US Army Corps
of Engineers®
Philadelphia District

State of New Jersey
Department of Environmental Protection

Regional Sediment Management Plan for the New Jersey Coast

System Optimization Report

Tiered Recommendations to Reduce Costs, Sand Resource Requirements, and Environmental Impacts of the NJ Shore Protection Program

Prepared For:
US Army Corps of Engineers
NJ Alternative Long-Term Nourishment Study
Philadelphia District (CENAP-PL-PC)

Prepared By:
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Table of Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

Introduction

This System Optimization Report (SOR) was developed to support the New Jersey Alternative Long-Term Nourishment (NJALTN) Study. The NJALTN is intended to evaluate methods to manage New Jersey's coastal projects on a regional basis to ensure maximum benefits are achieved from the Federal investment. The primary purposes of the NJALTN Study are to:

- Reduce long-term periodic nourishment requirements and costs
- Reduce sand resource requirements
- Minimize environmental impacts

These objectives are consistent with the national objectives for regional sediment management (RSM). Given the breadth of Federal projects, long-term commitment, and significant Federal investment in the coast for navigation and shore protection, New Jersey represents an ideal location to identify and realize these types of long-term benefits. The local sponsor, New Jersey Department of Environmental Protection (NJDEP), along with other local municipal stakeholders, will also be afforded significant benefits as a result of this Study.

This SOR provides a single, reference for the extensive related work for a range of stakeholders and summarizes the extensive work conducted to date as part of the NJALTN Study to improve coastal management along the NJ coast. A graphical atlas of the New Jersey coastline is presented to provide background information, including: definition of coastline reaches and littoral cells; shoreline change trends; summary of historical studies; inventory of existing coastal structures and shore protection projects; and identification of important coastal processes shaping the New Jersey coastline.

The SOR summarizes existing information, utilizes the information to identify project alternatives, provides a first-order assessment of alternative feasibility, and develops recommendations. The recommendations are provided as (1) potential strategies of a general nature that involve system-wide approaches, and likely span multiple projects or benefit sediment management practices along the New Jersey coastline; (2) potential strategies for currently authorized shore protection projects; and (3) potential strategies for currently authorized navigational projects.

Given the sixteen (16) federally authorized shore protection and navigation projects for the NJ coast, there are numerous opportunities to enhance existing projects, combine projects, and refine elements to achieve Study objectives, namely cost reduction, limiting use of sand resources, and minimizing environmental impacts. Therefore, the strategies are presented as tiered recommendations, and categorized to fall under one of three tiers.

The Tiered recommendations are prioritized based on a number of criteria, including expected benefits, opportunity for cost savings, and ability to be implemented within existing USACE authorized activities. Specific recommendations also are offered to advance each alternative within the USACE procedures.

Tier 1 recommendations are achievable in the short-term within existing authorizations. It is expected that individual analyses (e.g., economic, cost justification) could be performed and documented in a Memorandum for Record (MFR) to provide justification for implementation. Following the justification, recommendations would be approved and implemented at a District level. Construction general funds could be used to conduct the analyses and implement (design and construct) the strategies. The majority of strategies identified in this System Optimization Report (SOR) are classified as Tier 1.

Tier 2 recommendations are achievable within existing authorities, but require either documentation (position paper or Value Engineering Study) or a decision document (Engineering Design Report [EDR] and Limited Reevaluation report [LRR]). Recommendations will be approved at the District level (EDR) or the Division level (LRR). Construction general funds could be used to conduct analyses and implement strategies.

Tier 3 recommendations require a new congressional authority (i.e., WRDA), or study (i.e., Chief's Report of General Reevaluation Report) to implement strategies. The existing December 17, 1987 authority for the New Jersey Shore Protection Authority can be used to perform feasibility analyses for selected strategies identified in the SOR. Recommendations will be approved at Headquarters and Congressional level.

Understanding the Coast

In order to provide the foundation for the recommended strategies and actions, the SOR provides a summary of the New Jersey coastal environment and shoreline. The New Jersey shoreline is a constantly changing feature as interactions between coastal processes and existing landforms shape and alter the coast. These ongoing natural changes are also influenced by anthropogenic features, such as shore protection structures, dredging, and beach nourishment. Ultimately, sediment transport, and various sources and sinks that supply and remove sediment from the system, are also critical for understanding sediment movement and defining strategies for improving sediment management. Therefore, the SOR provides this backdrop to support regional sediment management practices and to ensure that the objectives of the NJ Alternative Long-Term Nourishment Study are based on a thorough understanding of the coastal environment.

Based on the coastal geomorphology of New Jersey's Atlantic Ocean coastline, the shoreline is divided into eight distinct reaches. These divisions are established using tidal inlet location, shoreline orientation, physical characteristics, and land use. Utilizing these reaches, a graphical atlas of the New Jersey Atlantic Ocean coastline presents key features in a visual summary. These features include:

- Primary physical processes including waves, currents, tides, winds, storms, and sea-level rise
- Historical shoreline change and trends
- Anthropogenic history and features including coastal structures, beach nourishment, and dredging and borrow areas
- Sediment transport rates and directions, sinks and sources of sediment, and sediment types

Broad Regional Strategies

To advance RSM strategies for federally-authorized projects in New Jersey, there are certain strategies that should be applied to the coastline as a whole. These strategies involve system-wide approaches, and likely span multiple projects or benefit sediment management practices along the New Jersey coastline. Eight (8) broad regional strategies for RSM are presented in the SOR. Some of these broad regional strategies require upfront investment, and do not have a quantitative known cost advantage currently (e.g., system wide monitoring), but are expected to pay dividends in the future in the form of greater understanding of coastal processes and multiple uses of monitoring data that can advance an adaptive management approach to shoreline protection. Specifically, these broad regional strategies include:

1. ***Wave and Sediment Transport Modeling*** - Although substantial materials have been published related to coastal processes and beach nourishment performance along the New Jersey coastline, a gap exists in the knowledge of regional and site-specific coastal processes related to wave energy distribution and physics-based sediment transport rates. Coastal engineering project design should be optimized from a performance and cost perspective through rigorous analysis of the prevailing coastal processes. Understanding site-specific wave and sediment transport processes, coupled with historic beach change (and project performance) data would result in more efficient design of beach nourishment templates and coastal structure alternatives. In this regard, refined coastal processes modeling should be considered part of an overall adaptive management approach.

2. ***Regional Geomorphic Change Analysis*** - Historical shoreline and bathymetric data along the coastline provide important information on regional changes in geomorphology. Over time, the shoreline and nearshore areas evolve in response to a combination of natural coastal processes and anthropogenic activities. Analyses of historical shoreline and nearshore bathymetric change is a necessary component to understanding the complex cause and effect relationships that form the New Jersey coastline. This strategy would provide the technical basis and analytical data needed to develop regional sediment management recommendations that maximize the benefits of shore protection activities, while reducing costs and sand requirements.

3. ***Improved and "Living" Sediment Budget*** - Existing sediment budgets developed by the USACE provide the preliminary basis for establishing an updated, living sediment budget. However, there are unresolved components of the existing sediment budgets related to offshore losses and sea level rise, hotspot erosion, and at tidal inlets. There also are inconsistencies between the existing shoreline change data and the sediment budget information. With ongoing shoreline and bathymetric surveys used to compute volumes of shoreline change, quantities of sand removed by dredging projects, and beach nourishment quantities added to the system, information exists to update the sediment budget regularly incorporating the latest data and observational trends. The sediment budget should be refined routinely as new projects are implemented and new monitoring data collected; hence, providing a "living" sediment budget.

On a regional basis, the refined sediment budget will help quantify the overall net deficit of sand to be compensated through beach nourishment. On a localized scale, the refined sediment budget will help locate site-specific features (e.g., hotspots and nodal points), and account for inlet influences on adjacent beaches and the overall coastal system. The sediment budget should be integrated into a user-friendly database to help inform decisions relative to how much, how often, and where authorized shore protection projects would need renourishment.

4. ***Enhanced Monitoring Program*** - Substantial efforts have been devoted to collecting data along the New Jersey shoreline to document beach profile change and monitor beach nourishment project performance. This strategy recommends supplemental observations and improvements to the existing monitoring plan, including specific focus on enhanced data analysis and recording efforts.

5. ***Sediment Needs Versus Sediment Availability and Borrow Area Development*** - This broad regional strategy focuses on the overall available sand volumes needed to maintain the authorized project design templates compared to the available sand resources in identified sand borrow sites. Marine spatial planning strategies were implemented that consider the proximity of permitted borrow sites and navigation channels to the authorized beach nourishment projects. The analysis shows an overall surplus of sediment for the New Jersey beach nourishment program. However, there are local deficits where offshore sand resources are distant from the beaches in need of nourishment. An alternatives analysis shows expanded sediment requirements and identifies priority sand resources needed to supplement existing borrow sites. Specifically, Reach 1 (between Cape May Point and Cape May Inlet), Reach 2 (between Cape May Inlet and Townsends Inlet), and Reach 4 (between Great Egg Harbor Inlet and Absecon Inlet) have significant shortfalls of sediment.

6. ***Dredge Diversity Assessment*** - The New Jersey Shore Protection Projects provide opportunity for a diverse dredging fleet, including potential expansion of USACE dredge assets. For example, opportunities exist for dedicated backpassing and/or bypassing facilities (or mobile dredge), and perhaps for a hopper dredge with pump out capabilities. This strategy evaluated the existing USACE dredge fleet and determined that the need to move sand from inlets to the beach and also to move sand updrift along a beach in backpassing operations indicates demand for a portable dredging system. Such a system might be deployable from either land or water to move sand from inlets to adjacent beaches and for backpassing operations.

7. ***Environmental Demonstration Studies*** - There are environmental resources, including fisheries, surf clams, benthic invertebrate community, and nesting shore birds, influencing implementation of shore protection projects. As such, the New Jersey shore protection projects may benefit from a better understanding of environmental impacts. Targeted environmental studies at key location(s) to evaluate

potential impacts would provide a means to implement trial pilot project(s). Well conceived environmental investigations also would provide insight on how to minimize potential environmental impacts at other locations; thus, facilitating environmental approvals at other site(s). Approaches considered included assessment of expanded dredging for beach nourishment and impacts of structures for erosional hotspot protection.

8. ***Breach Contingency Plan*** - A breach contingency plan is recommended at four (4) areas: North Beach/Harvey Cedars on Long Beach Island; Island Beach State Park; Strathmere (Whale Beach); and Lower Cape May Meadows. These areas experience severe erosion conditions prompting shore protection measures including beach nourishment to reduce imminent threat of storm damage. Developing breach contingency plans will facilitate rapid response to barrier island breaches. Rapid breach closure by using a breach contingency plan is in the Federal interest and more cost-effective when the time and volume of material needed to remedy the breach are reduced.

   A Breach Contingency Plan would be developed to streamline the contracting and construction activities and serve as the decision tool providing documentation and authority for future breach closures.

The recommended specific action, priority, and Tier level within the existing project authorization framework are analyzed for each of the eight (8) broad regional strategies.

Site Specific Strategies

Similar to the broad regional strategies, potential actions and strategies for optimizing the authorized shore protection projects and navigational projects along the Atlantic Ocean coastline of New Jersey were determined. This includes project specific actions that are presented on an authorized project by authorized project basis.

Each authorized project includes a general description, project history, summary of problems encountered during the project history, and a wide range of potential strategies considered for potential design, construction and/or implementation. Specifics of each potential strategy are presented to adequately describe the proposed action in context of the overall, regional processes, the existing authorization, and the history of projects and project performance at the site. Additionally, when feasible for each strategy, a first-order technical analysis is presented to evaluate the relative merit of each potential strategy/action as measured against following criteria:

- Authorization limitations
- Constraints
- Potential cost savings
- Service life
- Other benefits
- Tier level
- Prioritization
- Next steps

A wide range of strategies are considered and evaluated, including, but not limited to, nourishment cycle synchronization, nourishment prioritization, beneficial re-use of inlet material, borrow area expansion, inlet sediment bypassing, sediment backpassing, various structural modifications, improvements and additions, and refined beach nourishment templates. Details on strategies, that cover the entire New Jersey Atlantic Ocean shoreline, are presented in the tabbed sections for each authorized project.

Recommendations and Next Steps

Based on the evaluation and analyses of the various site specific and broad regional strategies presented throughout this report, an overarching strategy implementation framework was developed, as presented in Figure ES-1. This framework categorizes individual strategies to create high priority *programmatic* strategies that span multiple projects. Programmatic strategies are divided by Tier level and associated justification documentation. The highest site-specific applications are underlined in the flowchart. The programmatic strategies include:

- Sediment Backpassing – This set of strategies involves extracting sediment from a portion of the shoreline that is accreting and moving the material to an updrift location that is more erosional. This methodology, called sediment backpassing, is intended to work with the natural littoral drift within a system by recycling sand back updrift to the location where it had initially resided. Sediment backpassing was identified as a high priority strategy at Avalon, Brigantine, Ocean City, and Wildwood. This is a tier 2 strategy that would require a value engineering (VE) study prior to implementation.
- Inlet Sediment Bypassing – This set of strategies involves implementation of sediment bypassing methodology to move sediment from the northerly updrift beaches and jetty fillet region of an inlet to nourish beaches downdrift of the inlet. Sediment bypassing was identified as a high priority strategy at Cape May Inlet, Absecon Inlet, Barnegat Inlet, Manasquan Inlet, and Shark River Inlet. This is a tier 2 strategy that would require an Engineering Design Report (EDR) and Limited Reevaluation Report (LRR) prior to implementation.
- Nourishment cycle synchronization – This set of strategies involves synchronization of the project cycles in close proximity to one another. The intent is to reduce mobilization and demobilization costs by combining re-nourishments. This strategy was determined to be a high priority strategy at Cape May City and Lower Cape May Meadows, Avalon and Sea Isle City, and Absecon Island and Brigantine Island. Other areas may also be considered in the future. This is a tier 1 strategy that would require a brief Memorandum for Record (MFR) prior to implementation.
- Inlet Beneficial re-use and borrow area expansion – These strategies involve improved management of sediment sinks in inlets for shore protection. In cases that involve a federally authorized navigational project this involves consistent beneficial re-use of beach compatible dredge material. In cases that involve inlets that do not have a federally authorized navigational channel, this involves borrow area expansion or creation in the inlet. These strategies were identified as high priority for all the inlets along the New Jersey coastline. Depending on the inlet, these strategies consist of tier 1 and 2 levels and would require either a Memorandum for Record (MFR) or an Engineering Design Report (EDR) prior to implementation.

- Nourishment prioritization - This strategy intends to prioritize projects to focus on the most vulnerable developed areas. Due to the large scale of these specific nourishment projects, it is expected that funding for the full authorized projects, as well as the subsequent periodic nourishments may be difficult to consistently acquire. Therefore, this strategy includes prioritizing nourishment efforts to vulnerable developed areas that have shown the highest erosion rates. Completing these smaller priority based nourishments may be more manageable from both an operation and fiscal basis. As such, rather than wait for adequate funding to become available for the entire authorized project, critical erosional areas could be addressed more readily as funding becomes available. This strategy was identified as a high priority at Long Beach Island, Island Beach, Sea Bright to Manasquan, and Cape May. This is a tier 1 strategy that would require a brief Memorandum for Record (MFR) prior to implementation.

- Structural Improvements – This set of strategies involves coastal structure (either hard engineering or soft engineering) construction, adjustment, or modification to improve sediment management. There are a number of site-specific strategies that are detailed throughout the report, and include sites at Lower Cape May Meadows, Cape May City, Wildwood, Absecon Island, Ocean City, Brigantine Island, Shark River Inlet, Avalon and Stone Harbor, and Ludlam Island and Peck Beach. The strategies vary from additional groin construction, groin modification, inlet thalweg relocation, bio-engineered solutions, bulkhead improvements, etc. These strategies are all tier 3, meaning that they would require a new congressional authority (i.e., WRDA), or study (i.e., Chief's Report of General Reevaluation Report) to implement.

Figure ES-1 also presents the highest priority broad regional strategies recommended for implementation. This includes:

- Borrow Area Development – This implementation framework item is developed from the sediment needs versus sediment availability assessment. The regional analysis identified key areas of sediment shortage along the shoreline to meet the required nourishment needs. As such, continued borrow area development is needed in offshore waters. This is a tier 1 strategy that would require a brief Memorandum for Record (MFR) prior to implementation.

- Dredge Diversity Assessment - This strategy recommends expansion and diversification of the USACE dredge equipment and assets. Specifically, this involves the utilization or acquisition of a mobile dredging system deployable either by land for sediment backpassing of by water on a barge for sediment bypassing. This is a tier 1 strategy that would require a brief Memorandum for Record (MFR) prior to implementation.

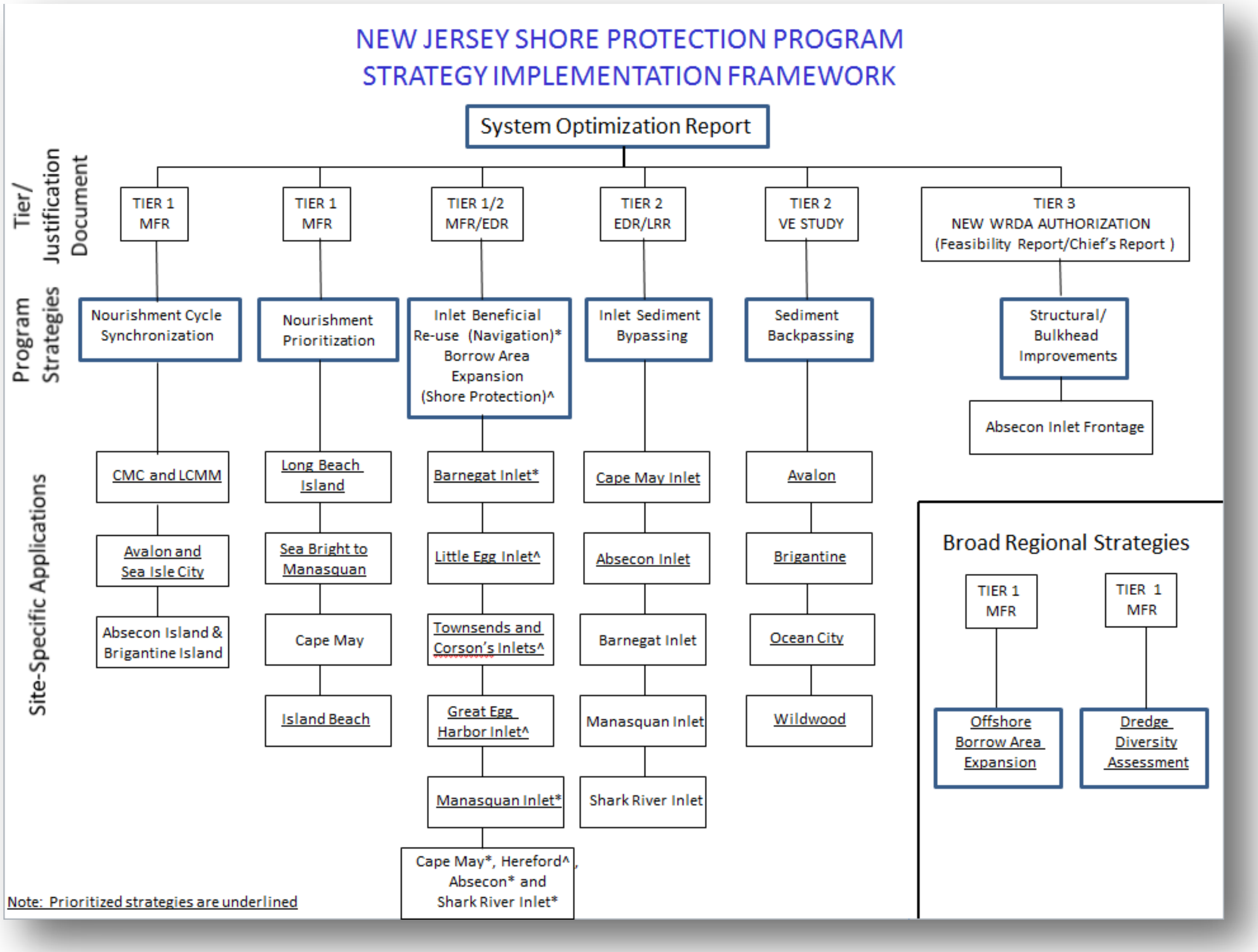


Figure ES-1. Summary of Strategy Implementation Framework.

