness Area, other than day-use facilities at Smith Point County Park. Dunes in this area range from high primary and secondary dunes to low, narrow segments.

Problem Identification. Low-lying areas along the mainland shore of Moriches Bay are vulnerable to inundation damages associated with storms. This vulnerability would increase with further erosion or breaching or inundation of the fronting barrier island. Areas susceptible to breaching are Pikes Beach, the area immediately east of Moriches Inlet and isolated segments of Smith Point County Park. Past breaches at Pikes Beach and the area near Moriches Inlet underscore this vulnerability, although breach potential has been reduced at both locations by past construction projects. However, breaching remains a concern for severe storms. Development along the barrier island shoreline is subject to damages associated with storm erosion, wave attack and tidal inundation. At the Smith Point County Park facilities, existing structures and the access route (i.e. William Floyd Parkway) are subject to frequent inundation. Furthermore, these facilities are vulnerable to wave attack and overwash. There is also a risk that Moriches Inlet would not remain stable if a breach formed and led to the creation of a new inlet.

3.4.5 Project Reach 5 – Smith Point to Fire Island Inlet

Description. This reach includes all of Fire Island from the eastern boundary of the Wilderness Area to Fire Island Inlet and spans approximately 24.5 miles (see Figure 3.5) in the Towns of Brookhaven, Islip and Babylon. The majority of this reach, including developed communities, is contained within the limits of the Fire Island National Seashore. The reach also includes all mainland areas bordering Great South Bay located in Suffolk County. Mainland development along Great South Bay is extensive with approximately 15,845 structures located in the 100-year floodplain. Communities on the barrier island include Davis Park, Fire Island Pines, Cherry Grove, Ocean Beach, Atlantique and Saltaire. Also included in this area are undeveloped portions of the Fire Island National Seashore and Robert Moses State Park. Dune and beach conditions are highly varied, and the barrier island is narrow. The Wilderness Area extends about 6.5 miles and is comprised of three principal physical segments, namely: (1) east of Old Inlet, (2) Old Inlet and (3) west of Old Inlet. Dunes and beaches are narrow east of Old Inlet, whereas a well-established primary and secondary dune system exists west of Old Inlet. Old Inlet is a low shoreline segment with little or no dunes. The remainder of Fire Island is characterized by sporadic, low-lying communities with the heaviest development near Davis Park, Fire Island Pines to Cherry Grove and Point O' Woods to Kismet. The barrier island, dunes and beaches in developed areas are typically narrow and low as shown in Photographs 3.17 and 3.18, whereas higher dunes characterize less developed sections.

Problem Identification. Due to the high density of structures along the mainland of Great South Bay, the primary mechanism for economic damage is storm inundation of the mainland that results as storm surge propagates through Fire Island Inlet. Additionally, a number of locations along Fire Island are susceptible to barrier island breach or inundation formation that would exacerbate flooding around Great

South Bay. Coupled with the relative instability of Fire Island Inlet, a breach could significantly increase mainland tidal inundation and shoaling of Fire Island Inlet, as the new inlet would likely persist. Storm damages to barrier island structures located behind narrow, low dunes also occur as a result of storm erosion, wave attack, tidal inundation and overwash. Long-term erosion rates are low to moderate, but shoreline undulations increase the likelihood of storm damages by notably narrowing the protective beach. Storm damages along both developed and undeveloped barrier island areas can primarily be attributed to increased tidal inundation in adjoining estuaries attending possible barrier island inundation or breach formation. Facilities (i.e., parking lots and roadways) at Robert Moses State Park and Smith Point County Park are fronted by narrow beaches and low dunes, and are vulnerable to wave attack, erosion and tidal inundation damages.

3.5 Expected Without-Project Future Conditions

The expected future without-project condition is a scenario that was developed to represent that baseline condition against which alternative measures can be evaluated to determine economic justification and need. Simply, the without-project condition is a forecast of the most likely future condition in the study area if no actions are taken. Future activities that impact the without-project condition are based upon historic practice and events, unless there is definitive evidence of new actions or policies scheduled for implementation. The future without-project condition for the Fire Island Inlet to Montauk Point Reformulation Study considers ongoing Federal, State, County, and municipal activities which are likely to occur independent of the outcome of this investigation. These actions are likely to continue and include: (1) inlet maintenance, (2) breach closure, (3) ongoing shore protection projects, and (4) local and private development and shore protection activities. Additionally, development policies related to the National Flood Insurance Program; Coastal Zone Management Policies; Coastal Erosion Hazard Areas; and the Fire Island National Seashore General Management Plan, among others, are anticipated to continue independent of the Reformulation Study. The following discusses the above activities, and their interaction with relation to the without-project scenario to be considered in the Reformulation Study.

Inlet Maintenance Projects. Three Federal navigation channels are located within the boundaries of the Fire Island Inlet to Montauk Point study area, including the Shinnecock Inlet Navigation Project, Moriches Inlet Navigation Project, and Fire Island Inlet Navigation Project. Each of the inlets is maintained for navigation with the removal and placement of material on the downdrift beaches to the west. The cost of maintenance dredging is shared with the State. Each of these inlets is currently used, and it is not anticipated that the State will want to close any of these and back out of the current cost-sharing agreements within the potential project life of 50 years. It should also be noted that these inlets also act as a reliable bay flushing conveyance to a degree beyond historic flushing, which helps to maintain bay water quality. Therefore, it is assumed that future maintenance dredging, and downdrift disposal will continue, as required for maintenance purposes. An alternative future modification of inlet maintenance practice would be the construction of sand bypassing plants for downdrift transport of trapped littoral drift. Such actions, possibly undertaken by the State, are not anticipated to significantly alter the future without-project scenario.

Breach Closure Activities. Since 1938, local government policy along the study area has been to close breaches (with the exception of Shinnecock Inlet that opened in 1938. Recently, New York State (as per the Governor's Coastal Erosion Task Force) made it State policy to close breaches. The U.S. Army Corps of Engineers has also developed a Breach Contingency Plan (BCP), which is intended to close breaches expeditiously. The BCP is an interim measure to address the time period prior to completion of the Reformulation Study. The long-term decision, whether breaches should be closed quickly, is being reevaluated as part of the Reformulation Study. As such, the baseline condition (i.e. future without-project scenario) is that any breaches that form in the study area will be closed within a period of one year. This condition is based primarily on historic practices.

Ongoing and Proposed Shore Protection Projects. Within the study area are three ongoing or proposed storm protection measures that may impact the future without project scenario. These projects include: (1) Moriches Inlet to Shinnecock Inlet "Westhampton Beach" Interim Project (constructed), (2) Fire Island Inlet to Moriches Inlet "Fire Island" Interim Project (proposed), and (3) Moriches Inlet to Shinnecock Inlet "West of Shinnecock" Interim Project (proposed). The future without project scenario recognizes that the Westhampton Interim Project has been constructed, and will be maintained for a period of 30 years from completion of initial construction (December 1997). The proposed Fire Island Interim and West of Shinnecock Inlet Interim Projects are presently being evaluated to consider remedial protection for the period before results of the Reformulation Study could be implemented. These studies are currently in the planning phase with implementation uncertain. Hence, the Reformulation Study will proceed assuming that these interim projects are absent, and that these areas will remain in their presently vulnerable condition.

Local and Private Activities. Historically, efforts have been undertaken by local homeowners, either independently or as an organized erosion control district, in response to storm events. These efforts vary by location, but have generally included the following actions: beach nourishment, various types of structural erosion protection measures, beach scraping and house relocation. It is also noted that, despite the threat of storm damages, landowners are continuing to develop lots on or near the existing dunes or near eroding bluff areas. It is expected that, within regulatory and fiscal limitations, these actions will continue to occur in the future without project condition.

In recognition of the above future without-project scenario and assuming no further actions are taken by Federal or non-Federal sponsors, the study area will continue to have periodic flooding and erosion problems. Flooding of low-lying communities will continue to endanger lives, cause property damage and delay traffic. Erosion of bluffs and beaches will continue to threaten hinterland infrastructure, and this threat will likely increase as development increases. Furthermore, continued erosion of barrier islands could increase barrier island breaching/inundation vulnerability with a concomitant increase of the frequency and severity of flooding of mainland communities. Erosion would also result in increased flooding damage along low-lying mainland and ocean shoreline areas where protective dunes are narrow. The impact of this increased vulnerability to storm damages in the study area is currently being examined as part of ongoing coastal process and economic analyses.

3.6 Needs and Opportunities

Based on the storm damage problems described for the study area, the needs for storm protection measures can be identified in terms of appropriate types of protection, project scale and location. In general, major needs throughout the study area include: (1) reduction of tidal flooding and attendant loss of life, property and economic activity and (2) reduction of beach and bluff erosion in critical areas. In providing for these needs, opportunities exist to enhance both economic and recreational activity. Economic activity will be enhanced due to a reduction in the frequency of flood damage and loss of business.

3.7 Objectives and Constraints

Objectives of and constraints to possible storm protection measures were identified in order to guide the development/screening process. Furthermore, these objectives and constraints were used to determine which measures merit further consideration or should be eliminated from future study phases.

3.7.1 Planning Objectives

Planning objectives were identified based on the problems, needs and opportunities as well as existing physical and environmental conditions present in the project area. In general, the prime Federal objective is to contribute to the National Economic Development (NED) account consistent with protecting the Nation's environment, pursuant to national economic statutes, applicable executive orders and other Federal planning requirements. The following general and specific objectives have been identified:

General

- Meet the specified needs and concerns of the general public within the study area
- Respond to expressed public desires and preferences
- Be flexible to accommodate changing economic, social, and environmental patterns and changing technologies
- Integrate with and be complementary to other programs in the study area
- Establish and document financial and institutional capabilities and public consensus

Specific

- Reduce the threat of potential future economic damages due to the effects of storm-induced flooding, wave attack, and shore recession
- Mitigate the effect of and either prevent or offset current long-term erosion trends
- Minimize impact to environmental resources and on adjacent shore areas

3.7.2 Planning Constraints

Formulation and evaluation of alternative improvement plans are constrained by technical, environmental, economic, regional, social, and institutional considerations. These constraints must be considered in current and future project planning efforts and are summarized below.

Technical Constraints

- Plans must represent sound, safe and acceptable solutions.
- Plans must be in compliance with sound engineering practice and satisfy Corps of Engineers regulations.
- Plans must be realistic and state-of-the-art. No reliance on future research and development of key components is acceptable.
- Plans must provide storm damage protection.
- Plans must provide features to minimize the effect of shoreline erosion processes.

Economic Constraints

- Plans must be efficient. They must represent optimal use of resources in an overall sense. Accomplishment of one economic purpose cannot unreasonably impact another economic system.
- The economic justification of the proposed project must be determined by comparing the anticipated annual tangible economic benefits, which should be realized over the project life with the average annual costs. The expected annual benefits must equal or exceed the annual costs.

Environmental Constraints

- Plans cannot unreasonably impact environmental resources.
- Where a potential impact is established, plans must consider mitigation or replacement and should adopt such measures, if justified.
- Where opportunities exist to enhance significant environmental resources, the plan should incorporate all justified measures.

Regional and Social Constraints

- Reasonable opportunities for development within the study scope must be weighed relative to others, and views of State and local public interests must be solicited.
- The needs of other regions must be considered and one area cannot be favored to the unacceptable detriment of another.
- Public access plans must be obtained where sand is placed to stabilize or create new beaches, unless such placement is purely incidental to project function or for cost savings to the Government.

Institutional Constraints

- Plans must be consistent with existing Federal, State, and local laws.
- Plans must be locally supported to the extent that local interests must, in the form of a signed local cooperation agreement, guarantee for all items of local cooperation including cost sharing.
- Local interests must agree to provide public access to the beach in accordance with Federal guidelines and with requirements of State laws and regulations.
- The plan must be fair and find overall support in the region and State.
- Plans must be consistent with State Coastal Zone Management Policies to the maximum extent practicable and consider such policies in plan formulation. These policies include, among other, the following major criteria:
  - Storm protection measures must consider non-structural options first, beachfill only second and structural measures only where necessary to satisfy planning objectives;
  - Each considered measure must identify environmental impacts and appropriate mitigation; and
  - Public access to water-related recreation resources must be protected, maintained or restored.

4. PRELIMINARY FEATURES SCREENING

4.1 Introduction

This section presents the preliminary screening of potential protective measures to determine those features to be considered in future study phases. These features (or measures) combined with other features or actions will comprise the elements of possible alternative plans for the reduction of storm damages in the Fire Island Inlet to Montauk Point study area.

4.2 Plan Formulation and Evaluation Criteria

The development of alternative plans, including the screening of individual features (or measures) and complete alternatives, must be within the context of an appropriate set of formulation criteria. The Water Resources Council's *Principles and Guidelines* require the systematic preparation and evaluation of alternative measures which address identified problems, needs and opportunities under the objectives of the Nation Economic Development (NED) consistent with protecting the nation's environment. The Principles and Guidelines require the application of four major evaluation criteria.

The *completeness* of a plan is determined by analyzing whether all necessary investments or other actions required to assure full attainment of the plan have been incorporated. The *effectiveness* of a plan is determined by analyzing the technical performance of a plan and its contribution to the planning objectives. The *efficiency* of a plan is determined by analyzing its ability to achieve planning objectives, as well as NED and Environmental Quality (EQ) outputs that minimize costs. The *acceptability* of a plan is determined by analyzing acceptance by concerned parties. A plan is acceptable if it is, or likely will be, supported by some significant sector of the public and public representatives or officials. During reiteration of the planning tasks, every attempt will be made to eliminate, to the extent possible, proposals unacceptable to any significant segment of the public.

Technical Criteria. The plans to be evaluated are based on technical criteria that incorporate appropriate engineering standards and guidelines. The level of protection provided by the plans must be technically feasible for implementation. In addition, the plans must protect the potential damage area without causing adverse impacts to adjacent areas.