While the overall program strategies are presented in the Strategy Implementation Framework (Figure ES-1), Table ES-1 provides details on the prioritized strategies for implementation. This table provides details on the highest priority strategies, specific to existing shore protection projects, recommended for implementation. Table ES-1 includes the specific strategy, tier level, a description of the strategy, the USACE business line, the recommended implementation action, and the required justification documentation

The implementation action column in Table ES-1 provides the estimated pathway for potential implementation, or next steps. The first step in nearly all strategies would be the identification of available funds to support the effort. For some strategies, it is expected that Hurricane Sandy supplemental funds may be available to expedite analysis towards obtain construction authorization. Specifically, this includes authorization for projects at Wildwood, Ludlam Island and Peck Beach, and Island Beach.

Table ES-1. Highest Priority Project-Specific Recommendations (Highest Priority Projects denoted with arrow)

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Lower Cape May Meadows/Cape May City, and Cape May Inlet						
►	Project (Cycle) Synchronization	1	Combine periodic nourishment efforts of authorized shore protection projects at Lower Cape May Meadows (4 yrs) and Cape May City (2 yrs) to reduce mobe/demobe costs. Extension of the LCMM nourishment cycle from 2- to 4-years would require a new authorization.	Shore Protection	Evaluate potential storm damage impacts, ensure Federal funding stream, coordinate dredging, and implement.	MFR - NAP
	Beneficial Re-use at Cape May Inlet (and discontinue sidecasting)	1	Enhance current beneficial use practices by placing dredged material on/near the beaches south of Cape May Inlet.	Navigation	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, and implement.	MFR - NAP
►	Sediment Bypassing at Cape May Inlet	2	Develop a semi-mobile bypass or floating dredge plant system to bypass sediment from north to south across Cape May Inlet.	Shore Protection	Conduct more detailed analysis of potential impacts caused by fillet extraction. Finalize and design project in an MFR. Use existing construction authorization.	VE Study
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP
	Nourishment Prioritization/Feeder Beach	1	Focus nourishments including feeder beach/overfill at highly-eroded areas of Coast Guard Beach to allow sediment to naturally migrate to southwest.	Shore Protection	Conduct detailed beach nourishment dispersion analysis, conduct engineering cost and benefits analysis, implement more detailed monitoring program and data analysis.	MFR - NAP

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Avalon/Stone Harbor						
►	Sediment Backpassing	2	Move sand from an accreting shoreline (southern Avalon) to an eroding shoreline within the project (northern Avalon).	Shore Protection	Assess potential storm damage and environmental impacts, obtain required permits, and coordinate dredging prior to implementation.	VE Study
	Offshore Borrow Site Expansion/Increased Dredging of Townsends and Hereford Inlets	1/2	Expand current or establish new offshore (Tier 1) and inlet (Tier 2) borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP/ EDR
Ludlam Island and Peck Beach (Great Egg Harbor Inlet to Townsends Inlet)						
►	Project (Cycle) Synchronization (with Avalon/Stone Harbor)	1	Combine periodic nourishment efforts of authorized shore protection projects at Avalon/Stone Harbor (construction phase; 3 yr cycle) with Ludlam Island (PED phase; 5 yr cycle) to reduce mobe/demobe costs; Extension of the Ludlam Island nourishment cycle from 5 to 6 years would require a new authorization.	Shore Protection	Evaluate potential storm damage impacts, ensure Federal funding stream, coordinate dredging, and implement.	MFR - NAP
	Borrow Area Expansion at Townsends and Corson's Inlets	2	Beneficially reuse sediment dredged from Townsends and Corson's Inlets for periodic nourishments on Ludlam Island (Townsends Inlet not a current authorized borrow area for the GEHI to Townsends Inlet).	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Obtain permits.	EDR

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Ocean City (Great Egg Harbor and Peck Beach)						
►	Borrow Area Expansion at Great Egg Harbor Inlet	2	Expand current Great Egg Harbor Inlet borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Obtain permits.	EDR
	Project (Cycle) Synchronization (with Peck Beach)	1	Combine periodic nourishment efforts of authorized shore protection projects at Great Egg Harbor and Peck Beach (construction phase; 3 yr cycle) with the Peck Beach component of the GEHI to Townsends Inlet (PED phase; 3 yr cycle) project. Formally aligning the Federal authorizations of these projects would require a new authorization.	Shore Protection	Conduct feasibility and PED analyses (LRR); obtain construction authorization.	MFR - NAP
	Nourishment Prioritization/Adaptive Management	1	Focus nourishments including feeder beach/overfill at highly-eroded areas of Ocean City (north of 20th Street) to allow sediment to naturally migrate to south.	Shore Protection	Conduct detailed beach nourishment dispersion analysis, engineering cost and benefits analysis, and implement more detailed monitoring program and data analysis.	MFR - NAP
►	Sediment Backpassing	2	Move sand from an accreting shoreline (central Ocean City) to an eroding shoreline within the project (northern Ocean City).	Shore Protection	Assess potential storm damage and environmental impacts, obtain required permits, and coordinate dredging prior to implementation.	VE Study
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Absecon Island and Absecon Inlet						
	Project (Cycle) Synchronization (with Brigantine Island)	1	Combine periodic nourishment efforts of authorized shore protection projects at Absecon Island (3 yr cycle) and Brigantine Island (6 yr cycle) to reduce mobe/demobe costs. Extension of the Absecon Island project from a 3 to 6 yr cycle would require a new authorization.	Shore Protection	Evaluate potential storm damage impacts, ensure Federal funding stream, coordinate dredging, and implement.	MFR - NAP
	Beneficial Re-use at Absecon Inlet	1	Beneficially reuse sediment dredged from Absecon Inlet on Absecon Island on a regular basis.	Navigation	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, implement.	MFR - NAP
►	Sediment Bypassing at Absecon Inlet	2	Develop a semi-mobile bypass system to bypass sediment from Brigantine Island to Absecon Island across Absecon Inlet.	Shore Protection	Conduct more detailed analysis of potential impacts caused by fillet extraction. Finalize and design project in an LRR. Identify construction authorization.	LRR
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP
	Bulkhead improvements and expansion along Absecon Inlet frontage	3	Raising or lengthening the Absecon Inlet southern jetty; addition of low-profile or T-Head groins at Atlantic City; improvements along Atlantic City Absecon Inlet frontage.	Navigation	Re-analysis required; identify permitting requirements and non-Federal sponsor with the requisite cost sharing; obtain new project construction authorization	New WRDA Authorization
►	Borrow Area Expansion/ebb shoal dredging at Absecon Inlet	2	Dredge channel to south of existing bootleg at Absecon ebb shoal locations which have high infilling rates.	Navigation	Evaluate hydrographic surveys to assess optimal channel; evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, implement.	EDR

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Brigantine Island						
►	Sediment Backpassing	2	Moving sand from an accreting shoreline (central Brigantine) to an eroding shoreline within a nourishment area (northern Brigantine).	Shore Protection	Assess potential storm damage and environmental impacts, obtain required permits, and coordinate dredging prior to implementation.	VE Study
Long Beach Island and Barnegat Inlet						
	Beneficial Re-use at Barnegat Inlet	1	Expand current Barnegat Inlet dredging to include flood shoals; enhance current beneficial use practices by placing dredged material on/near the beaches south of Barnegat Inlet.	Navigation, Shore Protection	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, implement.	MFR - NAP
	Borrow Area Expansion at Little Egg Inlet	2	Beneficially reuse sediment dredged from Little Egg Inlet to expand nearshore borrow areas in the vicinity of Long Beach Island (Little Egg Inlet not a current authorized borrow area for the Long Beach Island Shore Protection Project).	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Obtain permits.	EDR
	Sediment Bypassing at Barnegat Inlet	2	Develop a semi-mobile bypass or floating dredge plant system to bypass sediment from north to south across the inlet, or from the fillet south of the inlet to Long Beach Island beaches.	Shore Protection	Conduct more detailed analysis of potential impacts caused by inlet shoal extraction. Finalize and design project in an LRR. Identify construction authorization.	LRR
	Nourishment Prioritization	1	Prioritize nourishment efforts to vulnerable developed areas with significant erosion; Potentially evaluating functionality and improvements to new groins to prolong life of proposed strategic nourishments in certain areas.	Shore Protection	Obtain real estate easement agreements from holdout communities, conduct detailed beach nourishment dispersion analysis, conduct engineering cost and benefits analysis, and implement more detailed monitoring program and data analysis. Additional study needed for potential improvements associated with new strategic structure(s).	MFR-NAP

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP
Island Beach (Manasquan to Barnegat) and Manasquan Inlet						
	Nourishment Prioritization	1	Prioritizing nourishment efforts to vulnerable developed areas with significant erosion.	Shore Protection	Obtain real estate easement agreements from holdout communities, conduct detailed beach nourishment dispersion analysis, conduct engineering cost and benefits analysis, and implement more detailed monitoring program and data analysis.	MFR-NAP
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Sea Bright to Manasquan and Shark River Inlet						
▶	Sediment Bypassing at Manasquan Inlet	2	Develop a semi-mobile bypass or floating dredge plant system to bypass sediment from south to north across the inlet.	Shore Protection	Coordinate with CENAN since Sea Bright to Manasquan shore protection project is under CENAN jurisdiction. Conduct more detailed analysis of potential impacts caused by inlet shoal extraction. Finalize and design project in an LRR. Identify construction authorization.	LRR
	Beneficial Re-use at Manasquan Inlet (Modify placement location)	1	Enhance current beneficial use practices by placing dredged material on/near the beaches at an alternate location farther north of Manasquan Inlet.	Navigation	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, and implement.	MFR - NAN
	Beneficial Re-use at Shark River Inlet	1	Expand current Shark River Inlet dredging to include ebb shoal complex; Enhance current beneficial use practices by placing dredged material on/near the beaches rather than in the form of a nearshore berm.	Navigation	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, and implement	MFR - NAN
	Nourishment Prioritization	1	Prioritize nourishment efforts to vulnerable developed areas with significant erosion.	Shore Protection	Conduct detailed beach nourishment dispersion analysis, conduct engineering cost and benefits analysis, implement more detailed monitoring program and data analysis	MFR - NAN
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAN

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Wildwood						
	Project (Cycle) Synchronization (with Stone Harbor)	1	Combine periodic nourishment efforts of authorized shore protection projects at Wildwood (feasibility phase) with Stone Harbor (construction phase; 3 yr cycle) to reduce mobe/demobe costs.	Shore Protection	Evaluate potential storm damage impacts, ensure Federal funding stream, coordinate dredging, and implement.	MFR - NAP
	Increased Dredging of Hereford Inlet	2	Identify and expand inlet-based borrow areas at Hereford Inlet.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Obtain permits.	MFR - NAP
►	Sediment Backpassing	1	Move sand from an accreting shoreline (Wildwood) to an eroding shoreline within the project (North Wildwood).	Shore Protection	Assess potential storm damage and environmental impacts, obtain required permits, and coordinate dredging prior to implementation.	Component of potential authorized plan

Some examples of site-specific strategy implementation are provided in the recommendations and implementation section of the report. This includes sediment bypassing at Cape May Inlet, project cycle synchronization at Cape May City and Lower Cape May Meadows, and sand backpassing at Brigantine Island.

Another critical step in the project implementation pathway will be the stakeholder engagement. Early in the strategy implementation process, the USACE should strive to reach out to local communities and the New Jersey Department of Environmental Protection (NJDEP) to ensure that the proposed strategy is acceptable.

INTRODUCTION

Approach and Goals

The System Optimization Report supports the New Jersey Alternative Long-Term Nourishment (NJALTN) Study, intended to evaluate methods to manage New Jersey's coastal projects on a regional basis to ensure maximum benefits are achieved from the Federal investment. The primary purposes of the NJALTN Study are to:

- Reduce long-term periodic nourishment requirements and costs
- Reduce sand resource requirements
- Minimize environmental impacts

These objectives are consistent with the national objectives for regional sediment management (RSM). Given the breadth of Federal projects, long-term commitment, and significant Federal investment in the coast for navigation and shore protection, New Jersey represents an ideal location to identify and realize these types of long-term benefits. The local sponsor, New Jersey Department of Environmental Protection (NJDEP), also will be afforded significant benefits as a result of this Study, along with other local municipal stakeholders.

Tiered Recommendations

A key element of this System Optimization Report is to identify and prioritize specific projects, project enhancements, and studies that can be implemented to achieve the objectives of the NJALTN Study. These actions are presented as tiered recommendations. Given the sixteen (16) federally authorized shore protection and navigation projects for the NJ coast, there are numerous opportunities to enhance existing projects, combine projects, and refine elements to achieve Study objectives, namely cost reduction, limiting use of sand resources, and minimizing environmental impacts. The System Optimization Report identifies and evaluates benefits and limitations for a full range of alternatives, and offers Tiered Recommendations.

The Tiered Recommendations are prioritized based on a number of criteria, including expected benefits, opportunity for cost savings, and ability to be implemented within existing USACE authorized activities. Specific recommendations also are offered to advance each alternative within the USACE procedures.

Tier 1 recommendations are achievable in the short-term within existing authorizations. It is expected that individual analyses (e.g., economic, cost justification) could be performed and documented in a Memorandum for Record (MFR) to provide justification for implementation. Following the justification, recommendations would be approved and implemented at a District level. Construction general funds could be used to conduct the analyses and implement (design and construct) the strategies. The majority of strategies identified in this System Optimization Report (SOR) are classified as Tier 1.

Tier 2 recommendations are achievable within existing authorities, but require either documentation (position paper or Value Engineering Study) or a decision document (Engineering Design Report [EDR] and Limited Reevaluation report [LRR]). Recommendations will be approved at the District level (EDR) or the Division level (LRR). Construction general funds could be used to conduct analyses and implement strategies.

Tier 3 recommendations require a new congressional authority (i.e., WRDA), or study (i.e., Chief's Report of General Reevaluation Report) to implement strategies. The existing December 17, 1987 authority for the New Jersey Shore Protection Authority can be used to perform feasibility analyses for selected strategies identified in the SOR. Recommendations will be approved at Headquarters and Congressional level.

The System Optimization Report includes suggestions for supplemental technical work (e.g., localized sediment budget enhancements, modeling, or data collection) to produce technical information to further advance the Study objectives.

The objective is to summarize existing information, utilize the information to identify project alternatives, evaluate the high-level feasibility of alternatives, and develop tiered recommendations for implementation. Since there are multiple and varied recommendations, it is not possible for one report to fully design and permit the activities. A key element of this System Optimization Report is to define tiered recommendations for project alternatives that require supplemental Feasibility Study documentation, as well as the alternatives that do not require such documentation (i.e., that can be implemented within existing authorized projects). The intended audience for the System Optimization Report extends beyond USACE decision-makers, and includes NJDEP staff, elected officials representing the State of NJ and participating Municipalities, as well as the general public.

Single Source

Abundant data have been collected and analysis has been performed as part of the overall NJALTN Study. One purpose of this System Optimization Report is to consolidate existing information for decision-makers. Consolidation of prior and existing work in a format that can be leveraged by decision-makers will help document and advance the overall study objectives. Given the tremendous combined value of prior extensive work, one fundamental purpose of the System Optimization Report is to summarize and document this existing information. This System Optimization Report provides a single, reference for the extensive related work for a range of stakeholders. This readership may not be afforded the opportunity to review the individual work products and studies, but will understand the overall results, purpose and opportunities via this System Optimization Report. The System Optimization Report will, therefore, help advance the overall consistency and expedite implementation of projects and project refinements to advance the overall Study objectives.

The document also provides shoreline reaches within which management decisions can be made. This format is intended to be helpful to local managers and stakeholders interested in understanding a portion of the shoreline, pertinent existing studies, relevant components of the NJ Shore Protection Program, and site-specific recommendations.

Report Structure

The overall organization of the NJALTN Study System Optimization Report document includes seven (7) chapters:

- **Introduction** - Defines the purpose and goals of the NJALTN Study System Optimization Report.
- **Understanding the Coast** – Provides background information on the Atlantic Ocean coastline of New Jersey, including: definition of coastline reaches and littoral cells; shoreline change trends; summary of historical studies; inventory of existing coastal structures and shore protection projects; identification of important coastal processes shaping the New Jersey coastline; and remaining gaps in knowledge that may be filled to improve overall sediment management and NJALTN Study objectives. Chapter 2 includes an understandable graphical atlas of the New Jersey coastline for the diverse audience. Understanding the Coast serves as a single reference for the extensive work conducted to date as part of the NJALTN Study to improve coastal management along the NJ coast.
- **RSM Overview** – Defines the RSM program, how it relates to New Jersey specifically, and the tiered approach applied throughout the document. RSM Overview also explains the criteria and methodology applied to the cost savings actions and strategies.
- **Broad Regional Strategies** – Presents cross-cutting strategies to improve sediment management for the New Jersey coastline. Recommended potential actions represent strategies of general nature, involve system-wide approaches, and likely span multiple projects or benefit sediment management practices along the New Jersey coastline.
- **Site Specific Strategies for Authorized Shore Protection Projects** – Presents the currently authorized Shore Protection Projects along the New Jersey coastline. Each project alternative is summarized, along with objectives and recommendations for cost effectively managing the project through various sediment management techniques and technical approaches. The proposed actions and/or strategies are presented in tiers for each project. Each tiered recommendation includes potential opportunities and constraints, cost implications on a short- and long-term basis, funding and authorization alternatives, and additional expected tasks needed to implement the recommended action. Each recommendation is categorized into a specific tier, defined as:
  - Tier 1 – Tier 1 recommendations are achievable in the short-term within existing authorizations. It is expected that individual analyses (e.g., economic, cost justification) could be performed and documented in a Memorandum for Record (MFR) to provide justification for implementation. Following the justification, recommendations would be approved and implemented at a District level. Construction general funds could be used to conduct the analyses and implement (design and construct) the strategies. The majority of strategies identified

in this System Optimization Report (SOR) are classified as Tier 1.

  - Tier 2 recommendations are achievable within existing authorities, but require either documentation (position paper or Value Engineering Study) or a decision document (Engineering Design Report [EDR] and Limited Reevaluation report [LRR]). Recommendations will be approved at the District level (EDR) or the Division level (LRR). Construction general funds could be used to conduct analyses and implement strategies.
  - Tier 3 recommendations require a new congressional authority (i.e., WRDA), or study (i.e., Chief's Report of General Reevaluation Report) to implement strategies. The existing December 17, 1987 authority for the New Jersey Shore Protection Authority can be used to perform feasibility analyses for selected strategies identified in the SOR. Recommendations will be approved at Headquarters and Congressional level.

- **Site Specific Strategies for Authorized Navigation Projects** – Presents the currently authorized navigation projects along the Atlantic Ocean coastline of New Jersey. This chapter integrates potential strategies and actions for the navigational projects as a component of the larger sediment management approach.
- **Conclusions and Recommendations** – Summarizes the System Optimization Report and provides targeted actions and cost-saving strategies on a project-by-project basis. Potential cost-savings strategies are offered on a regional basis, including improvements to individual projects. Tiered recommendations are summarized, as defined above.

This System Optimization Report offers an action plan. Specific measures are detailed along with recommended authorities, under which they can be implemented, including the need for new authorizations as appropriate. Where possible, use of existing authorities is encouraged (e.g., project-specific continuing construction authorities) to advance the tiered recommendations.

Future Feasibility Study

This System Optimization Report is not intended to fulfill requirements of a standard USACE Feasibility Study to advance a specific project action. Appendix G (G-9) of US Army Corps of Engineers report ER 1105-2-100 defines the requirements for a Feasibility Study. Requirements are specific and extensive, and include a discussion of future without project conditions, a full evaluation of alternatives (including cost-benefit analysis, NEPA documentation, etc.), a recommended alternative/selected plan (including engineering design and summaries of economic, environmental, and social benefits), and full public involvement. Recommendations from this report will undergo traditional USACE feasibility study analyses as presented in the ER-1105-2-100 Planning Guidance Notebook, and will be presented in a traditional feasibility report format.

This System Optimization Report is the primary deliverable resulting from a contract between USACE Philadelphia and the Woods Hole Group.

UNDERSTANDING THE COAST

Regional sediment management practices that meet the objectives of the NJ Alternative Long-Term Nourishment Study must be based on a thorough understanding of the coastal environment. This includes the coastal processes, coastal landforms, sediment sources and sinks, as well as sediment transport patterns. Interactions between coastal processes and existing landforms shape and alter the shoreline into a constantly changing feature. Other factors influencing evolution of the shoreline are man induced changes such as shore protection structures, dredging, and beach nourishment. The types of sediment available for transport are important, as are the directions of transport and various sources and sinks that supply and remove sediment from the system. Patterns of shoreline change observed over short- and long-term time scales are a reflection of these complex interactions. This chapter provides a general discussion of the various factors acting to shape the NJ coastline as the basis for recommendations to improve regional sediment management.

Coastal Geomorphology

The Atlantic Ocean shoreline of New Jersey extends 127 miles from the northern tip of Sandy Hook at the entrance to Raritan Bay south to Cape May Point at the entrance to Delaware Bay. The shoreline forms the eastern boundary of the Coastal Plain physiographic province of New Jersey; the largest of the four provinces in the state. Sediments of the Coastal Plain are made up of unconsolidated sands, silts, and clays deposited in marine and terrestrial environments over the past 125 million years. Sediments dip towards the coast and extend beneath the Atlantic Ocean to the edge of the continental shelf. The topography of the Coastal Plain is relatively flat with a few hills of erosion-resistant sediment containing gravel or iron-sedimented sands (NJ Geological Survey, 1999). Waves and currents at the sea-land interface erode sediments from the Coastal Plain and redeposit them into shoals, beaches, and spits. These modern day features that comprise the New Jersey shoreline evolve in response to coastal processes.

The coastline includes the easternmost portions of Monmouth, Ocean, Atlantic, and Cape May counties. Shoreline areas in Monmouth County at the northern end of the coast are under jurisdiction of the US Army Corps of Engineers – New York District. The Philadelphia District has jurisdiction over the shoreline areas in Ocean, Atlantic, and Cape May counties (Figure 1). There are eleven tidal inlets along the 127 mile stretch of coastline. For the purposes of this overview, the shoreline has been divided into eight distinct reaches based on tidal inlet location, shoreline orientation, physical characteristics, and land use. A brief description of the shoreline reaches, north and south boundaries, and general characteristics is provided below.

Figure 1. Regional overview of NJ coastline showing study reaches and physiographic provinces.

- **Reach 1: Cape May Point to Cape May Inlet:** Reach 1 is located at the southern tip of New Jersey adjacent to the entrance to Delaware Bay. The shoreline is generally oriented in an E-W direction, except for the area closest to Cape May Inlet which trends more NE. Reach 1 is approximately 6 miles long from Cape May Point to the southwest jetty of Cape May Inlet, adjacent to the U.S. Coast Guard Reservation. The communities of Cape May Point, Lower Township, and the City of Cape May are included in this Reach. The shoreline is comprised of mainland beaches and coastal dunes backed by low-lying marsh or developed upland areas.

- **Reach 2: Cape May Inlet to Townsends Inlet:** Reach 2 extends approximately 15 miles from Cape May Inlet to Townsends Inlet. The area includes two barrier islands separated by Hereford Inlet. The barrier island to the south, known as Five Mile Beach, contains the communities of Lower Township (Diamond Beach), Wildwood Crest, Wildwood, and North Wildwood. Seven Mile Island is the barrier north of Hereford Inlet, including Stone Harbor and Avalon. Five Mile Island is oriented in a NE-SW direction, while Seven Mile Island is oriented NNE-SSW. Reach 2 exhibits the characteristics of a mixed energy system with short drumstick-shaped barrier islands and well-developed ebb tidal deltas. The term mixed-energy indicates that waves and tidal currents are important factors influencing the morphology of the coastal system. The shoreline is comprised of narrow sandy beaches backed in some places with man-made or natural dunes. Backbarrier areas in Reach 2 are characterized by an extensive network of salt marsh islands and small, protected, shallow bays connected by channels and tidal creeks.

- **Reach 3: Townsends Inlet to Great Egg Harbor Inlet:** Reach 3 extends 15 miles between Townsends Inlet and Great Egg Harbor Inlet. It includes the barriers of Ludlam Island and Peck Beach, separated by Corson Inlet. Ludlam Island has a NNE-SSW orientation and includes Sea Isle City and Strathmere. On the north side of Corson Inlet, Peck Beach has an orientation of NNE-SSW, and is home to the community of Ocean City and Corson's Inlet State Park. Reach 3 is also considered a mixed energy system with short drumstick-shaped barrier islands and inlets with well-developed ebb tidal deltas. The shoreline is comprised of narrow sandy beaches with narrow coastal dunes. The backbarrier areas of Reach 3 contain extensive salt marsh islands, small interconnected channels and tidal creeks, and small shallow bays.

- **Reach 4: Great Egg Harbor Inlet to Absecon Inlet:** Reach 4 includes Absecon Island, which stretches for 8 miles between Great Egg Harbor Inlet and Absecon Inlet. From south to north the barrier island includes the communities of Longport, Margate, Ventnor, and Atlantic City. The shoreline in Reach 4 is rotated more than the other Reaches, with a general ENE-WSW orientation. Reach 4 is considered a mixed energy system with a shorter barrier island than shoreline areas to the north. The beaches are relatively narrow with few protective coastal dunes. Extensive salt marsh resources interconnected with narrow channels and tidal creeks are present in the backbarrier areas of Reach 4, although larger open-water areas including Lakes Bay and Absecon Bay are also present.

- **Reach 5: Absecon Inlet to Little Egg Inlet:** Reach 5 extends approximately 9.5 miles from Absecon Inlet to Little Egg Inlet. The area includes two barrier islands separated by Brigantine Inlet. The southern barrier, known as South Brigantine Island, contains the City of Brigantine and the North Brigantine State Nature Area. North of the inlet lies North Brigantine Island, an undeveloped barrier that forms the southern flank of Little Egg Inlet. South Brigantine Island is oriented NE-SW while North Brigantine Island is oriented NNE-SSW. The shoreline immediately adjacent to Little Egg Inlet is aligned parallel to the main channel in a NNW-ESE direction. Reach 5 forms the northern boundary of the mixed energy coastal system along the New Jersey shoreline. The short barrier islands and tidal inlets with well-developed ebb tidal deltas are backed by broad salt marsh resources and tidal channels. The backbarrier areas also contain large open-water bodies at Reed, Little, and Great Bay.

- **Reach 6: Little Egg Inlet to Barnegat Inlet:** Reach 6 is located along the central New Jersey coastline between Little Egg Inlet in the south and Barnegat Inlet in the north. This reach contains the barrier known as Long Beach Island, which spans more than 20 miles. The shoreline has a NNE-SSW orientation and includes the communities of Long Beach Township, Beach Haven, Ship Bottom, Surf City, Harvey Cedars, and Barnegat Light. Reach 6 exhibits characteristics of a wave dominated barrier island system with long narrow beaches bisected by widely-spaced tidal inlets. These systems form where wave energy is large relative to the tidal energy. Most of the shoreline in Reach 6 is comprised of thin beaches with a single frontal dune line. One exception occurs immediately south of Barnegat Inlet where shoreline accretion formed a wide dune field. The undeveloped southern end of Reach 6 in the Edwin B. Forsythe National Wildlife Refuge also contains primary and secondary dune resources. Backbarrier areas of Reach 6 contain shallow elongated estuaries fringed by salt marsh resources.

- **Reach 7: Barnegat Inlet to Manasquan Inlet:** Reach 7 extends approximately 24 miles from Barnegat Inlet to Manasquan Inlet. It contains the barrier spit known as Island Beach, which is connected to the mainland at the northern end near Point Pleasant Beach, and extends to Barnegat Inlet in the south. The shoreline is oriented in a N-S direction. Communities on Island Beach from south to north include Island Beach State Park, Berkeley Township, Seaside Park, Seaside Heights, Lavalette, Brick.

Township, Mantoloking, Bay Head, and Point Pleasant Beach. Most of Reach 7 is considered a wave dominated shoreline with long narrow beaches interrupted by widely-spaced tidal inlets. With the exception of

Island Beach State Park, most of the coast contains narrow beaches with either a single primary dune, or no dune. The State Park area is undeveloped and contains a wider naturally vegetated dune system. Island Beach is separated from the mainland by Barnegat Bay, the largest bay along the New Jersey coastline. The northern end of Reach 7, between Point Pleasant Beach and Manasquan Inlet, is a coastal headland where mainland beaches directly abut open waters of the Atlantic Ocean.

- **Reach 8: Manasquan Inlet to Sandy Hook:** Reach 8 stretches 26 miles from Manasquan Inlet, through Shark River Inlet, to the northern terminus of Sandy Hook. The coastline between Manasquan Inlet and Shark River Inlet is oriented N-S and contains Manasquan, Sea Girt, Spring Lake, and Belmar. North of Shark River Inlet, the shoreline continues in a N-S orientation through the communities of Avon, Bradley Beach, Asbury Park, Allenhurst, Deal, Long Branch, Monmouth Beach, Sea Bright, and Middletown Township. With the exception of areas north of Monmouth Beach, all of Reach 8 is coastal headland with narrow beaches. Dunes are either absent or occur as a single frontal dune line. The spit at Sandy Hook is largely undeveloped and contains increasingly wider dunes at the northern end.

Summary of Existing Studies

Information has been gathered from sources identified through discussions with the USACE Philadelphia and New York Districts, database queries of scientific literature, and internet research. An annotated bibliography of relevant literature is provided in Appendix A.

The following USACE documents comprise the relevant Feasibility Reports/Studies, Environmental Impact Statements, Shore Protection Studies, and General Design Memorandums that serve as the basis for the authorized Shore Protection Projects along the NJ coastline.

- U.S. Army Corps of Engineers (2002). Manasquan Inlet to Barnegat Inlet – Final Feasibility Report and Integrated Environmental Impact Statement. U.S. Army Engineer District, Philadelphia.
- U.S. Army Corps of Engineers (2001). New Jersey Shore Protection Study, Great Egg Harbor Inlet to Townsends Inlet. Feasibility Report and Integrated Environmental Impact Statement. Philadelphia District.
- U.S. Army Corps of Engineers Philadelphia District, (December 2000) Great Egg Harbor Inlet to Townsends Inlet: Feasibility Environmental Impact Statement Study Volume 1. U.S. Army Corps of Engineers Philadelphia District.
- U.S. Army Corps of Engineers (2000). Townsends Inlet to Cape May Inlet, NJ Feasibility Study, USACE District, Philadelphia.
- U.S. Army Corps of Engineers (Sept. 1999). Barnegat Inlet to Little Egg Inlet, Final Feasibility Report and Integrated Final Environmental Impact Statement. U.S. Army Engineer District, Philadelphia. Main report plus appendices.
- U.S. Army Corps of Engineers (1998). Brigantine Inlet to Great Egg Harbor Inlet – Brigantine Island

- Interim Feasibility Study, Final Feasibility Report and Integrated Environmental Impact Statement. Philadelphia District.
- U.S. Army Corps of Engineers (1997). New Jersey Shore Protection Study, Townsend Inlet to Cape May Inlet Feasibility Study. Final Feasibility Report and Final Environmental Impact Statement. Philadelphia District.
- U.S. Army Corps of Engineers (1996). New Jersey Shore Protection Study, Brigantine Inlet to Great Egg Harbor Inlet. Absecon Island Interim Feasibility Study. Philadelphia District.
- U.S. Army Corps of Engineers. (1994, rev. 1995). Atlantic Coast of New Jersey, Sandy Hook to Barnegat, Beach Erosion Control Project, Section II - Asbury Park to Manasquan, New Jersey. General Design Memorandum, U.S. Army Engineer District, NY.
- U.S. Army Corps of Engineers. (1990). New Jersey Shore Protection Study: Report of Limited Reconnaissance Study. Philadelphia District.
- U.S. Army Corps of Engineers. (1989, rev. 1990). Atlantic Coast of New Jersey, Sandy Hook to Barnegat, Beach Erosion Control Project, Section I – Sea Bright to Ocean Township, New Jersey. General Design Memorandum, U.S. Army Engineer District, NY.

Primary Coastal Processes

The combined effects of coastal processes in the nearshore zone interact with the beach to create an evolving coastal landform. The dominant driving forces, which include winds, waves, tides and currents, storms, and sea-level rise interact in a complex fashion to cause nearshore sediment transport. In many coastal regions, New Jersey included, this sediment transport results in both localized and large-scale areas of erosion and/or accretion. To manage the shoreline effectively it is necessary to understand the primary coastal processes and their ability to move sand along the coastline.

A. Data Sources

Principal sources of information on coastal processes for the New Jersey coastline have been identified and used to develop regional summaries of winds, waves, tides, currents, storms, and sea level rise. The summaries are based on a combination of actual field measurements, hindcasting, and numerical modeling. Table 1 shows the available data collection sites for wind and wave information along the coastline. Regional summaries for the dominant coastal processes are described in the following sections (B-F).

B. Winds

Winds along the NJ coastline show a bimodal distribution based on season. Prevailing winds during the summer months are generally from the SSW with mean speeds of 10 to 11 mph. The mean direction of summer winds varies slightly from south to north, with a stronger southerly component in Reaches 1-3 and a stronger southwesterly component in Reaches 4-8. Wind speeds during the summer also vary along the coastline, with average speeds of 11.4 mph in Reaches 1-2 and speeds of 10.8 mph in Reach 8.

Table 1. Summary of Wind and Wave Measurement Sites.

Station	Operator	Location/Depth	Historical Data	Data Type
44066	NDBC	~ 80 miles east of Barnegat Inlet/ 267 ft	2009-2011	Wind speed & dir Wave height & period
44025	NDBC	~ 43 miles east of Asbury Park/120 ft	1991-2011	Wind speed & dir Wave height, period, and direction
44065	NDBC	~ 14 miles east of Seabright/164 ft	2008-2011	Wind speed & dir Wave height, period, and direction
ACYN4	NOAA NOS	Nearshore Atlantic City	1911-2011	Water level
ACMN4	Stevens Institute of Technology	Shore based tower at Absecon Inlet	2004-2011	Wind speed & dir
IMCS Met Tower LEO-15	Rutgers Institute of Marine & Coastal Science	Shore based tower at Tuckerton; 3 & 4 miles offshore of Little Egg Inlet	1996-2003; 1993-1995	Wind speed & dir; Wave height & period
BRBN4	Stevens Institute of Technology	Shore based tower at Brant Beach	2004-2011	Wind speed & dir
OCGN4	Stevens Institute of Technology	Shore based tower at Ocean Grove	2010-2011	Atmospheric pressure
SDHN4	NOAA NOS	Nearshore	1996-2011 1910-2011	Wind speed & dir Water level

Prevailing winds during the winter months blow from the WNW with mean speeds just under 17 mph. Little variation in direction or mean speed of prevailing winds occurs along the coastline during the winter season.

Dominant winds with the highest speeds are from the NE, corresponding to the most common coastal storm wind direction. NE wind velocities average between 19 and 20 mph. Winds in excess of 28 mph occur from the NE more than twice as frequently as any other direction.

Wind distributions with respect to duration offshore of NJ are reported by the Philadelphia District as follows: onshore (NE, E, and SE) 27% of the time; upshore (S) 11% of the time; offshore (SW, W, and NW) 44% of the time; downshore (N) 15% of the time; and calms 3% of the time. Prevailing winds by Reach are shown on Figures 2 through 7.

C. Waves

Offshore waves most frequently approach from the S, SE, and E quadrants. Average significant offshore wave heights range from 2.8 to 3.5 feet, with the largest waves occurring along the central portion of the coast in Reaches 4-6. The lowest average wave heights are along the northern coast in Reach 8. Average peak period is between 5.0 and 5.3 seconds, with slightly longer average periods along the central part of the coast. Monthly mean wave heights vary according to season, ranging from 2.4 feet in the summer to 4.3 feet in the winter.

Winter waves have a higher frequency of occurrence from the NE reflecting the influence of extratropical storms. These events generate larger wave heights and periods along all areas of the coastline. Significant wave heights during the 10-yr storm event range between 18.2 and 21.6 feet, and during the 50-yr storm event between 21.7 and 25.8 feet. The largest of these storm waves occur along the central part of the NJ coastline in Reaches 4-6, while the lowest storm waves occur in Reach 8 at the northern end of the coastline. Wave roses for each Reach are shown on Figures 2 through 7.

Wave focusing along certain areas of the coastline has the potential to cause "hot spot" erosion. Specific areas of wave focusing and increased wave energy have been identified in a Minerals Management Service (MMS) study of potential impacts from sand and gravel mining on the outer continental shelf of NJ (Byrnes, et al., 2000). Numerical model results of wave focusing from this study are provided for the following locations: Seven Mile Beach; Ludlum Island; Ocean City (Reaches 2 and 3); Brigantine Island (Reach 5); northern Long Beach Island (Reach 6); and northern Island Beach (Reach 7). A summary of these areas is provided below.

- **Reaches 2 and 3** - Increased wave energy along the shoreline occurs in Sea Isle City and Ocean City during wave approaches from the eastern quadrant (ENE, E, and ESE). As the wave approach direction shifts to the southern quadrant (SE and SSE), increased wave focusing occurs at the northern ends of the barrier islands in Avalon and Strathmere.

- **Reach 5** – Waves in Reach 5 from the ENE tend to concentrate in the south Long Beach Island and Little Egg Inlet regions. Waves approaching from the E, ESE, and SE cause increased wave energy along much of the shoreline between the southern end of Long Beach Island, through Little Egg and Brigantine Inlets, to the upper end of South Brigantine Island. As the incident wave climatology shifts more to the SSE, areas of greatest impact include North Brigantine Island and the southern end of Long Beach Island.