Economic Criteria. The plans must result in a net positive National Economic Development (NED) benefit. Proposed plans must be justifiable and provide benefits by reducing forms of damage such as structural losses and damages from tidal inundation, traffic delays or erosion. Although recreation benefits will be considered, these alone cannot make a project justifiable.

Environmental Criteria. Plans must consider environmental impacts associated with each alternative. Where potential impacts are identified, plans must consider mitigation or replacement, and should adopt such measures, if justified. For the purposes of this formulation this will be undertaken during future study phases by considering the impacts and necessary mitigation associated with considered plans.

4.3 Features Screening

The following paragraphs briefly describe the objectives for, and the evaluation of, potential project features. This preliminary evaluation was performed to explore the potential viability of various measures to address problems in the study area. Features considered include those that provide storm damage reduction benefits from a number of possible storm damage mechanisms, including:

- Tidal inundation
- Wave attack
- Storm recession
- Long-term erosion

The following features are currently being evaluated as part of the Reformulation Study:

- No Action
- Non-Structural Plans
- Beach Restoration
- Offshore Breakwaters (including Artificial Headlands or T-Groins)
- Seawalls (Rubble-mound)
- Groins
- Beach Restoration With Structures
- Removal/Modification of Groins
- Levees and Floodwalls
- Storm Closure Gates
- Inlet Sand Bypassing (Inlet Modifications)

4.3.1 No Action

Simply stated, this plan, means that no additional measures would be taken to provide for storm damage protection in the study area, and assumes continuation of the described future without-project condition. This plan fails to meet any of the objectives or needs of the project. While this plan was not considered for further development, it does provide the basis for measuring with-project benefits. Additionally, this plan would be implemented if project costs exceed project benefits (i.e. shore protection measures are not in the

Federal interest under current NED guidelines). This plan is based on the continuation of the Westhampton Interim Project for thirty years, in accordance with the RAPFT settlement, and breach closure activities within a period of one year.

4.3.2 Non-Structural

Non-structural plans include floodproofing, buyouts of threatened properties and land use management options. Floodproofing may be accomplished by providing an impermeable barrier around the structure, by raising the structure above the design flood or by relocating the structure out of the flood plain. Wet floodproofing techniques may also be utilized whereby floodwaters are allowed to enter the basement of the structure but utilities are relocated or protected from damage. Unlike floodproofing, buyouts of structures in the flood plain will prevent all damage to structures and will provide land that may be utilized for public use and conservation. However, buyouts may decrease the local tax base by removing land from private ownership. Land use management options include zoning regulations that provide restrictions on further development in areas where continued development is expected. Land use management is an effective way of controlling flood plain development and thereby minimizing future increases in the potential damage associated with flooding. Since the Reformulation Study includes a large geographical area with numerous villages and towns, coordination between the many political agencies and municipalities will be crucial to the implementation of any land use management options. Although land use regulation may be recommended, USACE authority to implement non-structural plans is generally limited to floodproofing or buy-outs. Non-structural techniques can also be effective in supplementing the protection provided by other structural features.

4.3.3 Beach Restoration

Beach restoration generally involves the placement of sand on an eroding shoreline to restore its form and to provide an adequate protective geometry. Beach restoration may include the following options: (1) beach and dune fill, (2) dune fill only, (3) beachfill only or (4) beachfill placement is response to extreme events to close breaches (e.g., BCP). Selection of the desired configuration depends on site conditions, and must consider whether fill placement is intended to combat shore erosion, flood inundation or both. A beachfill typically includes a berm backed by a dune and both elements combine to prevent inundation damages to leeward areas. Periodic renourishment is normally required to offset long-term and storm-induced erosion. At locations where long-term and storm-induced erosion are severe, renourishment and rehabilitation may prove costly. Beach restoration represents a quasi-natural method for reducing flooding and erosion damages, and is an important element for constructed storm damage reduction measures that must combat severe erosion. Beach restoration is commonly used in concert with other structural features (e.g. offshore breakwaters, groins, buried seawalls etc.).

Beach restoration typically involves the use of compatible sand from an offshore source (borrow area) to add sand to the barrier beach system. Quantities of offshore sand can sometimes be minimized by utilizing material otherwise available in the active littoral system, such as at stabilized inlets and nearby navigation channels. Common examples of alternative sand sources include the beneficial use of dredged inlet materials, inlet sand bypassing that acts to mechanically move beach sands across gaps (inlets) in the littoral system, stockpiles, feeder beaches and beach scraping.

4.3.4 Offshore Breakwaters

Offshore breakwaters are typically rubble-mound structures built seaward of the shoreline, and act to reduce wave energy reaching the shoreline. Offshore breakwaters may be built as a long continuous structure or as a series of shorter, segmented structures. The advantages of segmented breakwaters include cost-effectiveness and design flexibility. The effect of breakwaters is to cause gradients in wave energy in the lee of the structures that promote sediment deposition behind the breakwaters. When properly designed, these depositional features should not interrupt longshore sediment transport in a way that negatively impacts adjacent shorelines. As with other coastal structures, offshore breakwaters are often combined with beach restoration. For example, beach restoration may serve to reduce storm-induced damages, while the offshore breakwater system serves to reduce long-term erosion. The need for structural features combined with beach nourishment is particularly acute near inlets, where both long-term and storm-induced erosion may be severe. Beachfill and offshore breakwater combinations provide needed shore protection, and, when properly designed, will permit sand bypassing of the inlet. If located too far offshore, for instance, offshore breakwaters located near inlets may interfere with inlet behavior. Consequently, it is often advisable to locate the structures closer to shore where they would act as artificial headlands or combined with tradition groins to form T-groins. Additionally, breakwater placement closer to shore reduces construction costs and enhances fill stabilization relative to breakwaters located further offshore.

4.3.5 Seawalls

Seawalls are generally used to protect upland structures from wave impact and erosion damage. Seawalls are typically rather massive structures as they are intended to resist the full force of storm waves. Seawalls normally require extensive toe protection to preclude scour. Vertical seawalls are generally high and are often judged to be socially and aesthetically unacceptable. Moreover, vertical seawalls are vulnerable to catastrophic failures that may be attended by accelerated upland erosion. A rubble-mound seawall consisting of relatively large armor units and armored backslope provides a high level of stability when subjected to direct wave forces. An exposed rock structure in the absence of beach restoration does not abate shoreline erosion, because it does not provide the sand necessary to offset erosion processes. Seawalls are typically located landward of the active littoral zone, therefore, shoreline erosion is not affected. , the rubble-mound seawall is often coupled with beach restoration. An alternative to a conventional rubble-mound or vertical seawall is a buried rubble-mound seawall placed landward of the shoreline. Example applications of a buried seawall are described in Headland (1992) and Basco (1998). The buried seawall has the appearance of a sand dune and is only be exposed during severe events. When used in concert with beachfill, the seawall provides the last-line-of-defense storm protection, while the beach restoration combats long-term shoreline erosion.

4.3.6 Groins

Groins are coastal structures, normally constructed perpendicular to the shoreline, which act to interrupt longshore sediment transport. Groins generally extend from the dune/beach interface to MSL water depths on the order of 10 to 12 feet and are designed to impound sand. At a single groin, the updrift impoundment of sand is generally offset by an equivalent amount of erosion downdrift of the structure. Groins are often constructed in series or fields to provide protection for continuous shoreline segments. In this arrangement, erosion is displaced to the most downdrift groin, rendering the downdrift area susceptible to accelerated erosion. Erosion downdrift of a groin field can be mitigated through the use of low, tapered groin transitions and/or beach nourishment. Groin fields can also be designed to transition to areas of lower erosion losses or to terminal structures, such as jetties. Furthermore, groin compartments should be filled initially in order to promote sand bypassing throughout the groin field. Groins fields may be particularly effective at areas characterized by significant longshore sediment transport or high erosion rates. Groins are, however, vulnerable to storm-induced or offshore erosion losses. These losses may be reduced by the use of T-groins that may be an effective solution in areas of severe erosion, such as in the vicinity of tidal inlets. T-groins combine the features of traditional groins and breakwaters by reducing both alongshore and cross-shore beach erosion losses.

4.3.7 Beach Restoration and Structures

As stated previously, life-cycle costs may be much higher for beach restoration in areas of severe erosion. Therefore, it is advisable to consider beach restoration in concert with structural options that augment protection against severe storms (i.e. seawalls) or stabilize the beachfill against long-term erosion (i.e. breakwaters and groins). These structures act to reduce long-term maintenance requirements and/or residual damages arising from severe storm effects. Beach restoration performance may also be improved by including structures at locations requiring only isolated (short) lines of protection. The principal consideration in these cases is the poor performance typically characteristic of small beachfill projects.

4.3.8 Removal/Modification of Groins

The effects of groins on littoral transport were described above. Groins serve to protect the shoreline fronted by these structures, but may adversely impact downdrift shorelines. Adverse impacts of groin fields may be mitigated through beachfill placement and/or groin transitions or it may be best to remove or modify existing groins. Existing groin fields should examined to determine whether groin removal or modification is advisable. The present screening examines groin removal to determine whether other measures may benefit from removal/modification measures.

4.3.9 Levees and Floodwalls

Levees and floodwalls are generally considered the most direct method to protect backbay/mainland areas from tidal inundation. However, levees and floodwalls are not suited to protect against wave action, and are not considered for oceanfront applications. They protect developed areas by providing a continuous line of protection around a group of structures and are often described as local protection measures. The line of protection may be made of earthen materials, concrete, rock, metal sheetpiling or a combination of materials. Along the mainland shorefront, protective features would tie into high ground at each end of a project segment. In general, levees (dike or embankment, comprised of rock or earthen materials, protecting low land areas from flooding) are less expensive than floodwalls (comprised of concrete and/or sheetpiling) but require more land. If a large area is to be protected, the numerous rivers or canals draining into the bays will either require closure gates and drainage facilities such as pump stations or will require the line of protection to surround the water course on both sides, frequently extending inland to high ground. This often requires significant roadway and bridge relocation as the existing structures are usually too low to cross over the levee or floodwall. The levee/floodwall line of protection must be accompanied by an extensive interior drainage system to impound and/or pump stormwater runoff.

4.3.10 Storm Closure Gates

Flood control closure gates are designed to prevent storm surges from entering tidal inlets and/or canals. As mentioned previously, closure gates are also included in levee and floodwall features for canal and creek closures. In the present context, closure gates could be considered at Fire Island, Moriches and Shinnecock Inlets, as well as Narrow Bay and Quogue and Quantuck Canals. Storm closure gates constructed at these locations could reduce inundation damages by limiting storm tidal flows into study area estuaries. While several types of closure gates exist, they can be primarily classified as either mobile or fixed systems. Mobile systems can be raised, lowered or otherwise removed when there is no threat of coastal flooding. Fixed systems restrict flow during storms by inducing hydraulic losses and/or limiting flow area.

4.3.11 Inlet Sand Bypassing (Inlet Modifications)

Tidal inlets, either stabilized or unstabilized, represent perturbations to the continuum of littoral drift. Areas updrift (east in the study area) may be subject to accretion as longshore sediment transport is trapped. A portion of longshore sediment transport entering the inlet will also be distributed into shoals adjacent to the inlet. The remaining portion of longshore sediment transport will bypass the inlet and nourish the downdrift beaches. Trapping of longshore sediment transport, either updrift or within the inlet, may create sediment transport deficits downdrift that may result in shoreline erosion. The erosion experienced downdrift of inlets may be marked and can more significant than experienced outside of the inlet vicinity. As this erosion can be partly assigned to sediment trapping caused by the inlet, measures to enhance/restore littoral drift across the inlets in the study area will be investigated in future study phases. These measures will explore dredging of inlet shoals and channels and/or excavating updrift deposits with placement downdrift, and other inlet design modifications (e.g., modification of inlet cross-sections to reduce shoaling) to aid natural bypassing. Also to be explored are modifications of current inlet design and dredging practices that may provide measures to limit storm surge propagation through the inlets that leads to bay flooding.

4.4 Features For Further Analysis

Alternative plans for storm damage reduction in the study area will consider a combination of protective features to address the wide range of existing problems and conditions. The present screening, however, examines separable features, whereas feature combinations will be investigated in future study phases as part of alternative plans. Reduction of storm damages requires the abatement of the effects of shoreline erosion, because features implemented without combating erosion will become vulnerable to damages over the project life. On the other hand, areas not subject to erosion typically do not require shore protection measures. Accordingly, beach restoration is an important element for oceanfront improvements, especially in eroding areas. Beach restoration ensures the long-term viability of flood barriers (e.g. seawalls) and mitigates potentially negative impacts of and enhances the performance of sand retention structures (e.g. groins and breakwaters). On this basis, coastal shorefront structures alone were eliminated from further consideration, but are examined in combination with beach nourishment. The following elements are judged to be the most promising for consideration in alternative plans.

- Non-structural Plans
- Beach Restoration
- Beach Restoration with Structures (Breakwaters, Seawalls and Groins)
- Removal/Modification of Groins
- Levees and Floodwalls
- Storm Closure Gates
- Inlet Sand Bypassing (Inlet Modifications)

5. CONCEPTUAL FEATURES DESIGN

5.1 Introduction

This section describes the conceptual design of individual storm protection features that were selected for further evaluation along the Fire Island Inlet to Montauk Point study area. The following screening factors are briefly presented below for each feature:

- Performance – What is the role of the feature in the reduction of storm damages? Where is the feature located?
- Design – What are the specific feature requirements for the study area?
- Costs – What are the costs for feature construction and maintenance?
- Limitations – Does the feature fully address the problem? Can the feature be implemented?
- Impacts – What is the effect of the feature on the environment? Is the feature socially/aesthetically acceptable?