- **Reach 6** – Increased focusing occurs at Barnegat Inlet, Harvey Cedars, Surf City and Ship Bottom during ENE wave conditions. As the waves shift to the E, ESE, and SE greater energy is found in the Barnegat Light, Long Beach Township (Loveladies), and Ship Bottom communities. Waves approaching from the SSE result in little wave energy focusing along this stretch of Reach 6.

- **Reach 7** – Waves in Reach 7 from the ENE concentrate in the communities of Mantoloking, Lavallette, and Seaside Heights. Incident waves from the E, ESE, and SE focus throughout much of northern Island Beach from Bay Head to Seaside Heights. Approaches from the SSE have the greatest impact on the Seaside Park area, with little wave focusing elsewhere.

D. Tides and Currents

Tides along the NJ coastline are semi diurnal with two nearly equal high and low tides each day. The average tidal period is 12 hours and 25 minutes. The mean tidal range varies slightly along the coastline, with greater ranges between 4.3 and 4.4 feet in the northern and southern areas (Reaches 1, 6, 7, and 8). Slightly lower mean tidal ranges between 4.0 and 4.1 feet occur along the south central coastline (Reaches 3-5).

Limited information regarding current patterns in NJ tidal inlets is available in the USACE Feasibility Studies and Environmental Impact Statements for the various shore protection projects. Reports suggest five of the eleven inlets are flood dominant, with stronger flood current velocities than ebb velocities. Three of the inlets are reported to be ebb dominant, and conditions are not available for the remaining three inlets. Inlets with stronger flood currents tend to build larger flood shoals, denying sand to the seaward beach system. Inlets with stronger ebb currents tend to flush sediment seaward to maintain a more efficient inlet and development of a larger ebb shoal. Causes for flow dominance in tidal inlets are varied, with asymmetries resulting from interactions between harmonic constituents in the forcing tide, friction with the inlet sea floor, interactions with the estuary/inlet channel geometry, and variations in basin hypsometry. A summary of existing tidal current conditions for the NJ inlets is provided below.

- **Hereford Inlet** – Tidal flow is flood dominant with currents predominantly entering from the NE and E. Maximum velocities during the flood reach 2.7 ft/sec.
- **Townsends Inlet** – Tidal flow is flood dominant with currents primarily entering from the SE and E. Maximum velocities during the flood reach 3.5 ft/sec.
- **Corson Inlet** – Tidal flow reported from hydrodynamic modeling indicates that the inlet is ebb dominant. Maximum velocities of 3.94 ft/sec and 2.95 ft/sec were predicted for ebb and flood currents, respectively.
- **Great Egg Harbor Inlet** – The inlet throat at Great Egg Harbor is separated into two channels by a shoal. Measured data and modeled results indicate flow through the inlet is slightly ebb dominant. Maximum velocities during the ebb are between 2.49 ft/sec and 4.6 ft/sec. Maximum flood velocities range between 2.49 ft/sec and 4.1 ft/sec.
- **Absecon Inlet** – Current flows are higher in Absecon Inlet than in systems to the south, with peak flood velocities of 5.6 ft/sec and peak ebb velocities of 4.9 ft/sec. The inlet is flood dominant.
- **Brigantine Inlet** – Tidal flow is ebb dominant through the inlet throat, with peak velocities of 3.9 ft/sec and 3.6 ft/sec for the ebb and flood currents, respectively. Flow through the northern channel into the estuary is also ebb dominant, while the primary channel leading to the south is flood dominant. Approximately 28% of the discharge through the throat of Brigantine Inlet goes through the north channel, and the other 72% goes through the primary channel to the south.
- **Barnegat Inlet** – Tidal flow at Barnegat Inlet is flood dominant. Peak flood currents are on the order of 3.28 ft/sec and peak ebb currents are 2.3 ft/sec.
- **Shark River Inlet** – Tidal flow at Shark River Inlet appears to be slightly flood dominant, with peak flood velocities of 2.63 ft/sec and peak ebb velocities of 2.53 ft/sec.

E. Storms

The NJ coastline is impacted by tropical and extratropical (northeast) storms. Nor'easters are the most common cause of storm damage, although both storm types can result in beach erosion from storm surge and large waves. The most damaging storms over the past century are shown in Table 2.

Stage frequency analyses performed on historical storm surge data have been used by the USACE to predict elevations of the 50- and 100-yr storm events along the open coast of NJ. Elevations are predicted to be 6.9 feet and 7.9 feet above NAVD88, respectively.

F. Sea-Level Rise

Long-term water level measurements at stations along the coastline show the history of sea-level rise over the last century. Best fit linear regression analyses of the historical data show relative rates of sea-level rise on the order of 4 mm/yr (NOS, 2011; Table 3). When projected over the next 100 years, these historical rates suggest a rise in sea level for the NJ coastline of approximately 1.3 feet.

Climate change research conducted by the International Panel on Climate Change (2007) suggests that rates of sea-level rise will increase over the next century. Climate change models have been used to predict the effects from future greenhouse gas emissions, land-use practices, and other driving forces on future sea levels. These models suggest that global average sea levels will rise by the end of the 21st century anywhere from 0.59 to 1.94 feet.

Table 2. Major Storms Impacting the NJ Coastline.

Storm Date	Storm Type
Sep. 1821	Tropical
Dec. 1925	Tropical
Aug. 1933	Tropical
Sep. 1938	Tropical
Sep. 1944	Tropical
Nov. 1950	Extratropical
Sep. 1960	Tropical
Mar. 1962	Extratropical
Feb. 1978	Extratropical
Mar. 1984	Extratropical
Sep. 1985	Tropical
Oct. 1991	Extratropical
Jan. 1992	Extratropical
Dec. 1992	Extratropical
Jan. 1996	Extratropical
Mar. 1998	Extratropical
Apr. 2007	Extratropical
Dec. 2009	Extratropical

Table 3. NOAA NOS Measurements of Long-Term Changes in Sea-Level.

NOS Station	Data Period	Historical Sea-Level Rise (mm/yr)	Projected Sea-Level Rise in100 Years (ft)
Sandy Hook	1932-2006	3.90	1.28
Atlantic City	1911-2006	3.99	1.31
Cape May (Delaware Bay side)	1965-2006	4.06	1.33

Shoreline Change and Trends

Shoreline change data for the NJ coastline are available from the most recent U.S. Geological Survey (USGS) National Assessment of Shoreline Change (Himmelstoss et al., 2010). This study provides a summary of historical shoreline change from the mid 1800s to 2000. Long- and short-term rates of shoreline change were computed using linear regression techniques. Most useful to current NJ RSM management decisions are the short-term rates of change computed for the period 1977 to 2000. Short-term rates of change computed at 50-meter intervals along the coastline by the USGS study are illustrated in Figures 2-7.

The short-term shoreline change data captures approximately thirty years of shoreline movement and averages the rates of change over time using linear regression. Linear regression is performed by fitting a least-squares regression line to all shoreline points for a particular transect and, is a widely accepted method of calculating rates of shoreline change. The method effectively smoothes natural aberrations in shoreline position, and does not differentiate natural from anthropogenic changes.

Another source of shoreline response data for NJ is the Richard Stockton College Coastal Research Center (CRC). In 1986, the CRC established the New Jersey Beach Profile Network (NJBPN) to monitor the dune, beach and nearshore areas at over 100 study sites distributed approximately one mile apart along the entire NJ shoreline. NJBPN monitored this network of sites in the Spring and Fall annually since 1986, and it also maintains a network of more closely spaced sites monitored four times per year for participating communities (Avalon, Brigantine, Cape May Point, Mantoloking, Stone Harbor and Upper Township). Although not specifically analyzed for this RSM effort, the NJBPN data yield similar results for the various shoreline reaches.

Based on the short-term USGS data between 1977 and 2000, areas of greatest accretion are located at Cape May City, Wildwood Crest, Wildwood, central Ocean City, Barnegat Light, and the northern headland region of Monmouth County. Shoreline areas experiencing the greatest erosion are North Wildwood, Avalon, southern Ocean City, central Atlantic City, and Long Beach Township. The area south of Barnegat Inlet has experienced more dramatic change (both accretion and erosion) than the area north of Barnegat Inlet, which was comparatively more stable. A detailed summary of trends and rates of shoreline change for each of the study reaches is provided below.

- **Reach 1: Cape May Point to Cape May Inlet** (Figure 2) – Net erosion occurred at Cape May Point and the western half of Lower Township (Cape May Meadows). Rates of erosion were between -3.2 and -4.9 ft/yr at Cape May Point. The highest rates of erosion of -7.5 ft/yr occurred at the center of the Lower Township embayment. The eastern end of Reach 1 experienced a net accretion during the 1977 to 2000 time period. Average rates of accretion were on the order of +6.5 ft/yr. Localized erosion took place along the shoreline immediately west of the Cape May Inlet jetties during this time period.
- **Reach 2: Cape May Inlet to Townsends Inlet** (Figure 2) – The barrier beach at the south end of Reach 2, between Cape May Inlet and Hereford Inlet, experienced significant accretion to the south (Wildwood Crest and Wildwood) and erosion to the north (North Wildwood). Maximum accretion rates of +29.0 ft/yr occurred in Wildwood, and even greater erosion rates of -46.0 ft/yr were seen in North Wildwood. Similar trends were seen along the barrier beach further to the north, between Hereford and Townsends Inlets. Areas of Stone Harbor closest to Hereford Inlet experienced erosion with rates up to -3.2 ft/yr. The central portion of the barrier beach showed net accretion with rates as high as +8.5 ft/yr, while the northern end of the beach in Avalon underwent significant erosion at rates of -25.2 ft/yr.

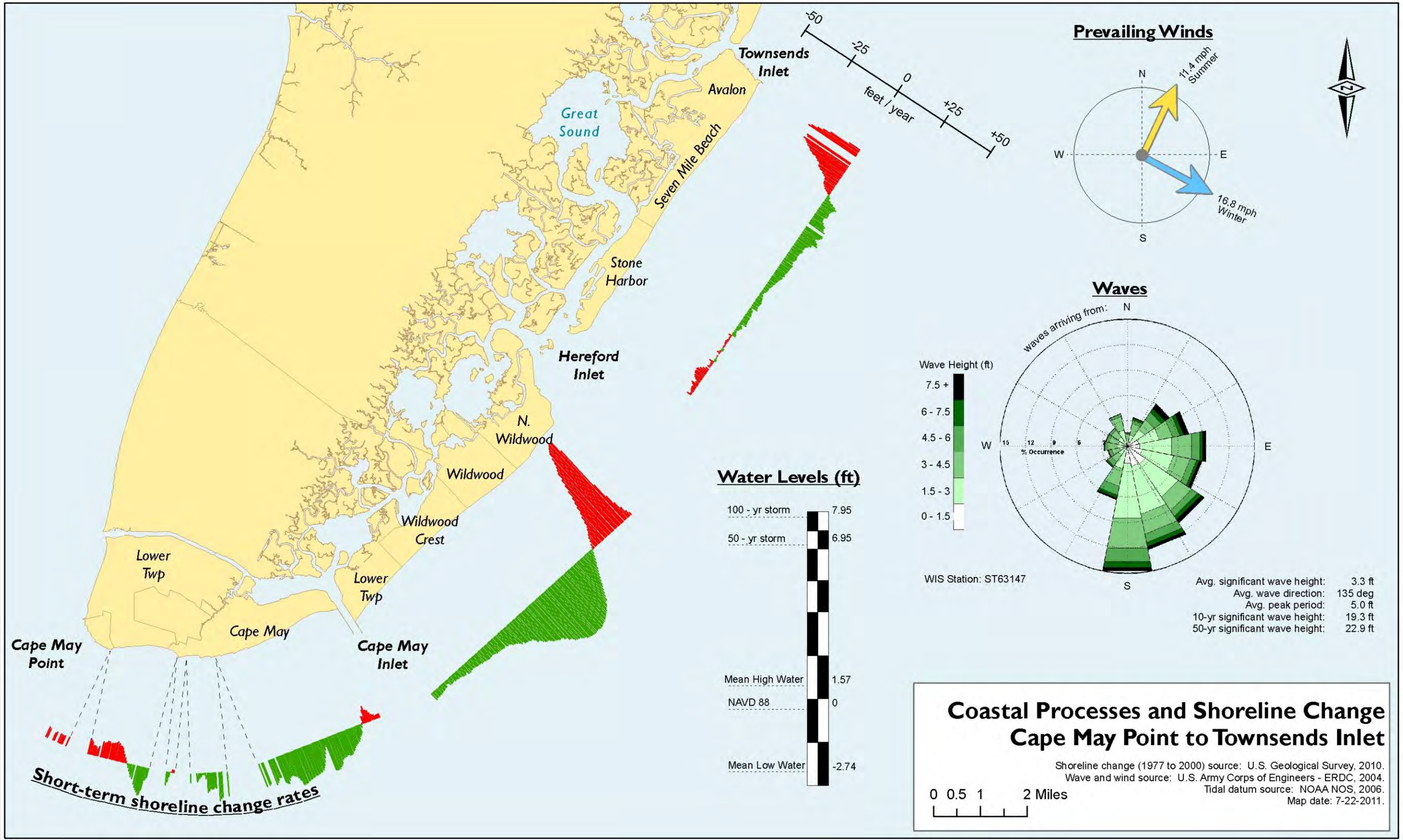


Figure 2. Coastal processes and shoreline change in Reaches 1 and 2.

- **Reach 3: Townsends Inlet to Great Egg Harbor Inlet** (Figure 3) – Net erosion occurred along most of the barrier beach between Townsends and Corson Inlets. The highest rates of erosion of -7.2 ft/yr took place at the northern end of Sea Isle City. The trend of erosion continued along the beach to the north of Corson Inlet, where rates of change reached a maximum of -20.0 ft/yr. The northern two-thirds of the barrier between Corson and Great Egg Harbor Inlets were characterized by net accretion. Maximum rates of accretion were on the order of +15.4 ft/yr in the vicinity of 22nd St. in Ocean City. The northern end of Ocean City showed areas of both accretion and erosion. The highest rates of accretion occurred along the shoreline directly facing Great Egg Harbor inlet.
- **Reach 4: Great Egg Harbor Inlet to Absecon Inlet** (Figure 4) – Net erosion occurred throughout most of Reach 4. The only areas of accretion were at the ends of the barrier beach immediately adjacent to Great Egg Harbor Inlet in the south and Absecon Inlet to the north. Rates of erosion increased gradually from south to north, reaching a maximum of -14.7 ft/yr in Atlantic City. Accretion rates at the ends of the barrier beach were between +0.6 and +4.3 ft/yr.
- **Reach 5: Absecon Inlet to Little Egg Inlet** (Figure 4) – South Brigantine Island accreted at the southern end and eroded at the northern end. Rates of accretion gradually reduced from +18.4 to +0.8 ft/yr from south to north. Shoreline erosion rates then gradually increased to a maximum of -16.5 ft/yr in the wildlife refuge south of Brigantine Inlet. Although the data are sparse for North Brigantine Island, the ocean facing beaches experienced significant erosion, while the beach facing Little accreted.
- **Reach 6: Little Egg Inlet to Barnegat Inlet** (Figure 5) – Net erosion occurred along most of the barrier beach in Reach 6. The primary exception occurred along the shoreline stretch immediately south of Barnegat Inlet where significant accretion took place. Most rates of erosion along the barrier beach ranged from -1.0 to -5.3 ft/yr, with an area of greater beach loss at the south end of Long Beach Township. Accretion South of the jetties at Barnegat Inlet was significant, where rates increased in a northerly direction to a maximum of +110.2 ft/yr immediately adjacent to the inlet.
- **Reach 7: Barnegat Inlet to Manasquan Inlet** (Figure 6) – Most shoreline areas of Reach 7 underwent net erosion. Exceptions occurred at the south and north ends of Island Beach State Park, Seaside Park, and Point Pleasant Beach where accretion took place. Average rates of erosion in Reach 7 were on the order of -1.5 ft/yr. Shoreline areas at Island Beach State Park, Dover (between Seaside Heights and Lavallette), and Mantoloking experienced erosion rates as high as -5.5 ft/yr.
- **Reach 8: Manasquan Inlet to Sandy Hook** (Figure 7) – Shoreline trends in Reach 8 varied from south to north. Between Manasquan and Shark River Inlet the primary trend was erosion, with a few pockets of shoreline accretion. The greatest rates of shoreline buildup occurred in Sea Girt

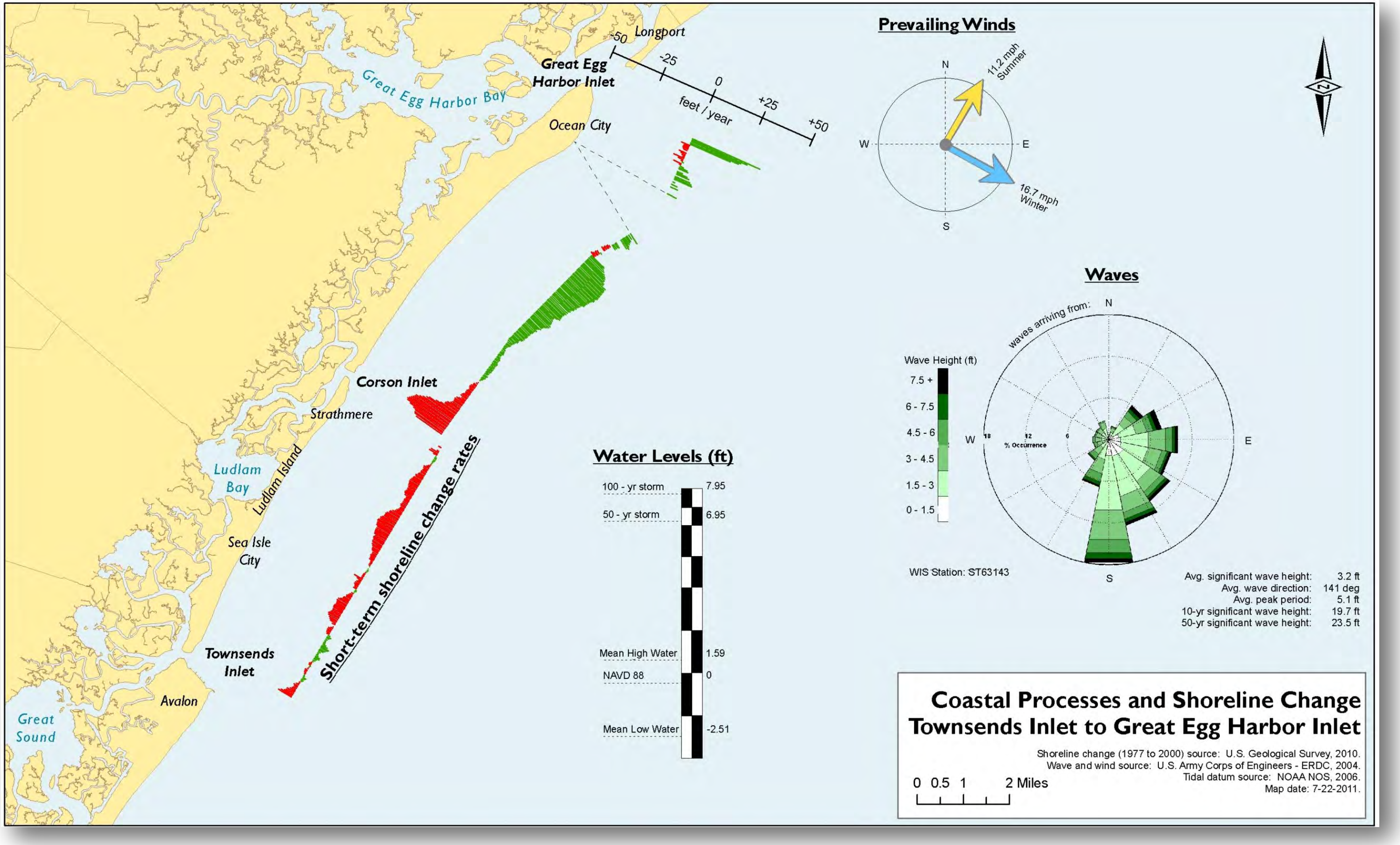


Figure 3. Coastal processes and shoreline change in Reach 3.