These screening factors help to select cost-effective solutions for the reduction of storm damages, and minimize adverse social and environmental impacts. Detailed evaluation of these factors will be performed in eventual plan formulation stages during future study phases. The present screening briefly introduces these screening factors to allow determination of those features for future consideration. Development of project features was performed to comply with the objectives and constraints set forth in Section 3.7. Most pertinent to the present engineering development were technical objectives and constraints, whereas economic, environmental, social and institutional issues will be examined more comprehensively as part of other Reformulation efforts, including preparation of an Environmental Impact Statement. Nonetheless, the design and selection of conceptual project features sought to satisfy all objectives and constraints previously described.

The following paragraphs describe storm damage reduction features for problems throughout the study area. Comparison of various features was made to select those features that should be considered for more detailed evaluation and those that may be included in preliminary project alternatives. Costs presented below reflect storm damage protection for each physical reach, even though there is no determination whether any or all areas would be economically justified for plan implementation. Economic analyses being performed in parallel to engineering efforts will provide information necessary to determining whether storm protection measures are justified.

5.2 Design Criteria

This section describes the factors influencing conceptual design of storm protection features. Overall, consistent parameters were selected for design in order to establish a consistent basis for feature comparisons. Design and screening of shore protection features was performed for a 100-year return period storm, i.e. a storm with a one-percent chance of being exceeded in any year. The following presents site conditions used in the conceptual design of project features.

Tides. Astronomical tides on the south shore of Long Island are semi-diurnal, ebbing and flooding twice daily. Mean tidal ranges at Fire Island, Moriches and Shinnecock Inlets are 4.1, 2.9 and 3.3 feet, respectively. The datum used for design is the National Geodetic Vertical Datum (NGVD), which is 1.6, 1.2 and 1.3 feet above MLW at Fire Island, Moriches and Shinnecock Inlet, respectively.

Storm Surge. Hydrodynamic modeling storm surge output stations (i.e., stage-frequency curves) produced for the Reformulation Study are shown in Figures 2.1 to 2.7. For the purpose of conceptual design, storm surge frequency relationships were separated as follows: (1) west of Moriches Inlet and (2) east of Moriches Inlet. Design storm surge elevations for the 100-year storm were 7.9 and 9.5 feet above NGVD, for areas east and west of Moriches Inlet, respectively.

Waves. Design wave heights for the 100-year storm were estimated as 19.0 and 19.8 feet east and west of Moriches Inlet, respectively, based on wave and storm erosion modeling data provided by CHL. These estimated wave heights were determined at the 10-meter contour. Corresponding wave periods were 18.7 and 19.2 seconds. Wave setup for the eastern and western areas during the 100-year storm was estimated as 3.3 and 3.5 feet.

Site Geology. Three primary layers characterize the generalized subsurface stratigraphy along the barrier island shoreline, namely: (1) upper sand, (2) clay and (3) lower sand. The upper sand layer consists of a poorly graded medium to fine sand and contains intermittent pockets and lenses of organic clays and silts. Organic clay and silt lenses range up to 20 feet thick, and are very soft in consistency. Sand corings from USACE reports were available to a typical profiling depth of 40 feet, and are confined to the upper sand layer. According to USACE (1985) and generalized geologic data, the upper sand layer is underlain by Gardiners clay. Geologic mappings of the study area indicate that the top of the clay layer is approximately 100 feet below Mean Sea Level (MSL) with a thickness ranging from 15 to 25 feet. A lower sand layer underlies the Gardiners clay.

The generalized stratigraphy along the bay shorelines of Long Island is separated into four principal layers, namely: (1) surficial deposits, (2) upper sand, (3) clay and (4) lower sand. Surficial deposits along the bay areas are comprised of loamy sand, tidal marsh and fill materials. Fill and marsh areas are primarily coastal features, whereas inshore surficial deposits are comprised mostly of loamy sand. The loamy sand consists of a mixture of underlying sandy soil, organic matter and fine grain soil particles derived from the decomposition of surface material. The lower three soil layers are generally consistent with the stratigraphy of the barrier islands.

Beach Profiles. Representative beach profiles were determined from surveys dated March 1995, October 1995 and March 1996. Representative profiles were determined for each physical reach to represent study area conditions for conceptual design analyses. These profiles are presented later in this report in conjunction with beachfill design.

Littoral Conditions. Average median grain sizes in the study area are characterized by a value of 0.40 mm with only minor longshore variations. Shoreline changes were determined for the period from 1979 to 1995, and are shown in Figures 5.1 and 5.2 for project and physical reaches, respectively. The most erosive shoreline segments presented correspond to Physical Reaches 3B (west of Shinnecock Inlet), 4B (west of Westhampton groin field), 4C (east of Moriches Inlet) and 4D (west of Moriches Inlet to Smith Point). It is anticipated that recent completion of the Westhampton Interim Project and renourishment operations will reduce shoreline erosion in reaches 9 and 10. Bluff erosion is prevalent along the eastern portion of the study area, and represents a significant source of beach sediments.

Shoreline undulations must be considered in the evaluation of storm protection features. These undulations can dominate long-term erosion rates and may be primarily responsible for property damages. Shoreline undulations were analyzed for four areas, namely Fire Island – Fire Island Inlet to Moriches Inlet, Westhampton – Moriches Inlet to Shinnecock Inlet, Montauk – Shinnecock Inlet to Georgica Pond, and Montauk – Georgica Pond to Montauk Point. Wavelengths of shoreline undulations range from 0.6 to 2 miles, with most wavelengths in the 0.6 to 1.1-mile range. Table 5.1 presents averaged root-mean-square undulation amplitudes for the study area.

TABLE 5.1
SHORELINE UNDULATION SUMMARY

Location	Amplitude (feet)		
	Total	**Landward**	**Seaward**
Fire Island	100	50	55
Westhampton	130	60	75
Montauk (West)	120	55	65
Montauk (East)	110	50	65

Sediment Budget. Sediment budgets were developed for the entire study area between Montauk Point and Fire Island Inlet. Budgets account for shoreline changes, bluff erosion, inlet sediment trapping or bypassing and barrier island overwash. Net longshore sediment transport for the study area is predominately from east to west and ranges between from negligible transport near Montauk Point to approximately 400,000 to 500,000 cubic yards per year (cy/yr) at Democrat Point on the east side of Fire Island Inlet. Sediment budget results were used to determine beachfill renourishment requirements, but will continue to be refined during future study phases.

5.3 Conceptual Features Design

5.3.1 Non-Structural

Non-structural measures are applicable to any study area location requiring storm protection. These features in concert with shoreline improvements can augment storm protection or may be implemented in lieu of shoreline protection at locations where other measures are economically, institutionally or environmentally unacceptable. Land use management options may be implemented to avoid exacerbation of future storm damages. Specifically, these land use plans could control development in threatened areas to avoid or minimize future storm damage.

Performance. Non-structural plans may be effective in reducing storm damages by either preventing water from entering individual structures or by removing structures from flood prone areas. These plans may include a number of different measures, which can be divided into three categories: 1) buyouts, 2) floodproofing and 3) land use regulations. Because there are a number of different measures, they are applicable to various situations. For example, buyouts of selected structures may be effective if areas are flooded to the degree that floodproofing is not a practical solution or if the land would provide a significant value if maintained in an undeveloped condition. Floodproofing can be used to supplement structural protection or to protect individual structures where structural protection would not be cost effective. Land use regulations are usually only effective in areas where future development (and damages) is expected. Each measure may be used alone or in combination with structural measures.

Buyouts. Permanent evacuation of existing areas subject to erosion and/or inundation involves the acquisition of the land and structures either by purchase or by exercising the powers of eminent domain. Following this action, all development in these areas is either demolished or relocated. Widespread buyouts would be extremely expensive and generally not cost effective compared to other plans. However, limited buy-outs may be an effective means to enhance or supplement protection provided by other alternatives.

Land Use Regulations. Through proper land use regulation, floodplains can be managed to insure that their use is compatible with the severity of a flood hazard. Several means of land use regulation are available, including zoning ordinances, subdivision regulations, and building and housing codes. Their purpose is to reduce losses by reducing future development and damages. These regulations are most effective in relatively undeveloped areas with significant growth potential. Since the eastern end of the study area has the greatest growth potential, land use regulations should focus on this area. In the western portion of the study area the potential for growth is small since the existing development approaches full buildout.

Development rights for parcels subject to storm damage can also be purchased or transferred so that these parcels will remain undeveloped. The cost for purchase of the development rites may be much less than the full cost of the land. Land use regulations can also be geared to address a post catastrophic loss condition by preventing rebuilding. Such action would likely be accompanied by buy out provisions.

Floodproofing. Floodproofing, by definition, is a body of techniques for preventing damages due to floods; requiring adjustments both to structures and to building contents. It involves keeping water out as well as reducing the effects of water entry. Such adjustments can be applied by an individual or as part of a collective action either when buildings are under construction or during remodeling or expansion of existing structures.

Floodproofing can involve providing a protective wall around a structure located directly on the existing structure or a wall with a space between the structure and the wall (ringwall). If protection is directly on the structure then the structural integrity of the building must be incorporated into the design. However, if the protection is a wall around the structure and is separate from the building then the structural integrity of the building is not involved in the design of the floodproofing measure. Floodproofing can also involve protecting utilities (usually in the basement) from flood damage and allowing water to enter the basement. This “wet floodproofing” method allows hydrostatic pressures to equalize thereby reducing basement wall collapses that may occur in “dry floodproofing.” The utilities can either be protected by an impermeable barrier or can be raised above flood levels. Lastly, floodproofing may also involve raising the entire structure. The feasibility of this method depends on the size of the structure, its construction and its condition. In general, wood frame structures built on crawl spaces are the easiest to raise while masonry structures or structures built on a slab are more difficult to raise. Structures are usually raised to a point where their main floor is above flood level.

Design. Although floodproofing must be tailored to the individual structure, typical designs can be used to show the range of options available. Since different floodproofing designs will be suited to different types of structures subjected to varying flood levels and since there are too many buildings to perform this analysis on an individual basis, a computer program was used to evaluate which floodproofing measure is most suitable for each building. The program will take into consideration the type of construction, whether the building has a basement, its main floor and ground elevations and the flood level. It will then decide on the appropriate floodproofing measure for that specific building.

Costs. Costs will depend on the type of non-structural measure. Buyout costs depend on both land and structure values that vary widely over the study area. In general, water front properties will be some of the highest valued properties. Larger structures on larger lots will also cost more than smaller structures on smaller lots. Buyout costs include the costs to relocate the present residents and also costs to demolish and remove the existing structure. Buyout costs must be determined on a structure by structure basis with individual real estate costs performed by qualified appraisers. Land use regulations do not involve costs but may involve use of funds for enforcement of regulations or for purchase of development rights. Floodproofing costs depend on the size, type and construction of the structure. Costs will depend on the flood elevation relative to the main floor and whether the structure has a basement. In general, if the flood level is less than about three feet above ground then the structure can be flood proofed at minimal cost. However, if the flood level is greater than approximately three feet above ground then the structure will need either to be raised or to be surrounded with a ringwall. In either case, the cost will be significantly greater than either wet or dry floodproofing.

Floodproofing costs were developed for each project reach, using a computer program that accounts for the type and size of structure, whether the structure has a basement, ground and main floor elevations and the 100-year flood level. The appropriate type of floodproofing (i.e. west/dry floodproofing, raising, ringwall or buyout) and associated costs were determined. A 20% contingency was added to the total cost, as well as $5,000/building for engineering and design. An additional 6% was included for construction management. Costs from these analyses are summarized in Table 5.2, assuming a 50-year project period and an interest rate of 7-1/8%.

Limitations. Limitations are also specific to the type of non-structural measure. For example, buyouts are effective in reducing flood damages, but are often not socially acceptable since entire communities would be disrupted if a buyout plan were to be implemented on any large scale. This would severely impact the tax base. Land use regulations are not effective if the area is already developed and consequently, this measure has limited effectiveness in the western end of the study area. Floodproofing, like other methods of preventing flood damages, has its limitations. It can generate a false sense of security and discourage timely evacuations. Indiscriminately used, it can tend to increase the uneconomical use of floodplains resulting from unregulated floodplain development. Floodproofing including raising structures can reduce damages but would still leave residents stranded and separated from emergency services. In addition, floodproofing may be ineffective against erosion and waves, which can scour foundations for even structures raised above flood level.

Impacts. The environmental impacts from non-structural measures are small compared to structural measures. Buyouts have no negative impact on the environment except for the demolition process that may cause typical construction impacts. These impacts can be minimized or mitigated during the demolition process, but may include the demolition of historically significant resources. Subsequent to demolition and removal, buyouts are expected to provide beneficial environmental impacts by adding habitat. Limited buyouts may be effective in improving public access to recreational beaches. This in turn could promote increased use of the shorefront. Land use regulations will have a beneficial effect on the future environment by preserving existing ecosystems and limiting future degradation due to development. They are often the most environmentally acceptable solution since they do not involve any construction. Floodproofing impacts are similar to impacts from demolition associated with buyouts.

5.3.2 Beach Restoration

Beach restoration is applicable to both barrier island and mainland oceanfront shorelines in areas that are currently subject to erosion, inundation and wave attack. In those areas where erosion may lead to increased damage vulnerability, beach restoration is a suitable method for abating shoreline erosion and minimizing storm damages. Beach restoration is particularly useful at locations characterized by minor or moderate erosion.

Performance. The purpose of the beach restoration feature is to offset against long-term erosion and to provide protection against storm-induced erosion/flooding. Storm-induced property damages include those arising from beach and dune erosion, barrier island breaches and flooding of upland areas. Long-term erosion can also cause property damage and results from longshore sediment transport gradients and/or anomalous offshore bathymetric features. A beachfill normally consists of a design berm that protects the dune from erosion, and a dune that provides a barrier to storm tides and waves. Beachfill alleviates erosion by providing a sacrificial storm barrier. Renourishment operations are required to maintain storm damage protection.

Design. Beachfill cross-section design was prepared for a 100-year storm, based on existing beach dimensions. Representative profiles for the study area were analyzed to quantify existing beach dimensions. An example beachfill cross-section is shown in Figure 5.3, which shows the relationship of the beachfill cross-section to an existing beach profile. The design dune extends to an elevation of +20 feet NGVD. This elevation was selected because it represents the median dune elevation along the entire study area. The elevation also represents a dune that provides protection against a 100-year storm. The combined tide, storm surge and wave setup elevation for the 100-year storm is estimated between 11 and 13 feet above NGVD. Consequently, the design dune provides about 7 to 9 feet of freeboard to protect against wave runup that typically reaches 15 to 20 feet above NGVD for the 100-year storm and overtopping. A slope of 1(v):5(h) was used for the seaward and landward dune slopes. Since dunes are generally above water, dune side slopes can be limited to the steepest slope that is stable for the given beach material. Existing dune slopes vary between 1(v):2(h) and 1(v):15(h), but average 1(v):5(h). A design dune crest width of 50 feet was selected, because storm recession modeling indicated that this dune dimension would survive a 100-year storm with half of the dune crest remaining.

Berm width and elevation were selected to correspond to existing beach conditions. The study area features a berm that is highly variable in both elevation and width. The existing berm elevation averages 11 feet NGVD. This value is selected for the conceptual beachfill, based on guidance in Engineering Manual 1110-2-3301 that suggests …. *if possible, constructed berm elevations should be designed to be the same or slightly less than the natural berm crest elevations. Restricting the construction berm height to natural berm height will prevent significant post-storm scarping*. Similarly, the selected berm width of

100 feet was based on an averaged berm width from Fire Island Inlet to the Village of Montauk. Seaward beach slopes were assumed equal to native beach conditions offshore to the estimated closure depth. This assumes that fill materials are compatible with native beach sands. A closure depth at the –27-ft NGVD contour has been identified at Fire Island (USACE, 1998a), and was used for conceptual design.

The following paragraphs summarize specific conditions along the study area that influence the conceptual beachfill design.

Project Reach 1 - This area is characterized by high bluffs and dunes fronted by narrow beaches. Beachfill in this reach would consist primarily of a beach berm fronting existing bluffs and dunes to protect against bluff recession and attendant damages from tidal inundation and/or erosion.

Project Reach 2 - The shoreline within this reach is characterized by segments of narrow beach backed by dunes of varying elevations. Beachfill would be comprised of beach berm placement seaward of the existing dune to protect against dune erosion and concomitant tidal inundation.

Project Reaches 3 to 5 - These reaches are characterized by widely variable beach and dune conditions. The conceptual beachfill feature would include both the design berm and dune to provide adequate tidal inundation and erosion protection.

Costs. Beach and dune construction would be accomplished using either hopper or pipeline hydraulic dredges. Fill material will be obtained from offshore borrow areas located along the study area. Newly constructed dunes would be stabilized with sand fences and dune vegetation. Wooden dune walkways would be constructed to reduce damage to newly constructed dunes and vegetation that would arise from pedestrian traffic. Initial beachfill quantities were determined from the comparison of beachfill cross-sections to existing profiles. In addition, advanced beachfill would be provided to preclude erosion of the design fill section. Advanced fill requirements, which indicate fill quantities that are necessary to stabilize the design fill, were estimated from sediment budget results. An erosion rate of 6 cubic yards per foot of beach per year (cy/ft/yr) was utilized for Reaches 1A, 3C, 4B, 4C and 5C, which is increased relative to historic rates due to recently accelerated erosion. Periodic renourishment of the beach would also be required approximately every 4 to 8 years over the project life. Periodic renourishment requirements are equivalent to advanced fill volumes.

Estimated design fill quantities are summarized in Table 5.3, for each physical reach. Also shown are advanced fill requirements, based on an assumed renourishment interval of either 4 or 8 years, depending of erosion severity. Physical reaches 1A, 3B, 3C, 4B, 4C, 4D and 5C were estimated for a 4-year nourishment cycle due to more severe erosion conditions relative to other locations that were estimated for an 8-year cycle. Fill requirements were adjusted to include dredging tolerance (15%) and overfill (10%) allowances. Renourishment would be accomplished by means of dredging from offshore borrow sources or upland trucking, depending on renourishment volume requirements.

Unit beachfill costs were determined for each physical reach of the study area, based on the distance from nearby borrow sources and fill quantities. These distances were used to determine whether beachfill placement would be performed using hydraulic pipeline or hopper dredges, and associated unit fill costs. These unit fill costs were combined with quantity estimates to determine initial and annual beachfill costs. Costs estimates do not include major rehabilitation, real estate and mitigation, and a contingency of 20% has been assumed, which is commensurate with the level of detail associated with cost variables. Engineering and design, and construction management have been estimated as 7% of initial construction costs. Total first and annual costs for beach restoration are summarized in Table 5.4 (1998 price level). Total annual costs were estimated using a 50-year project life and annual interest rate of 7-1/8%. These total annual costs include renourishment operations through the 50-year project life.

Limitations. Beachfill alone is a viable solution for the reduction of storm damages at locations where shore erosion is not severe. It is a natural method for restoring the protective capacity of the shoreline, but is limited in its effectiveness in areas where renourishment/rehabilitation is required frequently (e.g. adjacent to inlets or erosional hot spots). At these highly erosive locations, it is often advisable to combine beachfill with other methods for reducing erosion (e.g., groins, breakwaters or seawalls). The longevity of a beach restoration project is also related to the length of the filled shoreline. Consequently, beachfill projects are ideally applied to long segments and are less suitable for local, isolated storm protection. Another technical limitation of the beach restoration feature is related to placement of the design dune. By the placement of the beach dune landward of the project baseline, which represents the toe of the existing dune, the fill volume required to construct the design dune is minimized. However, in many areas, this results in a dune footprint that conflicts with existing development. Cost analyses would most likely indicate that the least expensive implementation of beachfill would involve the relocation or condemnation of some existing structures. This would most likely be unacceptable, requiring dune fill to be placed seaward of the existing dune. Additionally, the New York State Department of Environmental Conservation Coastal Erosion Management Regulations requires a 25-ft buffer between a structure and the landward toe of dune construction. In summary, these limitations force the beachfill to be placed seaward from its most cost-effective location, resulting in higher fill volumes, decreased fill stability and increased initial and maintenance costs.

Impacts. The primary impact of the beach restoration alternative is the creation of a larger beach and dune cross-section. The improved profile would feature a wide berm section in areas that currently feature a minimal berm cross section. The anticipated result would be a moderate increase in the longshore transport rate, that may require increased maintenance dredging at Shinnecock, Moriches, and Fire Island Inlets. Other impacts may include a reduction/increase in landward sediment transport during severe storms, which may affect barrier island dynamics and fringing bay habitats. Beach restoration using materials comparable to existing beach sediments results in minor long-term changes to physical coastal parameters (e.g. beach profiles and waves), although long-term erosion and storm-induced erosion are abated.

According to the National Research Council (NRC 1995), environmental impacts associated with beach restoration range from short- to long-term alterations that include both positive and negative consequences. NRC (1995) separated the effects of beach nourishment into three regions, namely: (1) subaerial habitats (i.e. supralittoral and intertidal), (2) subtidal habitats and (3) borrow areas. Subaerial impacts of beach restoration may include the disturbance of biota habitats, affecting species feeding, nesting, nursing and breeding. Impacts in subtidal regions may include the burial of surf zone habitats, increased sediment concentrations and sedimentation during and following construction and nearshore bathymetric changes. Borrow area dredging modifies borrow site bathymetry and removes benthic communities inhabiting surficial sediments, which may impact species feeding patterns. Additionally, borrow site dredging increases turbidity and may influence water quality. All of these impacts are site-specific and oftentimes temporary. However, the completeness and period of recovery is highly variable. Therefore, site-specific environmental resources must be examined to determine those habitats and physical conditions affected by beach restoration in order to properly determine or predict beach nourishment impacts.

5.3.3 Beach Restoration and Offshore Breakwaters

The use of breakwaters in concert with beach restoration is applicable at locations where beachfill alone is vulnerable to significant erosion with an attendant high cost for renourishment/rehabilitation.

Performance. Breakwaters are classified as beach stabilization structures, serving the following purposes: (1) reduce beach erosion (both long-term and storm-induced), (2) increase beachfill longevity and (3) maintain a protective beach for the reduction of storm damages. Breakwater design concepts presented below were developed to stabilize the beachfill.

Breakwaters may be either detached or shore-connected. Shore-connected breakwaters are constructed close to shore and promote the formation of a tombolo. Tombolo formation can be either natural due to sediment deposition or artificially constructed (beachfill placement). A variant of the shore-connected breakwater is the artificial headland. A series of artificial headlands forms pocket beaches that are characterized by a stable, equilibrium shoreline. Detached breakwaters are constructed offshore, and serve to stabilize the leeward shoreline against long-term and storm-induced erosion. Sand is deposited landward of a detached breakwater during normal wave activity. Breakwaters also reduce the offshore loss of sediments during storms. Two breakwater options were investigated for application to the Reformulation Study, namely: (1) artificial headlands and (2) detached breakwaters.

Design. One cross-section was developed for each breakwater type using design characteristics of the entire study reach. No modification of the design beach restoration cross-section was made, for the purposes of this screening. It should be recognized, however, that initial fill quantities may be reduced due to the protective capacity of the structures and that renourishment costs can be significantly less when breakwaters are coupled with beach restoration. This screening presents the design of beach restoration and breakwaters, assuming that the beach alone provides storm protection, excluding possible protection provided by the structures. Future analyses to further explore cost savings due to the protective capacity of breakwaters would be undertaken pending selection of this feature for further consideration.

Detached Breakwater. Figure 5.4 presents the conceptual detached breakwater cross-section. Structure design was performed using a water depth of 15 feet below NGVD, which is located approximately 1,000 feet offshore. The breakwater was sited at the 15-ft depth contour to avoid tombolo formation. The primary armor layer of the breakwater is comprised of two layers of 16-ton rough, quarrystone on a slope of 1(v):2(h) over an underlayer of two layers of 2-ton stone. The structure core consists of quarrystone ranging from approximately 10 to 200 pounds. A 12-inch bedding layer and toe berm are included for structure stability against wave forces, scour and differential settlement. Head armor stone is 16 tons at a slope of 1(v):3(h). A minimum crest width of about 20 feet at an elevation of +6 feet NGVD was selected. The toe berm is comprised of two layers of underlayer stone with a crest width of 10 feet. Breakwater lengths of 300 feet with a structure spacing of 400 feet were selected for preliminary purposes to promote salient formation, although the actual breakwater layout could vary significantly based on local conditions.

Artificial Headland. The conceptual cross-section of the artificial headland is show in Figure 5.5. The structure was designed to avoid erosion of the beachfill template and to promote stable tombolo features. A preliminary headland spacing of 350 feet and structure segment length of 300 feet were selected for cost estimating purposes. The headlands will be located approximately 150 feet offshore of the fill shoreline in a water depth of 8 to 10 feet below NGVD. The primary armor layer of the artificial headland consists of two layers of 14-ton rough, quarrystone on a slope of 1(v):2(h) with an underlayer of two layers of 1.5-ton stone. Head armor stone is 14 tons at a slope of 1(v):3(h). The structure core consists of quarrystone ranging from approximately 5 to 150 pounds with an interior crest elevation at –1.0 ft NGVD. A crest elevation of +10 feet NGVD was selected.

Costs. Initial quantities and costs for the beachfill element of this feature are identical to those described previously for beach restoration, except advanced fill requirements are reduced. Renourishment would also be reduced due to the breakwater. For the purpose of plan comparison, renourishment requirements in areas including breakwaters were estimated to be reduced by approximately 50 percent (relative to beachfill alone). These estimates are viewed as conservative insofar as reductions in renourishment requirements may be higher. Nonetheless, these reductions provide a means to determine whether additional expenditures for breakwater construction are justified by reduced renourishment costs. The determination of actual breakwater impacts on renourishment reductions would require more detailed design analysis. Quantities and costs were developed for the detached breakwater and artificial headland features, and were combined with beach restoration costs.

Initial first costs (structure only) were estimated as approximately $9,600 and $7,700 per unit structure length for the detached breakwater and artificial headland features, respectively. These estimates were used to determine breakwater costs per unit length of shoreline for each physical reach, based on structure segment lengths and gap spacing. The resulting costs per linear foot of shoreline were combined with beach restoration costs per physical reach, and are summarized in Tables 5.5 and 5.6. Costs presented in these tables include total investment costs, annualized investment costs, annual renourishment and annual structure maintenance. Annual renourishment costs were estimated using reduced renourishment quantities and 4 or 8-year nourishment intervals, as described previously for the beach restoration feature. Annual structure maintenance costs were estimated as 0.5% of initial construction costs. Cost estimates do not include major rehabilitation, real estate and mitigation, and a contingency of 20% has been assumed for breakwater costs. Engineering and design, and construction management for breakwaters have been estimated as 7% of initial construction costs with a contingency of 10%. Annual costs were determined using a 50-year project life and interest rate of 7-1/8%.

Limitations. A clear distinction must be made between shore protection and beach stabilization structures, where the former is intended to provide storm protection and the latter stabilizes a protective beach. The breakwater/headland features presented above are beach stabilization structures. Storm damage reduction is not provided directly by these structures, but rather through beachfill placement. Breakwaters or headlands in the absence of beachfill do not provide the necessary storm damage protection, but are proven to be effective in shoreline stabilization. However, breakwaters can be expensive to construct and performance experience in the U.S. is limited, especially on the open Atlantic Coast.