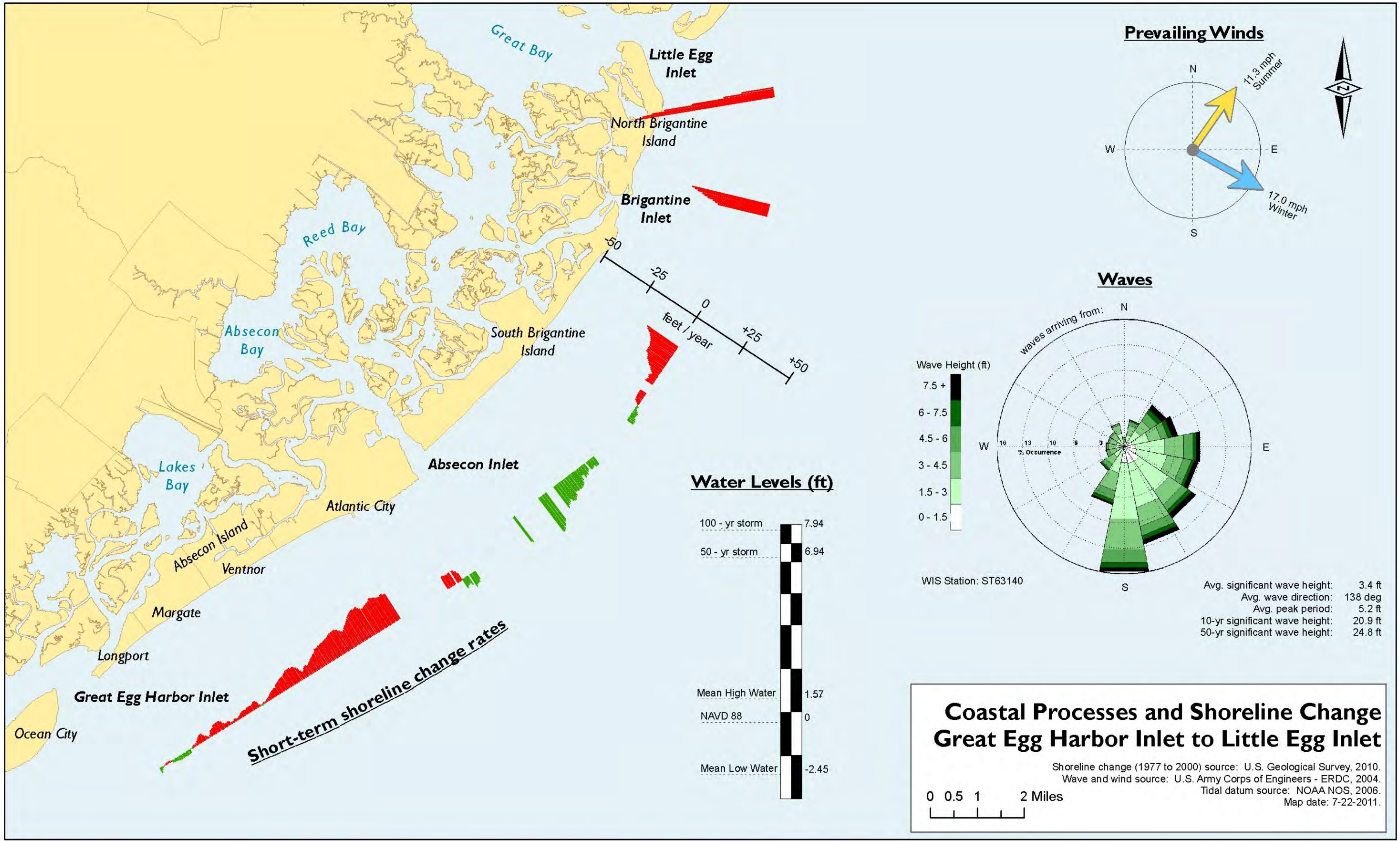


Figure 4. Coastal processes and shoreline change in Reaches 4 and 5.

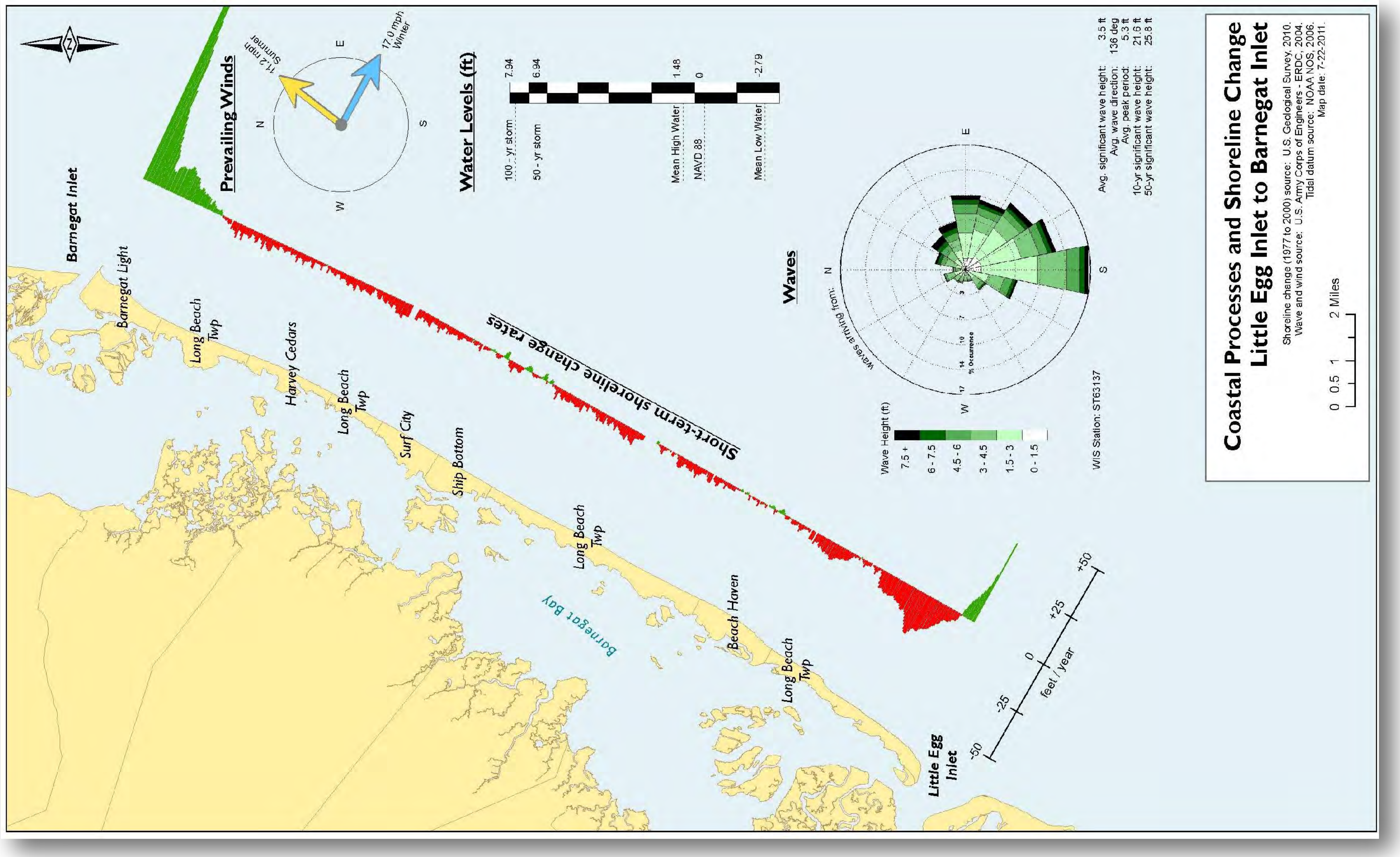


Figure 5. Coastal processes and shoreline change in Reach 6.

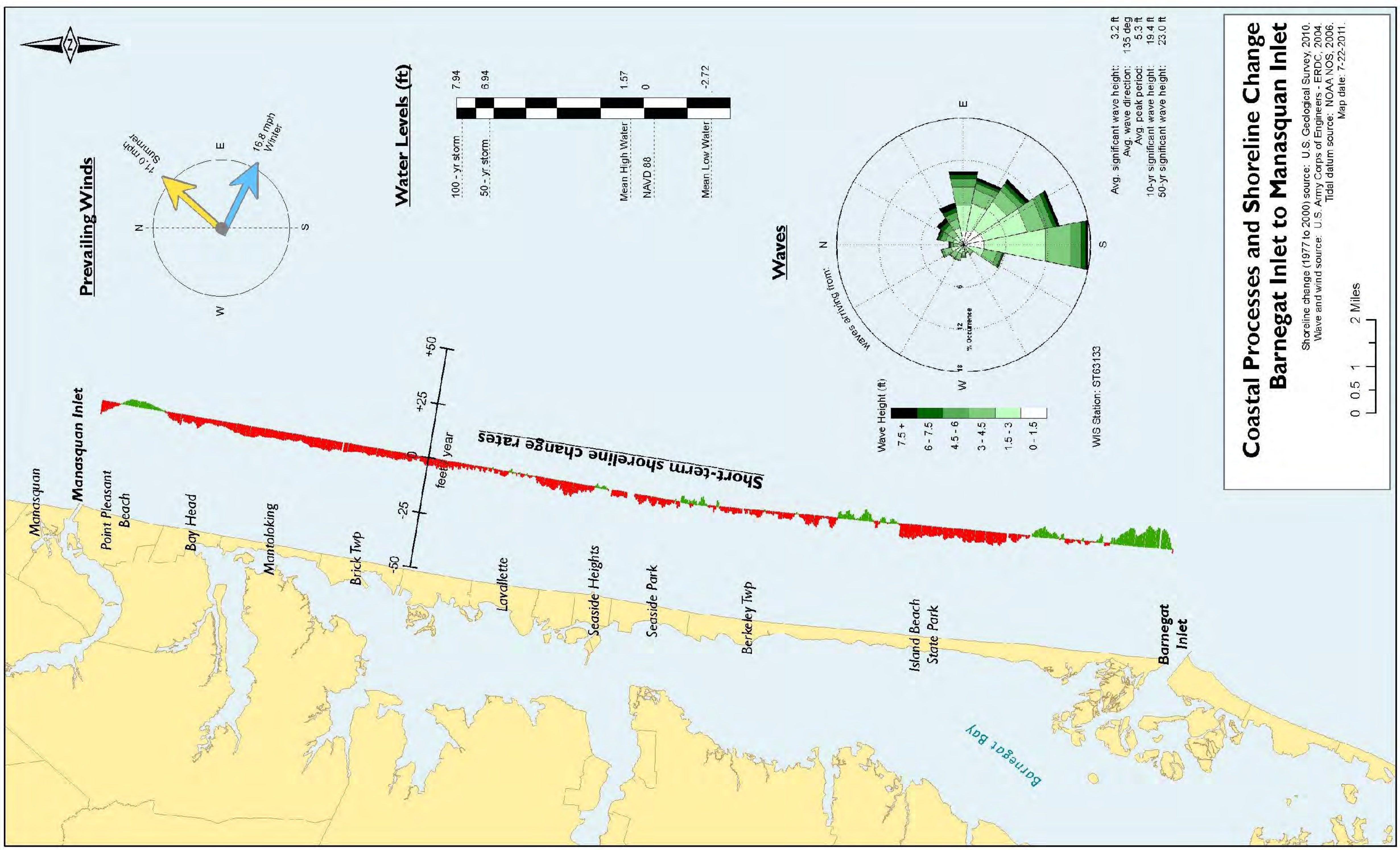


Figure 6. Coastal processes and shoreline change in Reach 7.

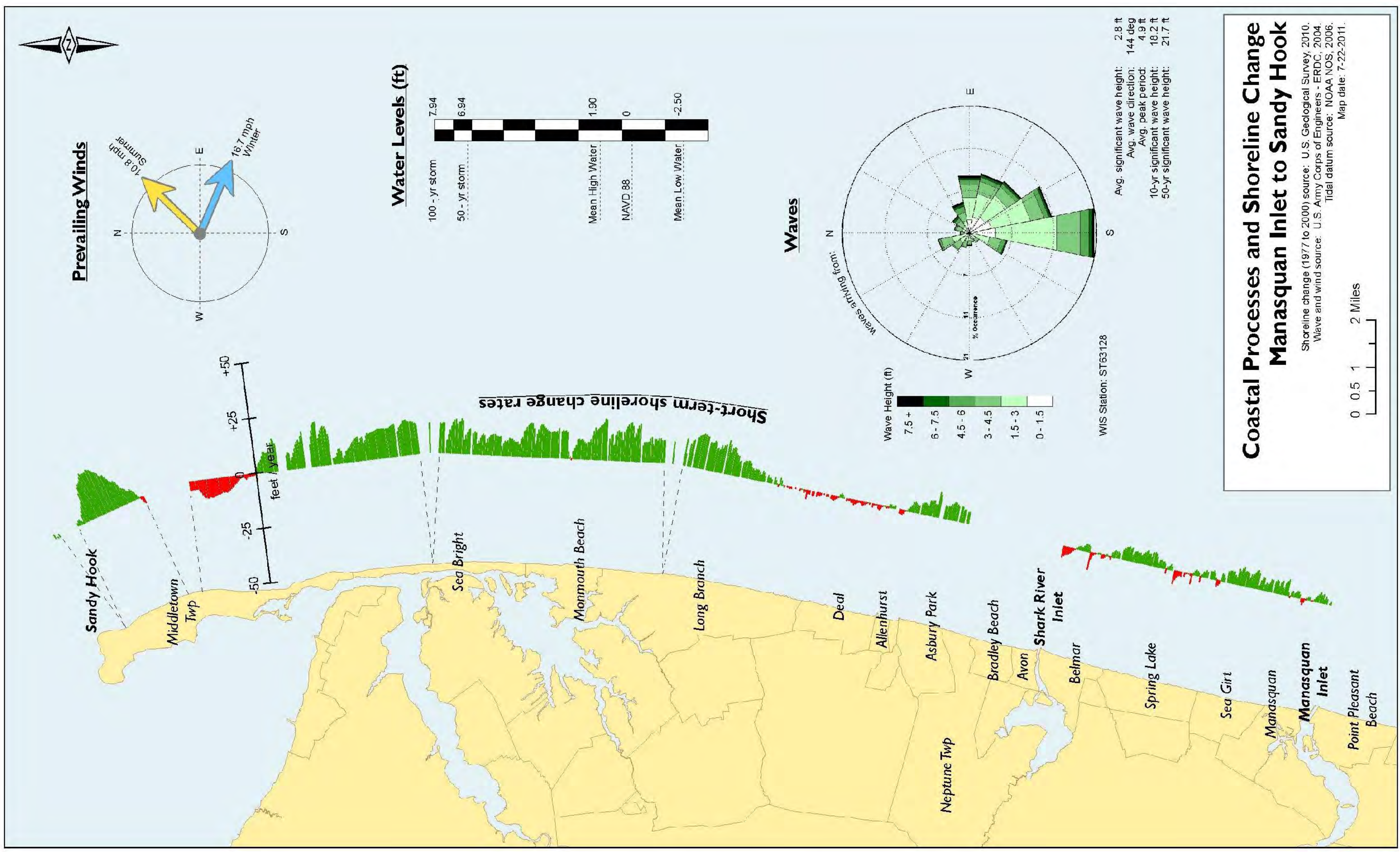


Figure 7. Coastal processes and shoreline change in Reach 8.

- with maximum accretion rates of +6.6 ft/yr. To the north of Shark River Inlet most of the shoreline experienced accretion, with the exception of the stretch between Allenhurst and the south end of Long Branch that experienced a small net erosion. Accretion rates between Long Branch and the start of Sandy Hook ranged between +2.3 and +18.1 ft/yr. A pocket of erosion occurred along central Sandy Hook, followed by significant accretion at the northern end of the spit.

Anthropogenic History and Features

Development along the NJ shoreline, including coastal engineering structures designed to protect property and infrastructure, has significantly altered large sections of the coast. An understanding of the general areas of development and past steps taken for shore protection, including both hard and soft erosion control measures, is an important part of an effective regional sediment management program.

Background information on types and extent of development in each of the study Reaches is provided below, along with a summary of past shore protection measures. Descriptions of coastal structures within each study Reach, including jetties, groins, revetments, seawalls, and bulkheads were taken from the USACE Feasibility Studies. These documents provided additional detail on the number and dimensions of existing structures. Beach nourishment projects completed by the USACE, NJDEP, and/or municipal interests are also discussed and illustrated for each shoreline Reach.

A. Reach 1

Reach 1 at the southern tip of NJ contains the communities of Cape May Point, Lower Township (Cape May Meadows), and Cape May City. Residential development along the coastline is heavy in Cape May Point and Cape May City (Figure 8), while shoreline areas in Cape May Meadows have been preserved by the Nature Conservancy as natural critical habitat for birds. Oceanfront buildings are located immediately behind the single frontal dune line. Cape May Meadows contains low-lying wetlands protected from the ocean by beach and dune resources. The northeastern end of Cape May City, immediately adjacent to the south jetty at Cape May Inlet, contains the U.S. Coast Guard Training Center. Development at the training center is much less dense than the nearby communities, with large naturally vegetated areas and recreational fields between the shoreline and the Coast Guard infrastructure. Coastal dune resources up to 250 feet wide protect the Training Center facilities.

Early shore protection measures at Cape May Point included a series of steel groins built between 1930 and 1942. A timber/steel bulkhead was also constructed against the bank at the eastern end of Cape May Point in 1934 to protect upland property. In 1945 a series of 9 timber and stone groins were installed along the shoreline to replace the earlier steel groins. These structures, which still exist today, were built approximately 500 feet long and 490 to 980 feet apart, creating 8 groin compartments (Figure 8).

Figure 8. Cape May Point groins.

To mitigate erosion east of the first groin compartment, stone-filled polymer baskets were installed to protect the dune in front of the Cape May Lighthouse and park. In May 1994, a 1,000 foot long Beachsaver Reef was installed across the 2nd and 3rd groin compartments as part of the State of New Jersey Pilot Reef Project. These reefs were placed across the entire length of the cells at the seaward ends of the groins, effectively creating an enclosed compartment. The Reef was initially successful in reducing sand loss from the beach; however, settling soon after placement limited wave attenuation, allowing beach erosion. A seawall of rock rubble and gabions was installed along the shoreline in the 5th groin compartment during the period 1999 to 2000. Most recently during the summer and fall of 2002, a Beachsaver Reef with a geotextile scour apron was constructed across the seaward ends of the groins in compartment 5. Rock was placed between the end reef units and the groins, enclosing the entire cell as a perched beach. At the same time, a precast concrete Double-T structure was installed across groin compartment 6 to act as a sill and create a perched beach.

The history of shore protection measures in Cape May City goes back to the 1920s when 24 groins were constructed along the shoreline to mitigate erosion caused by jetties built at Cape May Inlet in 1911. In 1930, a steel sheet-pile bulkhead was placed between the groins in Cape May City to control erosion. Between 1946 and 1952 the City replaced the smaller groin field with 5 large stone groins and a continuous stone seawall. This work was followed by the addition of 2 new groins on the west end of the City in 1952 and 1954. After the Ash Wednesday storm of 1962, the existing groins were rehabilitated and two additional groins were added for a total of nine structures that currently cover the entire length of the City's beachfront (Figure 9).

In addition to the structural shore protection measures, the USACE performed beach nourishment in Reach 1 as part of two authorized Shore Protection Projects: Cape May Inlet to Lower Township Storm Damage Reduction Project; and the Lower Cape May Meadows – Cape May Point Environmental Restoration Project. Initial construction of the Cape May Inlet to Lower Township project was completed in two phases. The first phase involved placement of 465,000 cubic yards of sand on the U.S. Coast Guard Training Center beach in August 1989. The second phase included placement of 900,000 cubic yards on the Cape May City beach in July 1991 (Figure 10).

Figure 9. Anthropogenic Factors in Reaches 1 and 2.

Figure 10. U.S. Coast Guard Training Center and Cape May City following 1991 shore protection project.

A total of 8 periodic nourishment cycles have been completed since initial construction (1993, 1995, 1997, 1999, 2003, 2004, 2007, and 2009), placing over 4,000,000 cubic yards of sand on the beach. Sand for these nourishment efforts was dredged from offshore borrow sites M1, 4, and 5 (Figure 8). The beach nourishment work in this area is largely responsible for the net accretion shown in the short-term shoreline change data for the eastern end of Reach 1 (Figure 2).

Work on the Lower Cape May Meadows – Cape May Point Environmental Restoration Project included dune/berm restoration from the Cape May City 3rd Ave. terminal groin to the Central Ave. groin in Cape May Point (Figure 11). Initial dune and beach construction was completed in 2005 with the placement of 1,406,000 cubic yards of sand from offshore borrow sites 4 and 5.

Figure 11. Cape May Point before and after beach replenishment in 2005.

Periodic renourishment of this project by the USACE has been delayed pending funding. Smaller truck hauled beach fills have been implemented in the groin compartments at Cape May Point during 2000 and 2004. Approximately 20,000 cubic yards of sand was placed in the 3rd and 4th groin compartments during the winter of 2000/2001. Another 9,600 cubic yards of sand was added to the 4th compartment during the spring of 2004.

B. Reach 2

Cape May Inlet, one of the 5 Federal authorized navigation projects along the NJ shoreline, forms the boundary between Reaches 1 and 2. The inlet was stabilized in 1911 with two parallel rubblemound jetties approximately 4,500 feet long. Since 1986 the USACE has maintained the channel using the sidecasting dredge Fry. Most of the work is conducted at a shoal that forms near the entrance to the inlet just inside the end of the southwest jetty. Typical dredging quantities for the Fry have been approximately 70,000 cubic yards per year. More recently the USACE hopper dredge Currituck has maintained the channel, placing sand west of the inlet in the nearshore zone of Cape May City, or in 2007 as nourishment for the Cape May Inlet to Lower Township Storm Damage Reduction Project.

Five Mile Beach to the north of Cape May Inlet contains the communities of Lower Township (Diamond Beach), Wildwood Crest, Wildwood, and North Wildwood (Figure 8). The barrier beach in these communities is heavily developed with both residential and commercial properties (Figure 12). The commercial development is centered in Wildwood around numerous low rise hotels and the world famous Wildwood Boardwalk.

The only part of Five Mile Beach without development is the southern 1.2 miles immediately adjacent to Cape May Inlet. This property belongs to the U.S. Coast Guard Training Center. The oceanfront development of Wildwood Crest and Wildwood is protected by significant beach resources. Accretion has extended the beach so much that many of the stormwater drains are clogged with sand. By contrast, existing development in North Wildwood is threatened by narrow beaches with a history of erosion.

Figure 12. Development along Five Mile Beach in Wildwood Crest.

Hereford Inlet is a natural system not authorized as a Federal navigation project. A channel through the ebb shoal was, however, dredged by the Federal government in 1967. Subsequently, the State assumed responsibility for maintaining a channel through the inlet. Dredging was performed annually using State funds between 1973 and 1981, with dredged material sidecast downdrift of the channel. Since 1981, the dredging has been performed on an as needed basis.

Seven Mile Island located north of Hereford Inlet contains the communities of Stone Harbor and Avalon (Figure 8). The predominant land use throughout this region is development associated with single family homes, and commercial establishments along the major roadways. The oceanfront buildings are located immediately behind, or on the landward slope of the island's single frontal dune. The one exception to this development pattern occurs along a 2.7 mile stretch at the center of the barrier where the buildings are set back from the shoreline. Dunes in this area are wider than adjacent shorelines, and the development has greater protection from coastal storms and erosion.

In terms of shore protection, Reach 2 contains a combination of groins, seawalls, and revetments. On Five Mile Beach the only structures are located in the community of North Wildwood. The inlet frontage is protected with a combination of seawalls and stone revetments. There are also a total of 11 groins that provide protection along the inlet frontage. The oceanfront of North Wildwood between 2nd and 13th Avenues is protected by a timber bulkhead constructed by the city in 1963.

Further to the north in Stone Harbor a continuous timber bulkhead runs along the entire oceanfront from 80th St. to the terminal groin at 127th St. A stone revetment is located along the seaward side of the bulkhead for added protection. A total of 8 groins built by the State of NJ are located along the beach in Stone Harbor.

The bulkhead system in Avalon is continuous along the inlet frontage around to 17th St. on the oceanfront. A stone revetment is located along the seaward side of the bulkhead for toe protection. The inlet side of Avalon also contains 4 stone groins constructed in 1966-1967 by the State of NJ. The seaward most groin at 8th St. forms the northern end of the Avalon oceanfront, protecting the beach from scour by tidal currents moving through Townsends Inlet (Figure 13). In 2001 the Borough of Avalon, in partnership with the NJDEP, extended the 8th St. groin by approximately 400 feet in an effort to reduce loss of sand into the inlet from erosion of more southerly beaches.

Figure 13. Erosion control structures along inlet frontage in Avalon.

In 2002 the USACE completed initial construction of the Federal Shore Protection project at Avalon. The project nourished beaches and built dunes in Avalon, Stone Harbor, and Stone Harbor Point with 4,400,000 cubic yards of sand dredged from Townsends and Hereford Inlets.

Periodic renourishment of this project on the authorized 3-yr cycle has been delayed since its original construction pending funding. Since this time the Borough of Avalon, with support from NJDEP, has taken responsibility for nourishing critically eroded beaches at the north end of the barrier. Nine (9) renourishment projects (2005, 2006, 2006, 2007, 2008, 2009, 2009/2010, 2010, and 2011) have been completed using a variety of methods and sand sources including hydraulic dredging from Townsends Inlet, truck hauling, and scraping/ hauling from downdrift beaches south of 31st St (backpassing). Most of the sand from these projects was placed within the "hot spot" erosional area between 9th and 18th Streets. The largest renourishment was performed by local and state interests during June 2010, when 643,000 cubic yards of sand from the Townsends Inlet borrow area was placed on eroding beaches between 9th and 26th Streets.

The only other beach nourishment work in Reach 2 has been in the communities of North Wildwood and Stone Harbor, where the State of NJ nourished public and private beaches using sand dredged from Hereford Inlet. Most recently in 2009, public beaches in North Wildwood between the terminal groin at 2nd Ave. and Poplar Ave. were nourished with 1,186,400 cubic yards of sand. During this same time period Stone Harbor beaches from 98th to 111th Sts. were nourished with 245,000 cubic yards of sand dredged from Hereford Inlet.

C. *Reach 3*

Townsends Inlet is a natural system not authorized as a Federal navigation project. To maintain navigability through the inlet the State of NJ performed sidecast dredging on an annual basis between 1950 and 1977, with discharge directly against the north shoreline of Avalon's inlet frontage. In 1978 and 1984 large-scale dredging was conducted in the inlet to provide beach fill material to the community of Sea Isle City to the north. Since this time, the inlet has been dredged numerous times with sediment most often placed on downdrift beaches in Avalon.

Ludlum Island to the north of Townsends Inlet contains the communities of Sea Isle City, Whale Beach, and Strathmere (Figure 14). Sea Isle City is a highly developed residential community that supports a seasonal population and a significant year-round population. To the north, Whale Beach is a narrow, sparsely developed stretch of Ludlam Island that encompasses the southern part of Strathmere and the northern part of Sea Isle City. Strathmere consists of mostly residential structures with little commercial development. Oceanfront properties on Ludlum Island are located immediately behind the single frontal dune line, or in some cases, are directly exposed to the ocean without the benefit of a dune.

Corson Inlet is a natural inlet system, and is not an authorized Federal navigation project. Hydraulic dredging has been performed in the past for beach nourishment at Sea Isle City. Most recently in 2009, approximately 1,285,800 cubic yards of sand was pumped from the inlet to beaches in Strathmere and Sea Isle City for a joint project between the State and the municipalities.

The barrier beach north of Corson Inlet contains Corson's Inlet State Park and the community of Ocean City. The State Park occupies approximately 1 mile of natural beach and dune at the south end of the barrier. To the north, Ocean City is a highly developed residential town that maintains a significant year-round population along with a high seasonal population. In most places the oceanfront development is protected by a single row of dunes.

Shore protection structures in Reach 3 include a mixture of bulkheads, revetments, and groins. Sea Isle City contains a timber bulkhead and/or stone revetment along the oceanfront from 29th to 57th Sts. In addition, there are 19 groins from 30th to south of 78th St., and a terminal groin was constructed south of 93rd St. in 1999. These structures are a combination of timber crib, stone, or timber with rubble mound heads. In Strathmere a timber bulkhead and 15 groins provide protection for the beach

Figure 14. Anthropogenic Factors in Reach 3.

and adjacent development (Figure 15). Seven (7) of the groins are constructed entirely of timber and eight (8) are timber with a stone rubble mound at the head.

Figure 15. Aerial view of Strathmere looking to the south.

Shore protection in Ocean City includes a timber bulkhead with stone revetment between 36th St. and 57th St, as well as 18 groins south of 36th St. Most of the groins are of timber construction. A series of sand-filled geotextile bags were also used to control erosion along the northern end of Ocean City. The original bags were destroyed during a storm in November 2009 (Figure 16), and then replaced by the City during early 2011 in combination with dune enhancement.

Reach 3 contains two separate Federally-authorized Shore Protection projects. The Great Egg Harbor Inlet to Townsends Inlet project includes beach nourishment and dune construction, and is pending adequate funding for initial construction.

Figure 16. 2009 storm damage to Ocean City geotextile sand bags.

The Great Egg Harbor and Peck Beach project is located at the northern end of Reach 3 in the Ocean City area. Initial construction at Peck Beach was completed in 2 phases during October 1992 and March 1993. Approximately 2,618,000 and 2,727,000 cubic yards of sand was placed on the beach from Surf Rd. southwest to 34th St.

Subsequent to the initial work, periodic nourishment has been performed five times during 1994/1995, 1997, 2000, 2004, and 2010. A total volume of 13.3 million cubic yards was placed on the beach as part of this Federal project since 1992. The ebb shoal area at Great Egg Harbor was used as the borrow site.

Short-term rates of shoreline change shown in Figure 3 for Peck Beach are influenced by these nourishment projects. In the absence of renourishment rates of erosion along the entire Peck Beach shoreline would have been higher than illustrated in Figure 3. In addition to the Federal Shore Protection projects, the State of NJ teamed with municipal interests to complete nourishment projects in Ocean City. An additional 360,000 cubic yards was placed on the beach during the 1995 periodic nourishment, and 303,000 cubic yards during the 2000 periodic nourishment.

The only other beach nourishment work in Reach 3 has been in Sea Isle City and Strathmere, where the State of NJ participated with local sponsors to restore the beaches. Most recently in 2009-2010, beaches in Sea Isle City between 1st and 15th Sts. and 40th and 52nd Sts. were nourished with 394,780 cubic yards of sand. Material dredged from Corson Inlet was also used to nourish beaches in Stathmere between Seaview and Williams and Webster and Polk Sts. A total volume of 891,000 cubic yards was used for the Strathmere project.

D. Reach 4

The southern end of Reach 4 is marked by Great Egg Harbor Inlet, which is not a Federal navigation project. The only structures at Great Egg Harbor Inlet are a stone revetment and jetty located at the southern end of Longport, constructed by the State in 1993. The northern end of Reach 4 is marked by Absecon Inlet, a Federally-authorized navigation project established in 1948. Absecon Inlet is stabilized on the north and south with a combination of coastal engineering structures (jetties, groins, revetment). While the inlet has been dredged by the USACE in the past (1957 and 1978), it does not require annual maintenance dredging.

The shoreline of Absecon Island extends through Longport, Margate, Ventnor, and Atlantic City, and is densely developed (Figure 18). The predominant land use in the communities of Longport, Margate, and Ventnor is residential, while Atlantic City is heavily commercialized. The developed oceanfront southwest of Atlantic City is characterized by a continuous row of separate residential dwellings interspersed with high rise condominium complexes, motels, hotels, and restaurants. Development density and commercialization increase with proximity to Atlantic City (Figure 17). The oceanfront of Atlantic City is characterized by a continuous row of hotels, casinos, and shops.

Figure 17. Coastal development in Atlantic City.

In Longport and Margate, the oceanfront buildings are located either on top of or immediately behind a maintained dune, or in areas where no dune system exists. In Ventnor and Atlantic City, the oceanfront buildings are located behind a maintained dune and boardwalk. The year round population of Absecon Island is a fraction of the total number of visitors during the summer, as the area attracts many tourists and recreational beach users.

Shore protection structures in Reach 4 include timber and concrete bulkheads, concrete seawalls, stone revetments, and stone and timber groins. In Longport, the entire oceanfront is protected by bulkheads and seawalls. A total of 4,050 feet of bulkhead, and 3,300 feet of concrete seawall and stone revetment protects the developed shoreline. These structures were built originally in 1917

Figure 18. Anthropogenic Factors in Reaches 4 and 5.

and rehabilitated in 1981. The entire shoreline of Margate is protected by 8,450 feet of timber bulkheads constructed between 1957 and 1964, and most recently modified in 1993. Ventnor has 5,300 feet of concrete bulkhead and 3,400 feet of timber bulkhead. The concrete bulkheads in Ventnor were constructed between 1925 and 1935, and the timber bulkheads were constructed between 1950 and 1952.

Bulkheads in Atlantic City are mostly confined to the shoreline fronting Absecon Inlet and were constructed in 1993. The bulkhead system is combined with a stone revetment providing additional toe protection. A 300 foot bulkhead along the inlet from Atlantic Ave. to Euclid Ave., and a 1,000 foot bulkhead (now buried by sand) facing the ocean from Seaside Ave. to Metropolitan Ave. were constructed in 1935. Eight (8) groins were also built between 1930 and 1958 along the inlet frontage. The Oriental Ave. jetty, a federal project forming the southern entrance to Absecon Inlet, was constructed in 1948, extended in 1962, and repaired by the State in 1983. There are twenty-nine (29) groins distributed along the ocean facing shoreline of Absecon Island, mostly concentrated in Atlantic City. Of these structures, only nine (9) stone groins are functional. The remaining timber and crib groins have fallen into disrepair and are permeable.

In 2004 the USACE completed initial construction of the Federal Shore Protection project for Absecon Island. The project included beachfill with dune protection in Atlantic City and Ventnor City, but did not complete the planned nourishment in Margate or Longport. Funding to date has not been sufficient to complete initial construction along the south end of Absecon Island, or to complete renourishment according to the 3-yr cycle. The authorized borrow site for the beachfill and dune protection is Absecon Inlet (Figure 18). Monitoring and design of a bulkhead authorized for Atlantic City are currently ongoing

E. Reach 5

The southern end of Reach 5 is marked by Absecon Inlet, a Federal navigation project authorized in 1948. The northern end is marked by Little Egg Inlet, which forms a natural entrance to Great Bay. The barrier islands of South and North Brigantine Island are located between the two inlets, and are separated by Brigantine Inlet. The southern barrier island is 6.5 miles long and contains the densely developed community of Brigantine, as well as a more northerly section maintained as a State Nature Area. The Edwin B. Forsythe National Wildlife Refuge comprises the entire 3.5 mile stretch of North Brigantine Island (Figure 18).

Predominant land use in Brigantine is residential. The developed oceanfront is characterized by a continuous row of residential buildings interspersed with condominium complexes and hotels (Figure 19). The south end of the island has a primary and secondary dune system that provides protection for the developed areas. The dune complex pinches out towards the north and the oceanfront buildings are located either on top of or immediately behind a small dune. The undeveloped portion of Reach 5 at North Brigantine State Nature Area and the Edwin B. Forsythe

National Wildlife Refuge features natural beaches, dunes, and back barrier wetlands.

Shore protection structures in Reach 5 designed to minimize erosion include bulkheads and groins. Between 1961 and 1968, five (5) timber and stone groins were constructed in Brigantine. Two bulkheads were built in 1964 and 1971, protecting approximately 2,300 feet of shoreline. The larger bulkhead between 15th and 9th Street N was damaged during the 1991-1992 storms, and was reconstructed in 1994.

Figure 19. Coastal development in Brigantine.

Two years after the bulkhead reconstruction, a beachfill project was constructed along 4,400 feet of shoreline from 9th Street N into the North Brigantine State Nature Area. This nourishment effort may have had some influence on the rates of shoreline accretion shown in Figure 4 for this area of Brigantine Island.

A federal Shore Protection Project authorized for 1.8 miles of coastline along the northern third of the city of Brigantine was completed in 2006. As part of initial construction, 648,000 cubic yards of sand was placed in 2006 between 15th Street N and 15th Street S. Sand for this project was obtained from a borrow area at Brigantine Inlet. Periodic renourishment following the 6 year cycle has not been completed; however, federal funds were received following the November 2009 northeaster to restore the beach to pre-storm conditions.

F. Reach 6

The southern end of Reach 6 is marked by Little Egg Inlet and the northern end by Barnegat Inlet. Long Beach Island stretches for 18.3 miles between the two inlets, through Beach Haven, Long Beach Township, Ship Bottom, Surf City, Harvey Cedars, and Barnegat Light (Figure 20).

Approximately 2.5 miles of the southern end of the barrier is in a natural pristine state maintained as the Forsythe National Wildlife Refuge. The remaining areas of Long Beach Island to the north are densely developed residential and commercial properties. Oceanfront buildings are located immediately behind or on the landward slope of the island's single frontal dune line. An exception to this development pattern occurs in the community of Barnegat Light, located at the northern end of Reach 6 immediately adjacent to Barnegat Inlet. Residential development in this area is protected by a 500 to 2,000 feet wide dune system built from sediment accumulated against the south Barnegat Inlet jetty (Figure 21).

Shore protection structures in Reach 6 are limited to groins. A total of 101 groins spaced at intervals ranging from 750 to 1,000 feet are located along the developed portion of the barrier between Barnegat Inlet and the southern end of Long Beach Township (Figure 21). The groins range in length from 250 to 420 feet, and are constructed of both timber and stone materials. At various times during the year certain groins are completely covered by sand. During other periods, however, the intertidal areas of the beach are below the crest elevation of the groins, and there is minimal sediment transport from one groin compartment to the next.

Figure 20. Coastal dunes protecting development in Barnegat Light.