The State of New York, Coastal Management Program, regulations limit the use of structures to locations where beachfill alone is not viable. It is judged that breakwaters or headlands could be an acceptable feature in the present context, because they would only be considered at locations where beach restoration alone is not effective.

Impacts. The impacts of beachfill in concert with breakwaters are comparable to those described for the beach restoration feature. Breakwaters increase the longevity of beachfill, decreasing the frequency and volume of renourishment operations. Accretion leeward of breakwaters could result in erosion elsewhere, unless special provisions are made. Breakwaters will also significantly alter surf zone characteristics, and may pose hazards to navigation and beach users.

Environmental impacts of rubble-mound structures may be separated as (1) short-term and (2) long-term, and can be both positive and negative. Short-term impacts are usually associated with project construction, although construction can be scheduled to minimize these impacts. Construction impacts may include noise and air pollution associated with heavy equipment use, disruption of nesting and feeding of fish, waterfowl and other wildlife, temporary water quality impacts (e.g. increased suspended sediment concentrations), destruction of benthic habitats, and mortality of clams and other invertebrates. USACE (1995a) states that water quality degradation during construction is generally confined to the immediate vicinity of project construction. Long-term impacts are associated with changes to the physical environment caused by breakwater construction. These include different nearshore wave breaking and circulation patterns, and the loss or gain of intertidal, marsh, upland and/or reef habitats

5.3.4 Beach Restoration and Seawalls

A seawall can be used to augment the level of protection offered by beach nourishment alone or to reduce the volume of fill required in the design fill section. Unlike breakwaters and headlands, seawalls serve to provide storm protection, but do not reduce beach renourishment requirements.

Performance. Rubble-mound seawalls were examined to augment the protective capacity of and reduce the reliance on beach restoration for storm damage reduction. The seawall feature would absorb direct wave impacts, restrict storm erosion and prevent breach formation. The proposed seawall design consists of a rubble-mound structure buried in the dune of the design beachfill. Beach restoration ensures the integrity of the seawall prior to severe storms. Because the seawall is placed within the dune, the size of waves that reach the structure is limited even during a severe event. Accordingly, it is possible to construct a robust rubble-mound structure that is highly resistant to storm wave attack.

Design. Conceptual design of the beach restoration and seawall feature was performed for areas east and west of Moriches Inlet. As an example, Figure 5.6 presents the conceptual seawall for the area east of Moriches Inlet. No modification of the beach restoration cross-was made for the present evaluation, although more detailed future evaluation will consider reducing initial fill requirements due to the protective capacity of the seawall. Renourishment requirements are not reduced due to seawall presence. Therefore, cost savings for a seawall and beachfill combination would arise primarily from reduced initial fill requirements.

The primary armor layer of the seawall is comprised of two layers of 4.5 (eastern) and 6.5 (western) ton quarrystone on a slope of 1(v):2(h). An underlayer comprised of two layers of 800 (eastern) and 1,400 (western) pound quarrystone would be placed on geotextile fabric. Design structure crest elevations are +15 and +17 feet NGVD for the eastern and western areas, respectively. A structure crest width of 15 feet was selected consistent with USACE (1984a). Toe protection consists of two layers of 4.5 (eastern) and 6.5 (western) ton armor stone at an elevation of +4 feet NGVD. The landward slope of the seawall includes two layers of primary armor stone for overtopping protection. The primary armor layer on the landward side of the structure extends to an elevation of approximately +5 feet NGVD.

Costs. Conceptual quantities and cost estimates were developed for the seawall and beach restoration for each physical reach. Quantities and costs for initial beachfill placement and renourishment operations are identical to those described previously for the beachfill feature.

Initial costs for the seawalls were estimated as approximately $5,600 and $6,800 per unit structure length for the eastern and western domains, respectively. These unit costs were combined with beachfill costs to estimate seawall and beachfill costs for each physical reach. Results are shown in Table 5.7. Cost estimates do not include major rehabilitation, real estate and mitigation, and a contingency of 20% has been assumed. Engineering and design, and construction management have been estimated as 7% of initial construction costs with a contingency of 10%. Annual costs were determined using a 50-year project life and interest rate of 7-1/8%.

Limitations. Seawalls protect only those land areas immediately leeward and offer no protection to the fronting beach. Recession of surrounding shorelines will continue unabated, although beachfill placement in front of the seawall may somewhat lessen this erosion.

Compliance with State of New York, Coastal Management Program, regulations limits the use of structures to locations where beachfill alone is not viable. Seawalls may be an acceptable solution at locations where beach restoration alone is not effective and requires additional structural shore protection. Furthermore, it is noted that several local community regulations may restrict seawall construction.

Impacts. Impacts of the beachfill and seawall feature are similar to those described for the beach restoration feature, although the required beachfill design template may be smaller when constructed in concert with the seawall. Additionally, a significant impact of seawalls is the loss of leeward bluff and/or dune materials as a source of sediments to the littoral zone. Overall, provision of a beachfill has two principal benefits: (1) limits and protects the seawall from direct wave impacts and (2) provides a source of material to compensate for the loss of sediments to the littoral zone from the protected uplands. Impacts of the seawall on wave and littoral conditions should be minor, because the proposed seawall feature is located landward of the active littoral zone. Seawalls constructed along the barrier islands provide additional protection against barrier island breaching, but may reduce the amount of overwashing sediments. Notwithstanding this potential impact, the seawall feature is characterized by crest elevations that are typically below existing natural dunes.

Biological impacts associated with seawall construction are limited to impacts to the subaerial beach. These impacts may include the temporary loss of subaerial habitats and the disturbance of species feeding and nesting patterns. Burial of the seawall in a dune would reduce these long-term effects.

5.3.5 Beach Restoration and Groins

Beach restoration and groins are applicable to severely eroding shorelines where beach restoration alone is not cost-effective due to high renourishment requirements. Groins can increase the longevity of beachfill by reducing losses due to long-term erosion.

Performance. Groins are classified as beach stabilization structures. Groins interrupt longshore sediment transport and promote sediment deposition. Groins are often constructed in series to provide protection to a continuous shoreline segment. For the present evaluation, groin compartments would be filled initially to promote sand bypassing.

Design. Beach restoration and groin design assumed that the beachfill cross-section would be unchanged, although advanced fill requirements are reduced. Typical groins were designed for the study area. Figure 5.7 presents the resulting groin design, which is comparable to the recently completed groins at Westhampton Beach and those described in USACE (1998b). These groins closely match the design beachfill geometry, following design procedures described in USACE (1984a).

Groin design can be summarized as: (1) a horizontal shore section (HSS) extending from a crest elevation of +11.0 feet NGVD to a bottom elevation of 0.0 feet NGVD; (2) an intermediate sloping section (ISS) extending from a crest elevation of +11.0 to 0.0 feet NGVD at a slope of 1(v):18(h); and (3) an outer sloping section (OS) extending from a crest elevation of 0.0 feet NGVD to a bottom elevation of –12.0 feet NGVD. One layer of 7-ton armor stone was determined for the ISS and landward end of the OS. One layer of 5-ton stone was used for the HSS, and two layers of 14-ton armor stone were included on the head of the OS. The HSS and ISS have side slopes of 1(v):1.5(h) and the OS has side slopes of 1(v):3(h). A core comprised of 50 to 1500 pound stone would be placed beneath a single layer of armor, except at the head of the OS.

According to USACE (1984a), groin spacing is generally two to three groin lengths where groin length is defined as the distance from the beach berm crest to the seaward groin end. Based on this criteria, groins spacing may range from 500 to 750 feet relative to a groin length of 250 feet. For the present evaluation, a groin spacing of 700 feet was selected for cost estimating purposes. It should be noted that the present groin design reflects long, low-profile groins that are effective at interrupting longshore sediment transport, but encourage bypassing. Ultimately, the groin capacity to hold sand is dictated by the elevation of the sand-tight core, which is a major factor in determining a groin’s trapping efficiency.

The effect of the proposed groin feature on renourishment is a significant factor in evaluating cost effectiveness relative to beachfill alone. Guidance in USACE (1984a) suggests that the proposed design could impede between 75 and 100 percent of the local longshore sediment transport. Similar rules applied to the Westhampton groin field would indicate 100 percent trapping, prior to complete filling of the groin compartments. A 50 percent reduction in renourishment requirements was used for cost comparisons.

Costs. Initial quantities and costs for the basic beachfill element of this feature are identical to those described previously, however, less advanced fill is required. Costs estimates also reflect reduction in renourishment quantities. Quantities and costs were developed for the groin feature per single structure.

These quantities and associated costs were then adjusted to reflect costs per unit shoreline length accounting for the groin spacing of 700 feet.

Initial first costs were estimated as approximately $1,700 per unit shoreline length. This estimate was used to determine groin costs per physical reach, and was combined with beachfill to reflect total costs. Results are shown in Table 5.8, which presents total initial costs for beachfill and groins, annualized initial costs, annual renourishment, annual structure maintenance and total annual costs. Annual costs were determined using a 50-year project life and interest rate of 7-1/8%. Annual renourishment costs were estimated using reduced quantities and a 4-year nourishment interval for high erosion areas and 8 years for all other areas. Annual structure maintenance costs were estimated as 0.5% of initial construction costs. Cost estimates do not include major rehabilitation, real estate and mitigation, but do include a contingency of 20%. Engineering and design, and construction management have been estimated as 7% of initial construction costs.

Limitations. Groins are beach stabilization structures and, as a result do not directly provide storm protection. Groins can only be implemented if the resulting benefits to the local and updrift shoreline offset possible negative impacts to the downdrift shoreline.

Compliance with State of New York, Coastal Management Program, regulations limit the use of structures to locations where beachfill alone is not viable. Groins are judged to be potentially acceptable at locations where the success of beach restoration alone is compromised by severe erosion (e.g. downdrift of an inlet), and where renourishment costs can be significantly reduced.

Impacts. Beachfill impacts are comparable to those described for the beach restoration feature. The addition of groins would have impacts that are similar to breakwater construction. These include increased beachfill longevity, an alteration of surf zone characteristics, and potential hazards to navigation and beach users. Short-term construction impacts may also be a significant factor in groin implementation. Potential groin impacts are summarized in the document USACE (1992). This document states that *although groins are useful, in some circumstances they have several undesirable qualities. In general, groins are unsightly, impede movement along the beach, pose hazards to swimmers, and may generate rip currents that carry sediment offshore. In addition, consideration must be given to the fact that trapping of sand in the groin fields may create sand starvation, and consequent erosion, on downdrift beaches. However, when groins are filled to capacity by fill material, the normal littoral drift will likely be bypassed around the seaward end of the groins until such time as loss of fill restores their potential as sediment traps.* These impacts may be lessened or eliminated by the use of low-profile groins that do not significantly exceed the height of the surrounding beach, and the inclusion of beachfill placement, maintenance and monitoring.

5.3.6 Removal/Modification of Groins

This feature is applicable to locations where existing groins may potentially have adversely impacted the beach and adjacent areas. Existing groins are located in the Towns of Easthampton and Southampton (8), at Westhampton Beach (16) and along Fire Island (2).

Performance. This feature would examine the removal or modification of groins in the study area to augment the performance of other shore protection features (particularly beachfill). For the present screening groin removal was examined, although future study phases may consider modification of existing groins to lessen possible adverse impacts on the existing littoral environment. Groin modifications could include tapering existing groin fields, lowering and/or shortening groins, or notching groins to enhance sand bypassing to downdrift shorelines. Groin removal/modification is not a storm damage reduction feature itself. The purpose of groin removal would be to reduce or eliminate interruptions in longshore sediment transport interruptions in order to restore natural sediment movement. A complete investigation into the feasibility or impacts of this alternative requires careful investigation aimed at quantifying the historic and ongoing impact of the existing groins. It would also be required that existing storm protection in areas where groin removal occurred was not adversely affected.

Design. The total number of structures that may be classified as groins is 26, not including jetties and drainage outfalls. These structures are located from Project Reach 1 in Montauk to Project Reach 5 in Ocean Beach on Fire Island. Most of the groins are quite substantial in size and are generally in good condition. The majority of the existing structures are comprised of rubble-mound, quarrystone construction, except the Ocean Beach groins that are constructed of pre-cast concrete armor units and the Shinnecock groins (steel sheetpiling). The feasibility and benefits of groin removal can be determined by estimating the groin impacts on shoreline changes and sediment transport processes. A comprehensive evaluation of groin removal would be performed by investigating: (1) historical shoreline and volumetric changes updrift and downdrift of structures before and after construction, (2) the contribution of the groin toward any irregularities in the existing beach layout, and (3) the groin impacts determined by implementation of the GENESIS shoreline change model. These results and engineering judgement would be applied to determine the anticipated impact of groin removal. Groin removal would be considered beneficial if the resulting negative updrift impacts (i.e., change of shoreline position) were minimal/manageable, and benefits to the downdrift shoreline were sufficient to justify removal costs. For the present investigation, a simple, conceptual analysis was conducted to screen this feature relative to other storm protection features.

Procedures that would be used to remove groins are dependent on structure size and site accessibility. Many structures would require the use of a barge for their removal, because: 1) existing roads are distant from groin locations and/or 2) groins extend well into the water and the groin crest would not support heavy equipment access.

Costs. Groin removal costs considered stone excavation, site removal, and impacts on renourishment quantities. Groin removal would include all groin materials not deeply buried, and would generally extend between the +10 and –10 ft contours. Groin removal costs were estimated using unit costs detailed in the USACE (1994). Total unit stone removal costs were estimated at about $80 to $100 per ton, including stone removal and disposal, and contingencies. As Federal groins in the study area are comprised of approximately 11,000 tons of quarrystone, groin removal costs were estimated as approximately $760,000 per groin. The exception is the Ditch Plains groin, which, because of its short length, would cost approximately $380,000 for removal. The removal of the Southampton groins was estimated as approximately $190,000 per structure.

Groin removal costs in areas not fronted by groins are zero and costs in existing groin areas are the total of removal costs and renourishment differences. For the present analysis, the without-groin (i.e. after removal) erosion rates were assumed equal to the erosion rate for the beachfill alternative, i.e. approximately 6 cy/yr/ft. Renourishment requirements were then estimated for reaches downdrift of groin removal areas by assuming a 25 percent reduction in the erosion rate at Reaches 2B, 4B and 4C.

Table 5.9 summarizes cost differences between groin removal and beachfill, and beachfill alone. Costs shown in this table include initial groin removal, first costs for the beachfill and beachfill with groin removal, renourishment costs, and total annual cost for the beachfill with groin removal. Additionally, Table 5.9 shows annual cost differences between the beachfill and beachfill with groin removal, where negative cost differences indicate potential savings by including groin removal. Annual costs were calculated using a 50-year project life and interest rate of 7-1/8%. Due to the small number of groins or their condition, Physical Reaches 1A, 3A and 5C costs are limited to groin removal with no adjustment of renourishment requirements as compared to beachfill alone. The results indicate that groin removal would have cost benefits in downdrift regions (i.e., west) from where groins were removed, although these cost savings are notably less than expenditures in the areas where groins would be removed. Consequently, groin removal results in overall cost increases based on the present analyses.

Limitations. Groin removal should not be undertaken without a thorough understanding of the likely impacts. Based on the present analyses, groin removal results in increased costs with no readily identifiable benefit in terms of beachfill performance.

Most of the groins were Federally constructed, although two of the Easthampton groins and the Ocean Beach groins were constructed by the State. Privately constructed groins are limited to the structures in Southampton. The institutional limitations or social objections for the removal of Federal groins may be significant. Groin removal may be not be feasible if it is anticipated that primary and secondary dune systems established naturally after groin construction would be diminished.

Impacts. The primary impact of groin removal would be the restoration of longshore transport rates closer. The result may include the widening of beaches west (downdrift) of the groin locations, and a narrowing of berms east (updrift) of the groin locations. A prior study (USACE 1984b) described the Ocean Beach and Easthampton groins as being *generally saturated with sand. As a result, downdrift effects of the groins are not particularly severe*, and it was stated that their removal would not have any significant impacts. However, more recent shoreline recession seems to have exposed more of the groins' length. Furthermore, this report described the Westhampton Groins as creating sediment transport reversals, and indicated the *danger of being severely overwashed or breached in the event of a storm*. This danger has been reduced by the Westhampton Interim Project. The study went on to determine that the removal of the Westhampton groins would result in significant short-term impacts (positive downdrift, negative in the groins' vicinity), but minimal long term impacts (as the longshore transport returns to its existing rate). It should be noted, however, that groin removal at Westhampton Beach could possibly cause erosion to revert to pre-groin conditions that led to multiple breaches and overwashing. Environmental impacts would include the immediate loss of the groins as intertidal and subtidal habitats.

5.3.7 Levees and Floodwalls

Levees and floodwalls are effective in reducing tidal flooding in coastal areas not subject to significant wave activity or currents. As such, levees and floodwalls are suited for mainland and backbay areas, but are not feasible for oceanfront protection. The levee or floodwall system provides a barrier against high storm tides that cause flooding. A levee or floodwall system must be accompanied by interior drainage facilities to allow the water on the protected side to drain during precipitation events. Without interior drainage facilities, water on the protected side would build up and cause flooding from the interior.

Performance. Levees and floodwalls are designed to provide a continuous line of protection around a group of structures or larger development. These features represent a flood barrier not directly exposed to ocean storms. Conceptual design performed for the present analysis describes the development of the levee/floodwall protection alternatives for the mainland of Long Island, except at Westhampton and Tiana Beaches. These features may be comprised of earthen materials, concrete, rock or a combination of materials. Levees and floodwalls must either be self-enclosed or tie into high ground at each end of a project segment. If a large area is to be protected, rivers or canals draining into the bays will either require closure gates and drainage facilities such as pump stations or will require the line of protection to surround the water course on both sides, extending inland to high ground.

Design. The levee/floodwall protection feature for the mainland of Long Island consisted of an update of the analysis described in (USACE 1982). This previous design report proposed three different types of protection along the south shore including earth levees, concrete floodwalls and offshore rubble mound structures. Levees were further subdivided into sand levees, earth levees and rip-rap faced levees. All levees included a clay core. Regular levees were utilized in areas of low wave energy, while rip-rap levees were specified for areas of higher wave energy. Where there is limited space due to the presence of structures, a floodwall was utilized in lieu of a levee. Rubble mound sea walls were chosen to connect gates across canals and in areas where shorefront activities would be severely impeded by construction of floodwalls or levees. The 1982 report also specified levees on Fire Island. However, the lack of available space makes this impracticable. The present analysis presents technical and cost updates for protection of the mainland between the Robert Moses Causeway and Montauk Point.

Combined hurricane/northeaster stage frequency curves from CHL were used to determine 100-year water surface elevations along the bay shoreline. Levee heights were set at 3' above these elevations to allow for wave setup, runup and design uncertainties. Design levels for the back bays assume that there will be no significant increases in future stages due to higher rates of barrier island overwash or the formation of new inlets.

Typical cross-sections were used for estimating levee and floodwall costs. The levee design section includes a 6-foot deep key with side slopes of 1(v):2.5(h). Ground elevations behind all bulkheads were recorded from existing topographic maps and were averaged by economic reach. These ground elevations were then utilized in conjunction with the 100-year water surface elevations to determine floodwall and levees heights. Rubble mound seawalls for the mainland were designed for a toe elevation of -2 feet NGVD, because structures would be placed close to the existing shoreline.

Levee lengths were determined for each economic reach along back bay shorelines. Levee and floodwall types for various study area locations assumed the same structure types that were used in the prior design report. The proposed feature is comprised of levees, rip-rap levees, flood walls, rubble mound sea walls, interior drainage outlets, closure gates and pump stations, and also includes canal closure gates, interior drainage and pump stations recommended for this feature.

Costs. Cost curves were developed for levees, rip-rap levees, rubble-mound seawalls and flood walls. Each of these curves represents levee or floodwall cost as a function of height. Total capital costs include initial construction, overhead and profit, engineering and design, supervision and administration, and real estate. Costs estimates do not include environmental mitigation, such as wetland replacement or restoration, but do include a contingency of 25%. Engineering and design, and construction management have been estimated as 7% of initial construction. Annual levee and floodwall costs have been estimated using a project life of 50 years and an annual interest rate of 7-1/8%. Total initial and annual costs are presented in Table 5.10 per project reach. This table also summarizes structure type, height and length selected for each project reach.

Limitations. Levees and floodwalls are not designed to protect against wave damage due to breaking waves, but rather are intended to protect against tidal flooding and storm surges. Consequently, levee features are not practicable for storm protection on the barrier islands. Levees and floodwalls are also inappropriate features in areas subject to erosion. In this regard, levees and floodwalls at actively eroding areas may be combined with beach restoration (or maintenance).

Levee features require extensive property easements along their length. This may meet with more significant opposition than other features (e.g., dune easements), because some property owners may be unwilling to provide the necessary easement. Furthermore, this alternative also may be impracticable due to the numerous closure gates required across tidal river inlets and associated environmental impacts.

Impacts. Beneficial impacts include providing direct protection to back bay areas from flooding. The line of protection would protect low-lying areas along the mainland shore from inundation. However, levee features would impact tidal wetlands. Although floodwalls can be used to minimize impacts to wetlands due to their smaller footprint, costs would be increased. As an alternative, levee placement could possibly be modified to avoid wetland impacts in some locations, but adverse wetland impacts may be unavoidable at other locations.

Levee construction would also require the modification and/or relocation of shore structures, including marinas and docks. Furthermore, businesses that utilize the waterfront would be adversely impacted during levee construction.

5.3.8 Storm Closure Gates

These structures are appropriate as stand alone features at locations where surrounding landmasses are high enough to preclude surge inundation, but may need to be combined with beachfill where surrounding land areas are low. Along the barrier islands in the study area, closure gates would require that storm erosion and inundation of the islands was not a significant contributing factor to estuary flooding. In other words, storm closure gates serve only to reduce flooding through inlets.

Performance. Tidal gates at Fire Island, Moriches and Shinnecock Inlets would provide barriers to flow to preclude or limit the propagation of storm surges into adjoining bays. The present examination also considers a closure gate at Narrow Bay to limit flow between Moriches and Great South Bays. In the event that flow control structures are operated at Moriches and Fire Island Inlets, no structure would be required at Narrow Bay. A flow control structure was not examined between Shinnecock and Moriches Bay, as flows between these estuaries are presently constricted.

Numerous gate geometries were considered. Articulated gates include a closure that can be raised, lowered or otherwise removed from service when the threat of flooding is absent. Weir structures are fixed structures. Weir gates restrict flow by inducing hydraulic losses and/or limiting available flow area. Weir structures were eliminated from further consideration, because normal tidal flows would be restricted. Tidal gate options selected for the present evaluation are as follows: (1) rising sector gate – Fire Island, Moriches and Shinnecock Inlets and (2) vertical lift gate – Narrow Bay. Selection of these options was based on overall effectiveness, navigation impacts, ease of operation/maintenance, constructability, inlet and environmental impacts, and relative aesthetic/social acceptance. Descriptions of these gate types are given below.

Rising Sector Gates. The rising sector gate closes by rotating the gate structure until the curved plate faces seaward. The advantage of this type of gate structure is that it does not hinder navigation while open. Vibration problems and a complicated rotary drive system are disadvantages of this structure.

Vertical Lift Gates. The vertical lift gate operates by lowering the gate into position between two structure piers. The advantages of this structure are that it is a proven design and simple to operate. The primary disadvantage is that the structure is a hindrance to navigation due to its low overhead clearance and large supporting piers.

Design. The goals used in conceptual design of tidal gate closures were as follows: (1) arrest storm surge propagation, (2) maintain existing inlet navigation depths, widths and overhead clearances, (3) maintain existing or stable inlet cross-sections to minimize shoaling effects, and (4) minimize structure lengths. A design storm water level of +5 feet NGVD was used for each bay. A gate height (i.e. top elevation) of +8 feet NGVD was used for Narrow Bay to be consistent with neighboring topography. Tidal gate heights were established at two feet above the design storm surge levels at each of the inlets. Wave overtopping was permitted to minimize structure heights and to reduce wave loading. Authorized channel depths in each inlet are 10 feet MLLW. Gate sill elevations were set at a minimum depth of 12 feet MLLW. At Narrow Bay, the authorized channel depth is 6 feet MLLW and sill depths were set at 8 feet MLLW.

The location of the closure gate at Fire Island Inlet is across the inlet channel between Democrat Point and the “Thumb”. This location was selected because it provides the shortest structure length, most direct connection to high ground and protection to Oak Beach. The gate consists of two different sill elevations across the inlet, specifically: (1) Democrat Point for a distance of 1,500 feet into the inlet with a sill elevation of –10 feet NGVD and (2) northwest to the “Thumb” for a distance of about 1,500 feet at an elevation of –31 feet NGVD. A total of twelve, 250-ft gates would comprise the total closure. Tie-back levees would connect the gate structure with high ground. The height of the closure gates would be +15.0 feet NGVD, based on a total water elevation of 13.0 feet NGVD for the 100-year storm. This feature would also require repair of the “Thumb” due to previous storm damages.

The rising sector closure gates at Moriches and Shinnecock Inlets would be located near the north or landward end of the existing jetties, generally aligned with the existing dune locations at each inlet. Sill depths were set at -15 feet NGVD with approximate total gate widths of 800 feet. Each gate structure would consist of four gate units, each approximately 170 feet long. The elevation of the closed rising sector gate would be approximately +13.0 feet NGVD and +14.0 feet NGVD at Shinnecock and Moriches Inlet, respectively. These heights are based on a 100-year total water surface elevation of 11.2 feet NGVD and reflect the general increase of storm tide elevations from east to west along the study area. A closure levee would be required at Shinnecock Inlet to connect the tidal gate with high ground. Inlet cross-sectional areas would be approximately 12,000 sq. feet, which is consistent with existing inlet flow areas and tidal inlet stability analyses.

The location of the vertical lift at Narrow Bay is adjacent to the William Floyd Parkway Bridge. A sill elevation of -8 feet NGVD was selected. The required length of the gate would be about 600 feet comprised of 5 gates connected to shore by 200-ft levees on either side to adjacent high ground. A vertical clearance of 65 feet would be provided.

Costs. Total capital costs include initial construction, overhead and profit, engineering and design, supervision and administration. Costs estimates do not include real estate and mitigation, and include a contingency of 20%. Engineering and design, and construction management have been estimated as 7% of initial construction costs with a contingency of 10%. While real estate costs were not included, land requirements would be minimal.

Storm tidal gate annual costs have been estimated using a project life of 50 years and an interest rate of 7-1/8%, and include operation, maintenance and depreciation costs. Total annual costs are presented in Table 5.11. The risk of increased costs should be noted due to uncertainties concerning construction difficulties, and inlet siltation and scour influences on gate operations and maintenance.

Limitations. Storm closure gates would restrict the passage of storm surge through Fire Island, Moriches and Shinnecock Inlets. Furthermore, the flow of storm waters through Narrow Bay between Great South and Moriches Bay would be precluded in the event that a storm closure gate was placed at either Fire Island or Moriches Inlet. Care must be exercised in viewing tidal gates as flood protection measures in and of themselves. Breaching of the barrier islands or structure flanking would significantly reduce gate effectiveness. As the existing barrier islands are vulnerable to breaching and overtopping, tidal gates alone would not provide the desired storm protection. Consequently, storm closure gates must be considered in concert with shoreline improvements.