Reach 6 contains one federally authorized Shore Protection Project. The Barnegat Inlet to Little Egg Inlet project provides flood and coastal storm damage reduction with a beachfill and dune along the oceanfront of the entire island. Initial construction in Surf City and a portion of Ship Bottom was completed during 2006-2007. Approximately 886,000 cubic yards of sand from an offshore borrow site was placed over 8,100 feet of ocean from North 25th Street in Surf City to South 5th Street in Ship Bottom. Additional funding is needed to complete the remaining portions of the project and to perform the periodic renourishment on the approved 7-yr cycle.

The Barnegat Light area immediately south of the inlet is not included in plans for initial construction of the federal Shore Protection Project due to low background erosion and the wide coastal dune (Figure 21). This area was filled with sediment between 1987 and 1991 when the south jetty at Barnegat Inlet was realigned nearly parallel with the north jetty. The high accretion rates shown in Figure 5 for Barnegat Light are due in part to fill placed during this jetty reconstruction.

G. Reach 7

The southern end of Reach 7 is marked by Barnegat Inlet, a Federal navigation project stabilized with arrowhead shaped rock jetties in 1940. To alleviate shoaling and navigation problems, reconstruction of the southern jetty took place between 1987 and 1991 when the jetty was aligned with the northern jetty. Manasquan Inlet forms the northern end of Reach 7, and Island Beach extends nearly 24 miles between the two inlets. The southern end of Island Beach is maintained in a natural state as Island Beach State Park. North of the State Park the barrier beach extends through Berkeley Township, Seaside Park, Seaside Heights, Lavallette, Dover Township, Brick Township, Mantoloking, Bay Head, and Point Pleasant Beach (Figure 22).

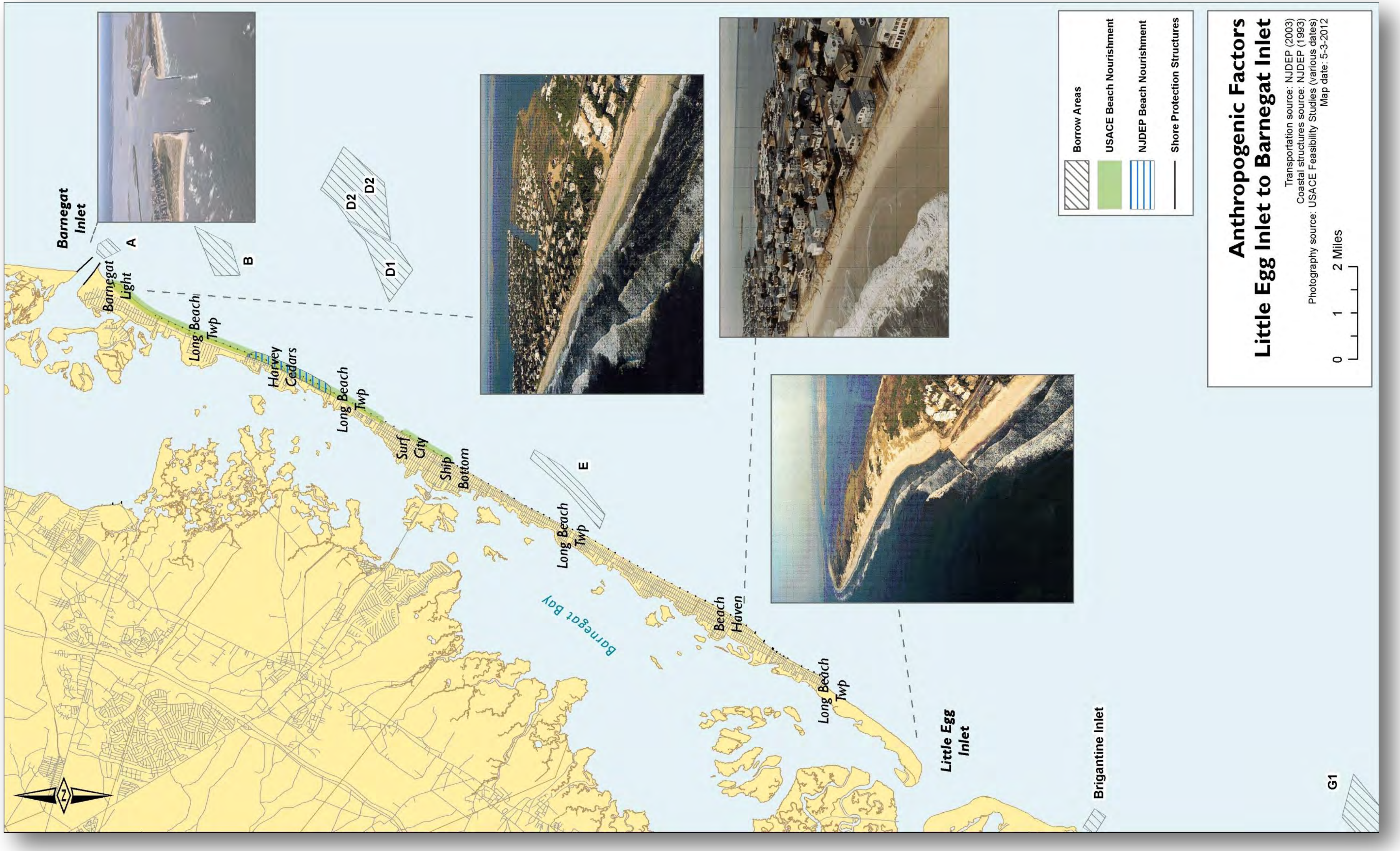


Figure 21. Anthropogenic Factors in Reach 6.

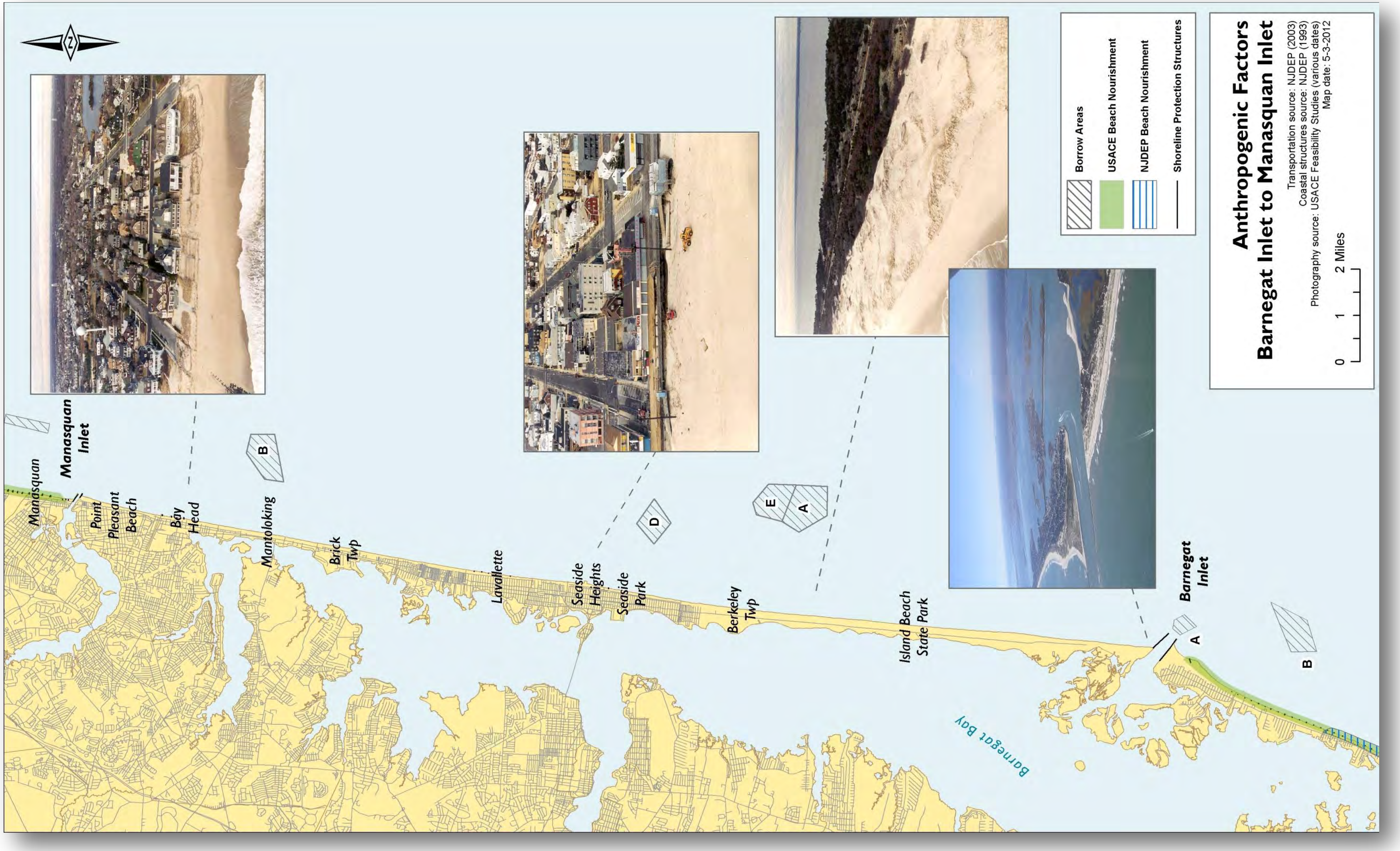


Figure 22. Anthropogenic Factors in Reach 7.

With the exception of Island Beach State Park the barrier is densely developed. Predominant land use is residential, with commercial properties along the major roadways and along the ocean facing boardwalks of Seaside Heights and Point Pleasant Beach. The oceanfront buildings are generally located on top of or immediately behind a maintained dune, or in areas where no dune system exists. The undeveloped portion of Reach 7 at Island Beach State Park features primary and secondary dunes in their natural state.

Shore protection structures on Island Beach include bulkheads, seawalls, and multiple groins. Seaside Park is protected by a 1,350 foot long bulkhead and Bay Head has a 4,300 foot long seawall. A total of sixteen (16) groins, constructed of timber and stone are located along the beach; nine (9) in Lavallette and seven (7) in Bay Head (Figure 23).

Reach 7 contains the Manasquan Inlet to Barnegat Inlet federally authorized Shore Protection Project. The project extends 14 miles from Berkeley Township northward to Point Pleasant Beach at Manasquan Inlet. Island Beach State Park was not included in the federal project based on minimal storm damage reduction benefits and State agencies' desires to preserve the area in its natural setting. An offshore borrow site was authorized for the initial fill of 10 million cubic yards, and for periodic nourishment every 4 years. Initial construction of the project is awaiting adequate funding.

Figure 23. Groins in Bay Head.

H. Reach 8

Manasquan Inlet forms the southern end of Reach 8. The inlet is a federally authorized navigation project stabilized with rock jetties in 1933, reinforced with dolosse in 1982, and rehabilitated in 1997. Maintenance dredging every 2-3 years provides safe navigation through Manasquan Inlet, removing an average of 40,000 to 50,000 cubic yards each time. Most recently, the USACE Currituck hopper dredge was used to maintain the channel, with placement of material at an offshore site.

Reach 8 extends 6 miles north of Manasquan Inlet to Shark River Inlet, through the communities of Manasquan, Sea Girt, Spring Lake, and Belmar (Figure 24). Development in this area is dense and the predominant land use is residential with commercial establishments along the major roadways. The oceanfront buildings are primarily located behind boardwalks with a single row of dunes and beach in front. Some areas in Manasquan and Belmar do not contain protective dune resources.

Shark River Inlet is another federal navigation project located between

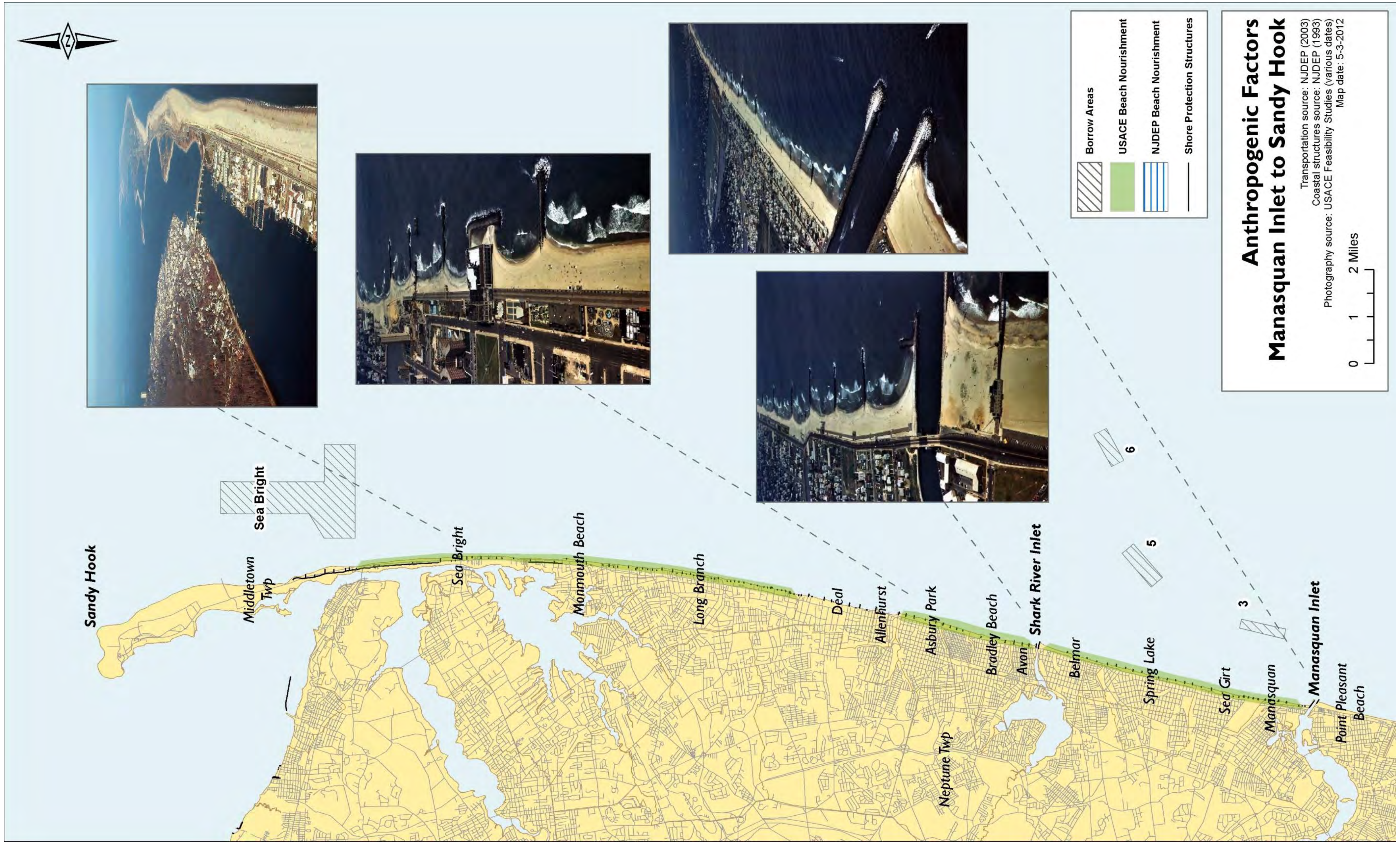


Figure 24. Anthropogenic Factors in Reach 8.

Belmar to the south and Avon to the north. The inlet was stabilized by two parallel stone jetties between 1948 and 1951. An external, shore-parallel spur was subsequently added to the north jetty to protect against erosion during storms. Until 2000, Shark River Inlet required infrequent dredging every 7 to 10 years. Since 2000 shoals at the entrance to the inlet required dredging one to two times per year, removing 20,000 to 25,000 cubic yards of sand. The material has been placed on the beach north of the jetty spur in Avon, or as a nearshore berm in approximately 10 to 14 feet of water.

Reach 8 continues 20 miles north to Sandy Hook, and includes the communities of Avon, Bradley Beach, Asbury Park, Allenhurst, Deal, Long Branch, Monmouth Beach, Sea Bright, and Middletown Township (Figure 24). With the exception of the northern beaches in Sandy Hook, this stretch of Reach 8 is heavily developed with residential and commercial properties. The beach is characterized by a narrow or non-existent beach, backed by a single row of dunes, or in some cases no dunes at all. The spit at Sandy Hook is maintained as a National Park, and is natural.

Numerous shore protection structures have been constructed in Reach 8 to minimize erosion. A series of twenty nine (29) stone groins and twelve (12) timber groins were installed on the beach between Manasquan and Shark River Inlets (Figure 25). North of Shark River Inlet the coastline is heavily structured with a combination of seawalls, revetments, and groins. A nearly continuous massive rubble mound stone seawall is present for 10 miles of coastline between Deal and Sea Bright. The seawall was built in sections in 1898, 1947, and the 1950s, and recently rehabilitated by the State in 2009-2010.

The federally authorized Sandy Hook to Barnegat Inlet, NJ beach erosion control project covers 21 miles of critically eroded shoreline. The project represents the largest beach nourishment project ever undertaken by the USACE, and is the largest beachfill project, in terms of volume, in the world.

The project area contains two sections: Section I extends for 12 miles from Sea Bright to Ocean Township (Deal); Section II extends for 9 miles from Asbury Park to Manasquan Inlet. Initial construction in the Monmouth, Sea Bright, and Long Branch areas of Section I was completed between 1994 and 1999. A total of 12,700,000 cubic yards of sand was pumped from offshore borrow sites. Subsequently Monmouth and Sea Bright beaches were renourished in 2001-2002, placing 2,100,000 cubic yards of sand from offshore sources. Initial construction in Section II was completed with the placement of 7,200,000 cubic yards of sand. The south reach of Section II between Manasquan and Shark River Inlets was completed in 1999, while the north reach between Shark River Inlet and Asbury Park was completed in 2001. All further work for renourishment in both Sections is subject to availability of funding.

Sediment Sources and Sinks

Sources and sinks of sediment along the NJ coast help shape the shoreline. Information in the Philadelphia (USACE-NAP, 2006) and New York District (USACE-NAN, 2006) sediment budget reports for the time period 1986 to 2003 identifies sediment sources and sinks for each study Reach.

Figure 25. Groin field north of Manasquan Inlet.

Annual rates of net sediment transport into and out of sub-regions within each study Reach were determined using the two USACE sediment budget studies. Sub-regions were classified as a source or sink for sediment based on the net volume of material. For example, the Philadelphia District study for the Cape May sub-region shows a net transport of 62,000 cy/yr into the area from the north, and a net transport of 212,000 cy/yr out of the area towards the Cape May Meadows sub-region. The net transport for the Cape May area is -150,000 cy/yr (volume entering – volume leaving), indicating more sediment exits the sub-region than enters it.

Areas with negative balances for net transport were classified as sediment sources and areas with positive balances were classified as sediment sinks. In general, sediment sources are characterized by eroding shorelines and sediment sinks are characterized by accreting shorelines.

Tidal inlets also serve as important sources and sinks of sediment. Annual transport rates to the ebb- and flood-tidal shoals shown in the USACE sediment budget studies were used to define sinks of sediment in the inlet regions. A brief summary of the sediment budget contributions and losses for each study reach is provided below.

- **Reach 1: Cape May Point to Cape May Inlet** – Most shoreline areas in Reach 1 serve as a source of sediment to the littoral system, especially the Cape May Point and Cape May City sub-regions that supply between 50,000 and 150,000 cubic yards of sand per year, respectively (Figure 26). Beach erosion has been a problem in these areas as evidenced by the shoreline change rates between 1977 and 2000 (Figure 2) and the history of shore protection efforts (e.g., groin construction, Beachsaver Reef, beach nourishment). Although shoreline change data show accretion in Cape May City, the data have been influenced by successive renourishment efforts.