A disadvantage of storm gates is the inability to allow rescue vessels ocean access during storms and refuge harbor access for ocean vessels. Inlet closure would require these vessels to find shelter east of Montauk Point or west of Fire Island Inlet. Otherwise, vessels would have to weather storms offshore. The U.S. Coast Guard (USCGS), Third District, New York, has previously indicated that inlet closure during storms was unacceptable.

Impacts. The storm closure gates, when open, would have little impact on total tidal exchange. In this connection, water quality effects in the estuaries may be minor. The gate structures would segment and train flows. Therefore, closure gates would change sedimentation characteristics of the inlet. Closure gates would also involve construction across the inlets and may require closure dikes that would possibly disrupt or destroy nearby habitats. Additionally, storm closure gates would be massive structures that may be socially unacceptable and would interfere with fishing activities within the inlets.

5.3.9 Inlet Modifications

Modifications to Fire Island, Moriches and/or Shinnecock Inlets will be investigated during future study efforts. These modifications would focus on reducing inlet-trapping capacity and could involve modification of inlet dredging practices to enhance sand bypassing and/or construction of sand bypassing plants. Other modifications could include revision of current inlet design cross-sections or other features to limit storm surge propagation through the inlets, and concomitantly bay tidal inundation. These modifications cannot be classified as storm protection features, but could reduce long-term erosion in the region.

5.4 Pond Drainage Requirements

Storm protection features fronting Georgica Pond, Mecox Bay and Sagaponack Lake require the provision of outlet structures to ensure adequate stormwater drainage and water quality. Currently, the existing beach fronting these water bodies is periodically excavated to allow drainage when pond water levels are high. Storm water outlets would be required along with storm protection construction in these areas to allow drainage through a widened beach. Drainage outlets would reduce flooding of low-lying backshore properties. The outlet structures would also reduce the length of time that storm water resides in the ponds with an associated improvement of water quality.

Conceptual interior drainage facilities are summarized in Table 5.12. Cost estimates were prepared based on conceptual designs, and included a 20% contingency, 10% for engineering and design and 10% for construction management, but do not include real estate and mitigation. A summary of the outlet costs is shown in Table 5.13 for Project Reach 2.

5.5 Cost Summary

Costs were estimated using the previously described costs/quantities for each feature, and total annual costs are summarized in Table 5.14. Closure gate, floodproofing and levee and floodwall costs are presented per project reaches, whereas other features are presented for both physical and project reaches. Closure gates assumed that features are implemented at each ocean inlet (i.e., no gate at Narrow Bay). Groin removal is shown relative to the cost differences between beachfill and costs required for removal operations in concert with beachfill (positive indicates cost increases for groin removal). It should be noted that several features (i.e., groin removal, closure gates) would not likely be satisfactory stand-alone solutions. Consequently, these features must be considered in concert with other storm protection features (e.g. beachfill).

The design and costs for local protection projects, such as levees and floodwalls or floodproofing, along the bays in Project Reaches 3 to 5 are based on maintaining the existing inlet and bay hydrodynamics. The design of these alternatives is extremely sensitive to storm surge levels in the bays, and to a large extent storm surge elevations in the bays are controlled by the number, size and location of inlets, breaches, and overwash areas. Any major change in inlet or barrier conditions, including the presence of a significant breach, could result in overtopping of the design. Since exceeding the design level of levees or floodproofed buildings would create a significant public safety hazard, these features will only be considered in conjunction with some barrier island planning element which ensures predictable future hydraulic conditions within the bays. The barrier island element could range from a breach management or closure plan to prevent the development of new inlets, to stabilization plans that minimize breach formation and reduce the volume of flow overtopping the barrier. Any of the range of protection alternatives considered for the barrier islands would provide reasonable certainty regarding future changes in bay hydrodynamics and the potential frequency of design exceedance.

Because of the interdependence between future barrier island conditions and the design requirements for levees, floodwalls or floodproofing, these local protection features will only be considered as an added element to those plans identified for further consideration along the barrier island. Since the current estimate of local protection costs is based on existing hydrodynamics, there is an inherent assumption that the level of storm protection provided by the barrier would continue into the future. Results show in Table 5.14 for Project Reach 2 do not include the pond drainage structures, which would increase initial costs by the amounts shown in Table 5.13. General observations that can be drawn from the screening level investigations are described in the following paragraphs.

The most cost-effective storm protection solution along the barrier island shorelines (i.e., Project Reaches 3 to 5) is likely to be beach restoration. However, non-structural measures are shown as less costly along Shinnecock Bay (Project Reach 3). Non-structural measures in lieu of or in concert with beachfill may be warranted in the event that beachfill is not implementable or supplemental protection is required in areas of high residual damages. In Project Reach 5, levees and floodwalls may provide an effective method to reduce localized areas of high residual damages. Development or design of such alternatives, however, requires that the future barrier island alternatives and conditions be established and maintained.

The non-structural floodproofing feature is the most cost-effective solution along the mainland oceanfront shoreline between Southampton and Montauk Point, i.e. Project Reaches 1 and 2. This observation arises primarily from the nature of the problems in these areas, which are more isolated than along the estuaries located to the west and may indicate that non-structural features are appropriate solutions for isolated problem areas. Non-structural measures, however, do not reduce damages due to erosion and waves and, consequently, may need to be supplemented with other features that provide protection against erosion and waves. Beach restoration and beach restoration with groins are the least expensive features that provide erosion and wave protection. Beach restoration with breakwaters (or headlands) were not considered for further study since these alternatives cost more than beach restoration and beach restoration with groins. Even though these two alternatives cost less than beach restoration with seawalls, they may not be as effective in addressing highly localized flooding and erosion. In addition to non-structural measures, beach restoration, beach restoration with groins and beach restoration with seawalls will be considered in future analyses for Project Reaches 1 and 2.

Costs for beach restoration and seawalls, groins, headlands or breakwaters exceed beachfill costs at this level of study. Past experience, however, has shown that the use of structures with beachfill could prove to be a lower cost option at erosional hot-spots or at locations that require short lengths of storm protection. Consequently, it is necessary to investigate the cost effectiveness of coastal structures on a more localized basis than has been presented. These investigations will examine small, isolated areas and erosional hot spots to determine if structures in concert with beachfill are warranted to reduce renourishment requirements. As an alternative, beachfill in concert with seawalls may also be advantageous at some locations, where fill requirements can be markedly lessened due to the protection capacity of the structure. Additionally, beach restoration and seawalls may be effective at locations where isolated flooding and erosion damages are experienced due to dune/bluff erosion, but beach erosion is not significant. Such an option may be used to bolster dunes or bluffs with limited beachfill serving principally to restrict structure exposure to storm waves and as feeder material to longshore sediment transport.

It is uncertain at this juncture that features are economically justified for the entire study length. Project Reaches 1 and 2, for example, may not justify contiguous storm protection improvements, because development is sparse and existing conditions provide adequate protection along much of these reaches. In this regard, feature lengths and cost comparisons may be significantly altered from those in Table 5.14. Other features (i.e. beachfill and seawalls, groins, headlands or breakwaters) may be more cost-effective for smaller projects. Another consideration is that design procedures implemented herein do not explicitly reflect localized erosion hot spots or shoreline undulations. The area west of Shinnecock Inlet, for example, has experienced severe erosion during recent years, but accretion or lesser erosion may mask the significance of this erosion over the remainder of Physical Reach 3B. Further evaluation of localized problems is necessary prior to the final selection of features that may eventually comprise storm protection alternatives.

TABLE 5.12
POND DRAINAGE SUMMARY

Item	Georgica Pond	Mecox Bay	Sagaponack Lake
Outlets	2-20 inch diameter	6-60x60 inch	4-48x48 inch
Outlet Lengths	400 feet	400 feet	400 feet
Invert Elevation (Upstream)	1.5	1.5	1.5
Invert Elevation (Downstream)	0.0	0.0	0.0
Normal water surface elevation	4.5	4.0	4.5

TABLE 5.13
POND DRAINAGE COSTS

Water Body	Total Cost
Georgica Pond	$135,000
Mecox Bay	$1,338,000
Sagaponack Pond	$662,000
Total	$2,135,000

6. FEATURES SELECTION

6.1 Introduction

Site-specific conditions were evaluated to determine the needs, opportunities and constraints that influence storm damage reduction plan development. This evaluation was performed in order to determine those alternative features that will be considered in specific design reaches. While the study area exhibits generally similar physical characteristics, variation among study segments must be considered. Accordingly, matrices were developed to compare the needs, opportunities and constraints for different locations in the study area. Alternative storm protection features were then evaluated to identify potential measures. Finally, site conditions were evaluated relative to these potential storm protection features to select measures for detailed planning.

6.2 Screening Matrices

Table 6.1 summarizes storm damage problems in each reach with specific reference to tidal inundation, shoreline erosion, bluff/dune erosion, breach formation, overwash and wave attack. Existing topographic/shoreline information, and damage histories were used to identify those areas susceptible to future storm damages. Table 6.1 also summarizes each reach in terms of economic resources, including development density, damage history, existing coastal structures, and environmental/institutional constraints. These factors were weighed to determine the areas most likely to meet the planning criteria and constraints established for the Reformulation Study. The following ratings were used in the screening of applicable project features:

-	No factor
+	Significant factor
o	Minor factor

Criteria described below were considered in selection of storm damage protection measures.

Problems and Opportunities

- Inundation – threat of inundation in shoreline regions; barrier island reaches include mainland shoreline areas
- Shoreline Erosion – threat of long-term and storm-induced shoreline erosion
- Bluff/Dune Erosion – threat of bluff or dune erosion during normal conditions and/or storms
- Breach Formation – vulnerability of barrier island to breaching
- Overwash – vulnerability of shoreline areas overwash

- Wave Attack – threat of wave attack of shorefront structures

Economic Resources

- Damage History – severity of past coastal damages
- Barrier Island Development – density of barrier island development subject to future damage
- Mainland Development – density of mainland development subject to future damage, barrier island reaches account for mainland damages arising from barrier island inundation
- Coastal Structures – presence of coastal structures that indicate existing or past storm damage problems

Environmental Constraints

- Coastal Barrier Resource System (CBRS) – indicates whether reach falls within CBRS unit
- Significant Fish & Wildlife Habitats – presence of identified habitats within or adjacent to reaches

Institutional Constraints

- Coastal Barrier Resources Act (CBRA) – storm damage protection measures limited by CBRA
- New York State Coastal Zone Management Policies – feature compliance with policies
- Public Access – ease of providing public access/existing public access
- Fire Island National Seashore – relevant to reaches within the National Seashore
- Other – local regulation, wilderness designation, historical constraints

Table 6.2 summarizes the effectiveness of various storm protection features relative to damage mechanisms. This table also rates features in terms of cost, environmental and institutional criteria. Screening criteria used to evaluate the performance and implementability of various shore protection features are described below.

Feature Performance

- Inundation – effective in reducing inundation damages
- Shoreline Erosion – offsets or limits shoreline erosion
- Bluff/Dune Recession – offsets or limits bluff/dune erosion
- Breach Formation – reduces risk of breach formation
- Overwash – restricts overwash
- Wave Attack – limits wave attack of shorefront structures

Other

- Cost – relative cost with provision for technical uncertainty and/or complexity
- Environmental Acceptability – relative environmental impact and likelihood of feature acceptance
- Institutional Acceptability – institutional constraints on feature

The following ratings were applied to the performance and constraint criteria:

--	Significant negative impact or constraint
-	Negative impact or constraint
o	Minor impact or constraint
+	Positive impact or acceptability
++	Very positive impact or acceptability

Economic resources summarized in Table 6.1 were subjectively evaluated to determine whether storm protection features could possibly be economically justified. Parallel efforts are currently underway to better quantify the existing storm damage/benefit pool to consider the maximum threshold for project implementation. It is also noted that environmental and institutional acceptability ratings are relative to other features, and are subjective evaluations based on generally accepted practice.

6.3 Relative Cost Comparison

Cost comparisons considered the length/scale of protection required, anticipated complexity and significant technical constraints. Direct cost comparisons shown in Table 5.14 were considered, although judgement was applied in some cases to determine feature cost-effectiveness for localized problems. It is judged, for example, that localized improvements may be economically justified in Project Reach 1, rather than large-scale construction. Feature costs were then weighed based on past experience to select the features most applicable to these smaller areas.

6.4 Feature and Constraints Screening

Results of the storm damage reduction features screening are summarized in Table 6.3, which identifies features to be considered for more detailed development in each of the study area reaches (and subreaches). Design subreaches identified in Table 3.2 (and Figures 3.1 to 3.5) refer to areas that can be treated as: (1) economically justified or stand-alone projects or (2) subreaches characterized by isolated problems that are treatable by isolated solutions. Feature selection is described further in the following paragraphs.

6.4.1 Project Reach 1 – Montauk

Physical Reach 1A – Ditch Plains. Developed areas in this reach are located at Ditch Plains and Montauk Beach. Other areas in this reach are sparsely developed and are less subject to storm damage. Consequently, it is doubtful that storm damage reduction measures are required elsewhere, although bluff erosion may threaten individual or small groups of shorefront structures. Based on the localized nature of these problems, the most viable shorefront features are beach restoration, beach restoration and seawalls or beach restoration and groins. As previously noted, the effectiveness of beach restoration depends on project length. Therefore, the needs of isolated problem areas may require the use of coastal structures. Storm protection for the entire reach, on the other hand, could be provided by beach restoration alone. While non-structural floodproofing measures for the developed areas is the least costly feature (see Table 5.14), beach restoration may also be required to ensure erosion protection or non-structural actions may be more costly when compared to localized shorefront improvements. Non-structural measures may also be warranted in concert with shorefront improvements. The three selected shoreline features were beach restoration (Ditch Plains and Montauk Beach), beach restoration and seawalls (Ditch Plains and Montauk Beach) and beach restoration and groins (Ditch Plains and Montauk Beach). Non-structural measures, such as floodproofing or relocation, will also be further examined for developed areas, and non-structural land use management opportunities for currently undeveloped areas will be identified.

Physical Reach 1B – East Hampton Beach. Conditions in this reach are comparable to those described for Physical Reach 1A. Design subreaches were selected at Hither Hills State Park and East Hampton Beach, based on vulnerability of existing shoreline development and access routes. Isolated shorefront structures are also present throughout this reach, and are generally located seaward of the existing dune/bluff face. Features selected for further development in Physical Reach 1B are beach restoration (Hither Hills and East Hampton Beach), beach restoration and seawalls (East Hampton Beach), beach restoration and groins (East Hampton Beach), and non-structural measures, such as floodproofing and land use management.

Physical Reach 1C – Beach Hampton. The major developed area in this reach is the community of Beach Hampton. Other areas in this reach are generally undeveloped, although there are individual structures situated near the bluff face that may be vulnerable. Beach restoration (Beach Hampton), beach restoration and seawalls (Beach Hampton), beach restoration and groins (Beach Hampton), and non-structural measures were selected for further evaluation.

6.4.2 Project Reach 2 – Ponds

Physical Reach 2A – Georgica. Storm damages are mostly related to bluff/dune recession along the entire reach, whereas overwash and inundation is a problem in the Georgica Pond area. Bluff/dune erosion could be reduced through beach restoration. Beach restoration (with appropriate drainage structures) is applicable to Georgica Pond. Features selected for further evaluation include beach restoration (Physical Reach 2A, Apaquogue, Georgica Pond and Wainscott), beach restoration and seawalls (Georgica Pond), beach restoration and groins (Apaguogue, Georgica Pond and Wainscott), and non-structural measures.

Physical Reach 2B – Sagaponack. Conditions in Physical Reach 2B are comparable to Physical Reach 2A, both in terms of storm damage problems and development patterns. Storm damage reduction features selected for further analyses include beach restoration (Physical Reach 2B, Peters Lane, Sagaponack Lake and Surfside Drive), beach restoration and seawalls (Sagaponack Lake and Peters Lane), beach restoration and groins (Peters Lane, Sagaponack Lake and Surfside Drive), and non-structural measures for developed and undeveloped areas.

Physical Reach 2C – Mecox. This reach has nearly continuous shorefront development along the Atlantic Ocean characterized by individual homes just landward of the dunes/bluffs. Storm damage reduction features selected for further analyses include beach restoration for all of Physical Reach 2C and individual subreaches, beach restoration and seawalls (Mecox Bay and Dune Road), beach restoration and groins (Dune Road, Mecox Bay, Watermill Beach and Wickapogue), and non-structural measures.

6.4.3 Project Reach 3 - Shinnecock

Physical Reach 3A – Southampton. Mainland development along Shinnecock Bay is heavy, therefore the integrity of the protective capacity of the barrier island is critical. Breach formation along the barrier island is not anticipated in Physical Reach 3A. Consequently, Physical Reach 3A is primarily susceptible to dune erosion possibly leading to inundation and wave attack damages. The selected features for this reach were beach restoration (Physical Reach 3A, Agawam, Southampton and Southampton Beach), beach restoration and seawalls (Agawam), beach restoration and groins (Agawam and Southampton) and non-structural measures (either in concert or in lieu of shorefront improvements). The beach restoration and seawall feature at Agawam was selected, because this location is characterized by severe dune erosion that threatens oceanfront structures proximate to the existing dune. Levee and floodwalls were not selected in Project Reach 3 due to high costs associated with construction relative to non-structural costs. The continuance of the Breach Contingency Plan (USACE 1995b) will also be examined to determine if provisions for rapid response to breach formation are warranted.

Physical Reach 3B – Shinnecock Inlet. Conditions in this reach are highly variable due to the presence of Shinnecock Inlet. Development is sparse, but breaching and/or inundation of the barrier island or damages to the Shinnecock Fishing Cooperative located west of the inlet are a significant concern. The selected features for these areas were beach restoration (Physical Reach 3B, Shinnecock Inlet – East, Shinnecock Inlet – West and Ponquogue), beach restoration and groins (Shinnecock Inlet – West and Ponquogue), beach restoration and seawall (Shinnecock Inlet – West), non-structural measures and the Breach Contingency Plan. The area west of Shinnecock Inlet is particularly subject to storm damages and long-term erosion, thus the cost effectiveness of beach restoration may be examined in greater detail. Improvements or modifications of Shinnecock Inlet should also be considered, including inlet dredging and sand bypassing.

Physical Reach 3C – Tiana Beach. Mainland development in this reach is heavy and the barrier island is vulnerable to breach formation. Beach restoration for all of Physical Reach 3C was carried forward for further design analyses. Subreaches were identified to evaluate the need for beach restoration and groins due to varied shoreline erosion rates. The Breach Contingency Plan and non-structural measures were also selected for additional evaluation.

6.4.4 Project Reach 4 – Moriches

Physical Reach 4A – Westhampton. The Westhampton groin field dominates site conditions in this reach. Significant barrier island damages and/or breaching are not anticipated, assuming the continuance of renourishment operations. No subreaches were identified. Groin removal was not selected due to costs, institutional constraints, and possibly severe erosion in the area currently protected by the groins. As stated previously, groin removal may lead to severe erosion and a return to pre-groin conditions that were characterized by multiple breaches and overwashing. Consequently, groin removal does not meet the planning objective of reduced storm damages. Groin removal would also be more costly than other measures and would require local acceptance and support, which is unlikely given recent litigation decisions. Beach restoration, groin modification, non-structural measures and the Breach Contingency Plan were carried forward for further development. Groin modification will examine the impacts/functioning of the groin field as a result of the recent filling/tapering project, which would provide the basis for possible modification of the existing Interim Project. Mainland levees and floodwalls were eliminated in Project Reach 4 due to costs in providing regional storm protection, but may be considered in the event that residual storm damages are high, especially for localized protection.

Physical Reach 4B – Pikes. Site conditions in the area are dictated by the Interim Project, although the project life extends only for a period of only thirty years. Selected features include beach restoration, beach restoration and groins, non-structural measures and the Breach Contingency Plan. Each of these measures would be evaluated to determine whether modifications or abandonment of the Interim Project would be warranted. The beach restoration and groins feature would be examined to determine whether extending the Westhampton groin field would reduce renourishment requirements or provide a more effective long-term solution than the existing Interim Project.

Physical Reach 4C – Moriches. Subreaches identified in this reach were as follows: (1) Moriches Inlet – East (8,000 feet), (2) Moriches Inlet – West (6,000 feet) and (3) Great Gun (4,000 feet). Storm damages in this and adjoining low-lying areas along Moriches Bay would arise from barrier island breaching and/or inundation. Storm protection features selected for further evaluation in this reach are beach restoration, non-structural measures, inlet modifications, the Breach Contingency Plan and beach restoration and groins (Moriches Inlet – East and Moriches Inlet – West). The beach restoration and groins feature west of the inlet was selected based on experience at Shinnecock Inlet. The beach restoration and breakwaters feature was not selected due to higher costs relative to groins.

Physical Reach 4D – Smith Point County Park. The area along the barrier island is undeveloped with the exception of Smith Point County Park facilities at the extreme western end. Heavily developed areas on the mainland are present, including Mastic Beach. The reach contains several areas with narrow beach widths and low dunes, which are vulnerable to breaching. Smith Point – West contains park facilities that are currently exposed to inundation and wave attack. Features selected for further development in this reach include beach restoration, beach restoration and seawalls (Smith Point – West), the Breach Contingency Plan and non-structural measures. The beach restoration and seawall feature at Smith Point – West was selected to evaluate localized protection of park facilities absent of a larger-scale project.

6.4.5 Project Reach 5 – Fire Island.

Physical Reach 5A – Wilderness Area. Features selected for further evaluation in Physical Reach 5A include beach restoration, the continuance of the Breach Contingency Plan and non-structural measures. Mainland development leeward of this reach is heavy, and inundation damages arising from breaching or inundation of Old Inlet could be severe. Hence, rapid response to breach formation may be warranted. Local protection using mainland levees and floodwalls was eliminated in Project Reach 5 due to high costs and the need to identify the future bay and inlet hydrodynamic conditions. Local protection may, however, be considered in response to high residual storm damages along Great South Bay, even with beachfill or other barrier island features.

Physical Reach 5B – Cherry Grove. Barrier island breaching and/or inundation is a concern because mainland development leeward of Physical Reach 5B is heavy. Additionally, breaches are a concern due to the instability Fire Island Inlet. Barrier island damages are primarily limited to developed areas. The features selected for further evaluation in this reach include beach restoration, non-structural measures and the Breach Contingency Plan. As shoreline undulations may limit the success of beach restoration, a beach restoration and breakwater feature was selected for further evaluation in all subreaches. Beach restoration with seawalls or groins was not selected. Seawalls were eliminated based on costs associated with protecting a long shoreline area. Groins were not selected, because breakwaters may be better suited to shoreline undulation behavior that is similar to shoreline response to breakwaters that includes tombolo and salient features.

Physical Reach 5C – Atlantique. Barrier island structures in these areas are subject to inundation, wave attack and overwash damages. Additionally, this reach is susceptible to breaching/inundation, and mainland damages associated with breaching and/or inundation could be severe. Features chosen for Physical Reach 5C include beach restoration, beach restoration and breakwaters, non-structural measures and the Breach Contingency Plan.

Physical Reach 5D – US Coast Guard Station. Barrier island damages are limited to wave attack and inundation, however, barrier island breaching/inundation is possible. Beach restoration, non-structural and the Breach Contingency Plan will be evaluated for the entire reach. Furthermore, protection of Park facilities will be investigated by considering the beach restoration and seawall feature and non-structural measures (e.g. roadway relocation).

Physical Reach 5E – Robert Moses State Park. Conditions in this reach are comparable to Physical Reach 5D. Features selected for continued analysis include beach restoration, non-structural measures, and the Breach Contingency Plan for all of Physical Reach 5E, and beach restoration and seawalls along facilities in the State Park. Furthermore, modification of the navigation project at Fire Island Inlet will be examined.

6.5 Findings

Table 5.3 presents the findings of the features screening procedures. Continuous beach restoration for all of Project Reaches 1 and 2 is unlikely to be economically justified, as development and problem areas are isolated. The most cost-effective solutions in this area, based on the present analyses and past experience, are non-structural and localized beach restoration. Beach restoration with seawalls or groins were selected for more detailed evaluation, notably at localized problem areas in Project Reaches 1 and 2. Non-structural measures were selected for further evaluation at all locations, as stand-alone or companion features to shorefront improvements. Non-structural measures may also be implemented in Project Reaches 1 and 2 to avoid exacerbation of future storm damage problems.

Barrier islands in the study area are susceptible to breaching and/or inundation that could lead to inundation of heavily development mainland communities. Beach restoration is the most cost-effective, large-scale shore protection feature and will be subjected to detailed examination. Non-structural measures were selected for further evaluation, but generally have higher costs than beach restoration. Isolated problems areas along the barrier islands were identified. These areas generally consist of erosion hot-spots (e.g. west of Shinnecock Inlet, Tiana Beach, Hampton Beach, Pikes Beach and part of Fire Island) or areas where shorefront structures are vulnerable to direct wave attack and inundation (e.g. west of Shinnecock Inlet, Smith Point County Park, Fire Island and Robert Moses State Park). Structural features selected at these locations in concert with beach restoration include breakwaters, seawalls and groins. All areas along the barrier islands were also chosen for examination of the Breach Contingency Plan and non-structural measures.

Provision of sand bypassing at Fire Island, Moriches and Shinnecock Inlets was selected for further assessment. These actions would reduce the potentially adverse impacts of the inlets on the study area shorelines by ensuring interruptions of longshore sediment transport are minimized. Other inlet modifications will also be considered to provide less intrusive measures than storm tidal gates to reduce storm surge flow into the adjoining bays.

6.6 Continuing Analyses

The storm damage reduction solutions identified for specific sites will be developed in more detail to more thoroughly evaluate their cost effectiveness and acceptability. This will include formulation of preliminary designs and layouts at three different scales in order to allow for subsequent performance evaluation and economic optimization. The further development of alternatives is necessary to perform accurate site-specific assessment of alternative effectiveness and environmental impacts.

Structural plans will undergo further development for each identified reach at three design levels. For example, a beach fill cross section template might be designed with three different berm and dune dimensions with greater protection at the expense of higher cost. Prior to commencing with these designs, a basis of design report will be prepared. This report will set the criteria by which all subsequent designs will be prepared. The structural designs and layouts will be done to a level of detail required to judge effectiveness, impacts and costs. Design performance will be assessed using shoreline erosion and hydraulic modeling. After completion of the designs at three levels of protection, an assessment will be made as to their applicability and effectiveness and recommendations will be made for which structural alternatives (if any) will be considered in each area. Nonstructural plans for the study area will also undergo further development. One of these plans, a floodproofing plan has been discussed in this report. Additional plans to be developed include possible land use controls and relocation or buyout of threatened structures. Since the Corps of Engineers does not have land use authority, the plan development will also include implementation strategies.

Following preliminary design and performance modeling of individual plan features, any necessary adjustments or mitigation features will be incorporated into the plans. The benefits and costs of each plan will be evaluated. The plan providing the greatest net benefits in excess of cost will be designated the National Economic Development (NED) plan, which will be compared to the selected plan, if different from the NED plan. Following plan selection, the selected plan will be developed in more detail and the reformulation report and Draft Environmental Impact Statement (DEIS) will be prepared.

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