  Cape May Meadows is identified as a sediment sink based on the USACE sediment budget study (Figure 26). This conclusion is partially supported by the shoreline change results showing accretion along the eastern end of the embayment; however, the western portion of the beach has experienced notable erosion (Figure 2). The large-scale beach nourishment project in this area during 2005 suggests beach erosion is a problem, and that this sub-region may be more appropriately classified as a sediment source. Further investigation and refinement of the sediment budget is warranted.

Dredging records indicate Cape May Inlet is a sediment sink, as material must be dredged from the entrance channel annually to maintain navigation.

- **Reach 2: Cape May Inlet to Townsends Inlet** – The two barrier beaches in Reach 2 are similar since the southern ends of the barriers act as sediment sinks and the northern ends act as sediment sources (Figure 26). These findings are supported by the shoreline change data shown in Figure 2 (southerly accretion and northerly erosion). The greatest changes in Reach 2 take place between Wildwood and Lower Township where approximately 223,000 cy/yr is removed from the littoral system through beach accretion at the south end, and 266,000 cy/yr is supplied through beach erosion in the North Wildwood area. Stone Harbor and south Avalon communities serve as a sediment sink, removing approximately 45,000 cubic yards of sediment per year from the littoral system through beach accretion. The northern end of Avalon provides a source of nearly 244,000 cubic yards of sand per year through beach erosion.

  Sinks of sediment also exist at Hereford and Townsends Inlets as material builds up on the flood- and ebb-tidal shoals. Erosion of the Stone Harbor beach flanking the north side of Hereford Inlet forms a small source of material to the inlet. These losses/additions of material influence the quantity of sand available for bypassing at each inlet.

- **Reach 3: Townsends Inlet to Great Egg Harbor Inlet** – Both barrier beaches in Reach 3 are shown to be sediment sources (Figure 27). Most material is supplied by the northern end of Ocean City with 525,000 cy/yr, followed by Ludlam Island which contributes approximately 105,000 cy/yr. The shoreline change data show net erosion for Ludlam Island which supports the finding that this sub-region acts as a sediment source (Figure 3). Classification of the northern end of Ocean City as a significant sediment source is supported by the long-term history of beach renourishment in this area. The moderate to low rates of erosion, coupled with areas of shoreline accretion seen in Figure 3 are influenced by these renourishment activities, and do not reveal the true nature and extent of sediment movement from the beach. The southern end of Ocean City is also classified as a source of material to the littoral system. Based on the USACE sediment budget study contributions are small, on the order of 76,000 cy/yr. This conclusion is contradictory to the shoreline change results, which show high rates of erosion immediately north of Corson Inlet and a significant area of shoreline accretion along the central portion of the barrier. Further refinement to the sediment budget could resolve these differences.

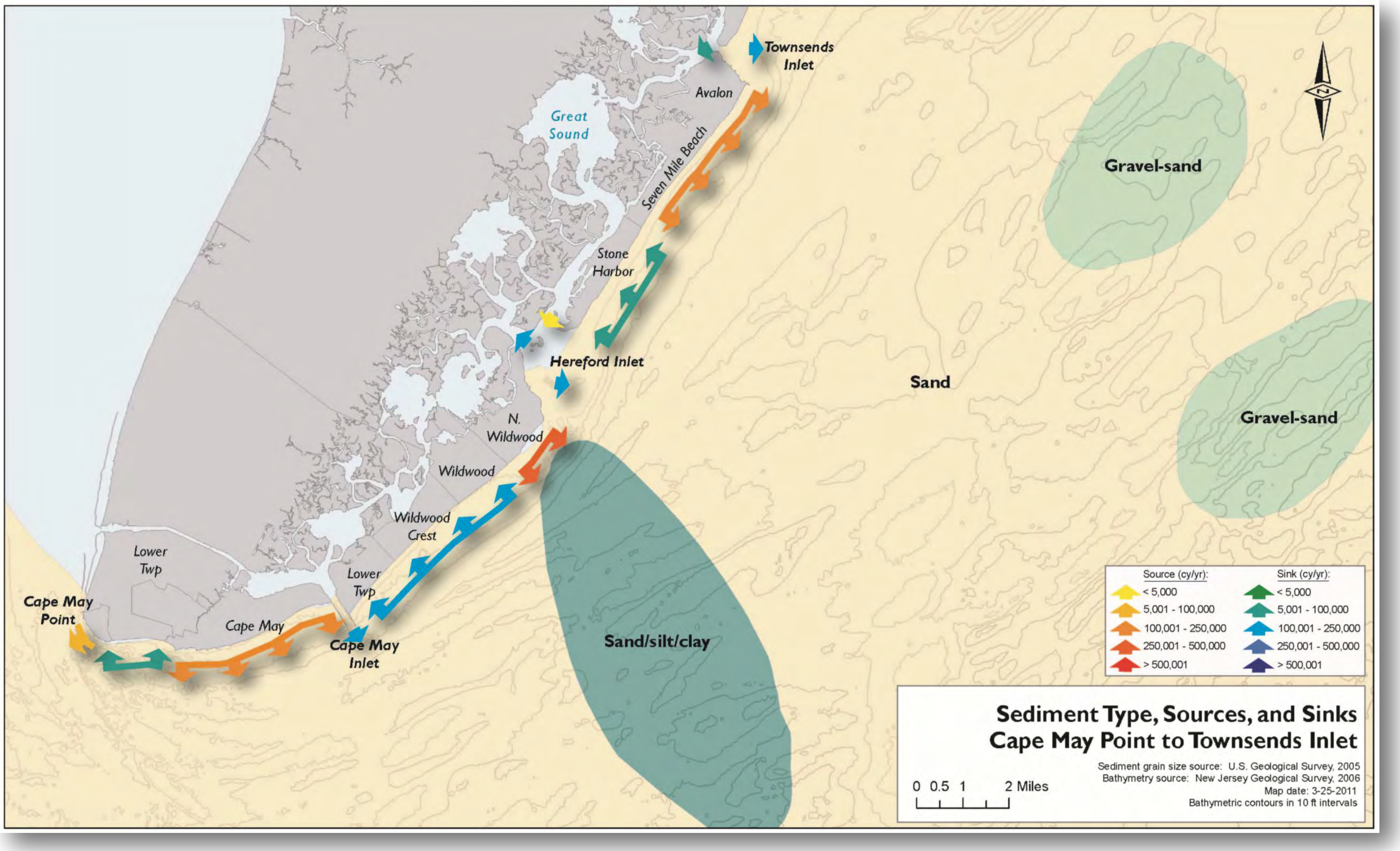


Figure 26. Sediment Sources and Sinks in Reaches 1 and 2.

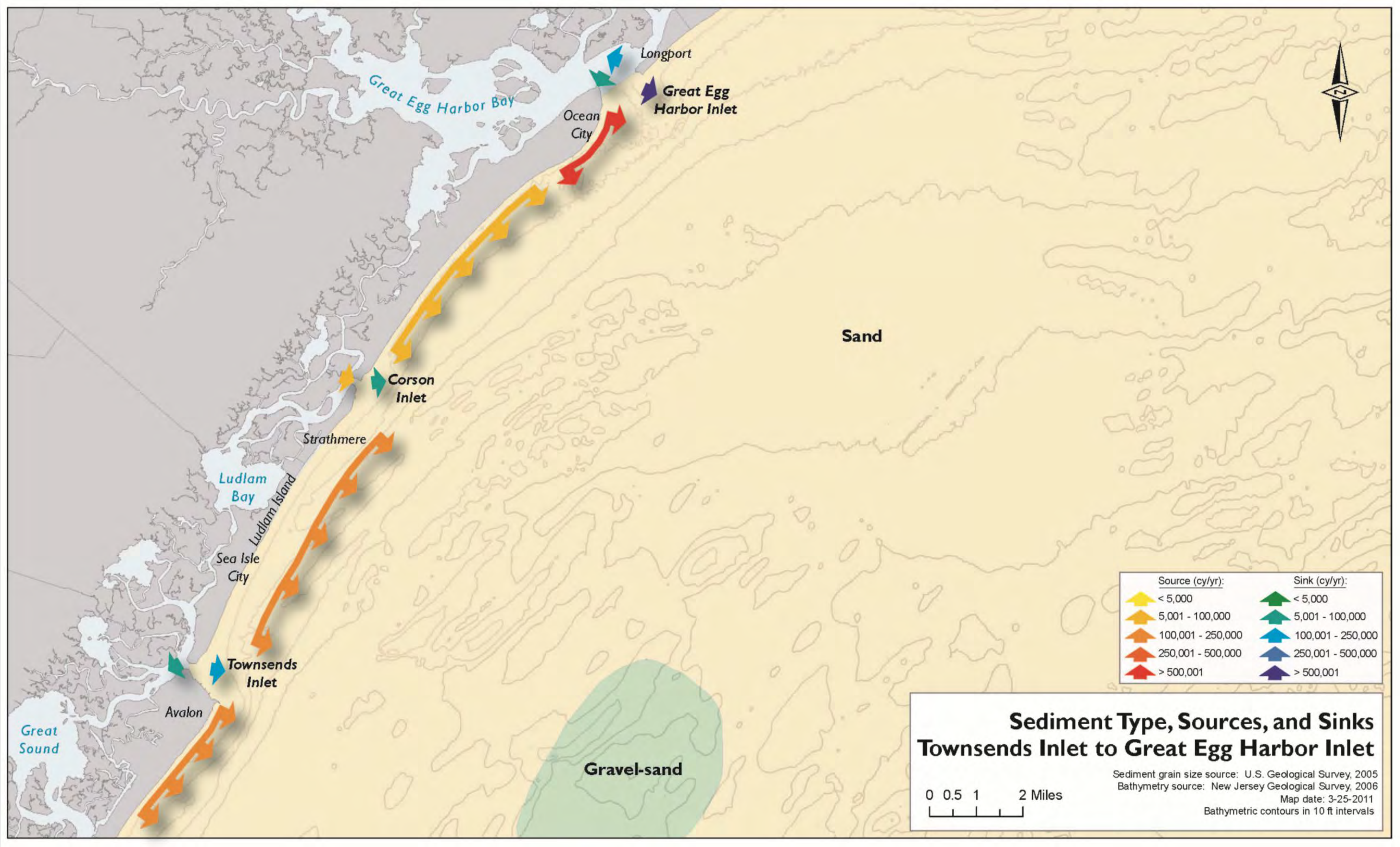


Figure 27. Sediment Sources and Sinks in Reach 3.

Corson Inlet, located near the center of Reach 3, serves as both a source and sink for sediment. Erosion of the flood shoal contributes sand to the inlet system, while growth of the ebb shoal accounts for a loss of sediment.

At Great Egg Harbor Inlet, sediment accumulation on the flood- and ebb-shoals, and on the inlet facing shoreline of Ocean City are sinks for sediment. Of particular importance is the ebb shoal at Great Egg Harbor Inlet, which removes on the order of 630,000 cy/yr of sediment from the littoral system.

- **Reach 4: Great Egg Harbor Inlet to Absecon Inlet** – Shoreline areas in Reach 4 on Absecon Island serve as sediment sources that provide 200,000 cubic yards of sand per year (Figure 28). This finding is consistent with the shoreline change information that shows net erosion (Figure 4). The beach nourishment in 2004 as part of the federally authorized shore protection project supports the classification of Absecon Island as a sediment source.

  The USACE sediment budget for Absecon Inlet indicates the system provides both sources and sinks for sediment. Growth of the ebb shoal and accretion along the inlet facing shoreline of South Brigantine Island serve as storage areas for sediment, while erosion of the flood shoal inside the inlet provides a source of material.

- **Reach 5: Absecon Inlet to Little Egg Inlet** – All shorelines in Reach 5 are classified as sources of sediment (Figure 28). North Brigantine Island contributes 450,000 cubic yards of sediment per year. This is consistent with the shoreline change analysis that shows significant rates of erosion for North Brigantine Island (Figure 4). Sediment contributions from South Brigantine Island are approximately 92,000 cy/yr. Beach nourishment efforts by the USACE in 1996 and 2006 support the classification of this beach as a sediment source; however, the shoreline change data suggest that the southern end of the barrier is accretionary. Refinement of the sediment budget and shoreline data could resolve these differences.

  Sinks of sediment exist at Brigantine and Little Egg Inlets as material builds up on the flood- and ebb-tidal shoals. Sediment also is lost from the littoral system in shoreline areas flanking the inlets; south of Brigantine Inlet and north of Little Egg Inlet (Figure 28).

- **Reach 6: Little Egg Inlet to Barnegat Inlet** – Most of the barrier beach in Reach 6 serves as a sediment source to the littoral system (Figure 29). The primary exception occurs at the northern end of Long Beach Island in the community of Barnegat Light, which accumulates sediment. Quantities of sediment contributed increase from south to north. Between Long Beach Township (south) and Ship Bottom approximately 185,000 cy/yr are supplied through beach erosion. Further to the north between Surf City and Long Beach Township (north), approximately 270,000 cubic yards are contributed each year. These findings are generally consistent with

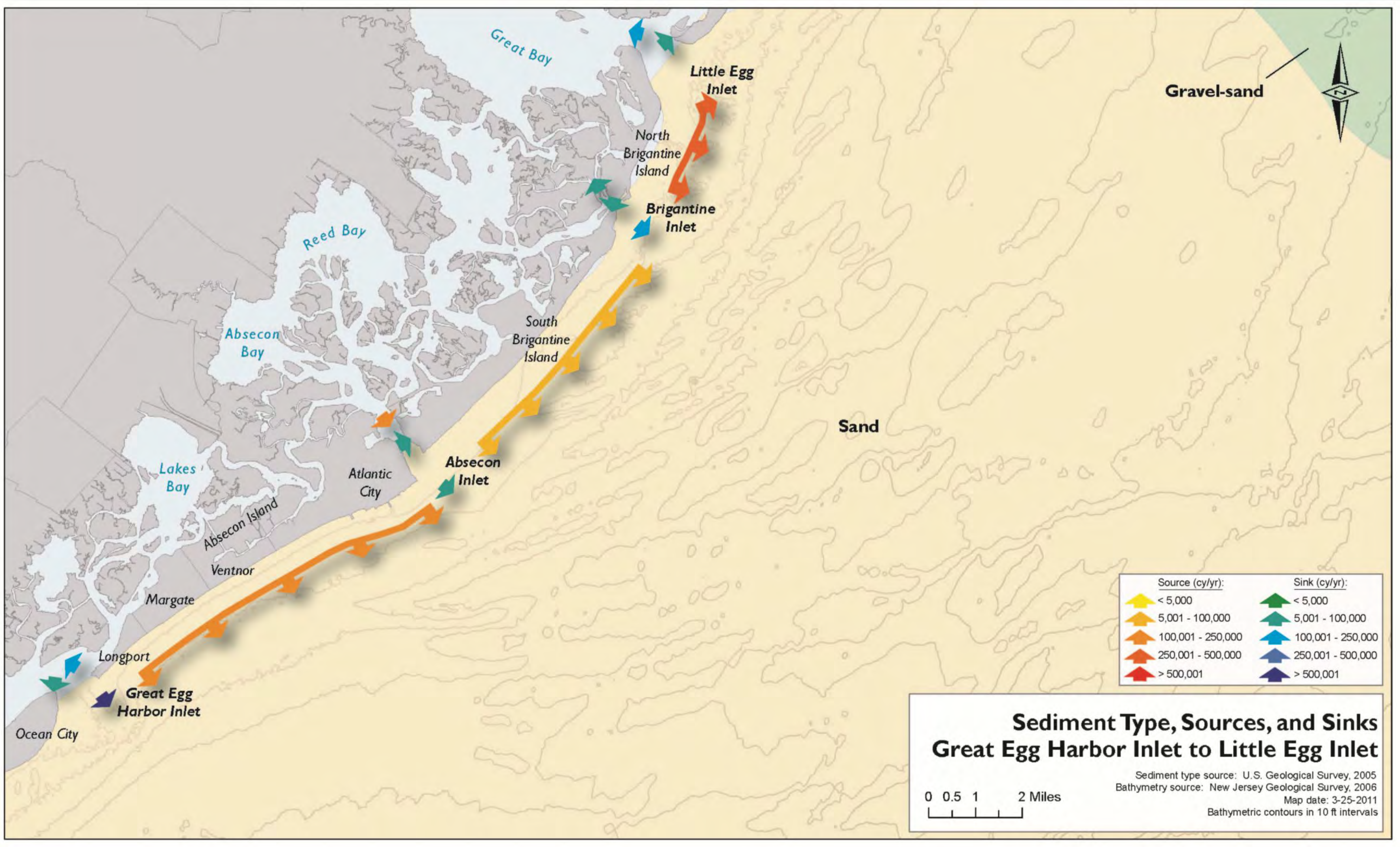


Figure 28. Sediment Sources and Sinks in Reaches 4 and 5.

- the shoreline change data presented for Long Beach Island showing net shoreline erosion (Figure 5). The Barnegat Light area is classified as a sediment sink, accumulating nearly 340,000 cubic yards of sand per year. The extraordinarily high rates of accretion in the shoreline change data for this area are partly explained by jetty reconfiguration and associated filling between 1987 and 1991. The shoreline orientation and inlet structures formed an area that traps sediment thus, creating a sediment sink.

  The USACE sediment budget for Barnegat Inlet indicates the system provides both sources and sinks for sediment. Growth of shoals inside the inlet is evidence of sediment accumulation, while erosion of the flood shoal to the west creates a source of material for potential transport to the ocean beaches.

- **Reach 7: Barnegat Inlet to Manasquan Inlet** – Beaches in Reach 7 are classified as sediment sources, with the quantity of material supplied decreasing significantly from south to north (Figure 30). The undeveloped Island Beach State Park area is shown to contribute 285,000 cubic yards of sediment per year, while the northern beaches between Seaside Park and Point Pleasant supply between 70,000 and 75,000 cy/yr. In general, the shoreline change results presented in Figure 6 support the sediment budget conclusions. Dredging records indicate Manasquan Inlet is a sediment sink, as material must be dredged from the entrance channel every 2 to 3 years to maintain navigation.

- **Reach 8: Manasquan Inlet to Sandy Hook** – Most shoreline areas in Reach 8 are shown to be sediment sources (Figure 31). The only exception occurs in the community of Deal near the center of Reach 8 which is classified as a sediment sink. Quantities of sediment contributed to the littoral system are generally lower than the other study Reaches to the south. Between Sea Girt and Belmar the rates of sediment contribution are 67,000 cy/yr. In the Bradley Beach, Asbury Park, and Sea Bright areas, the rates of sediment contributed to the littoral system are approximately 30,000 cy/yr. The Long Branch, Monmouth Beach, and Sandy Hook (Middletown Township) beaches are all shown to contribute between 129,000 and 178,000 cubic yards of sediment per year. In the community of Deal, the only Reach 8 sub-region classified as a sediment sink, rates of accumulation are 22,000 cy/yr. The sediment budget components are not consistent with the shoreline change data presented in Figure 7. The differences can be explained by the beach nourishment quantities of sediment in Reach 8 between 1994 and 2002. These projects skew the short-term shoreline change rates towards accretion, masking the long-term trend of shoreline erosion. Additional refinement of the sediment budget and shoreline information is warranted to resolve differences, and provide a basis for future management of these areas.

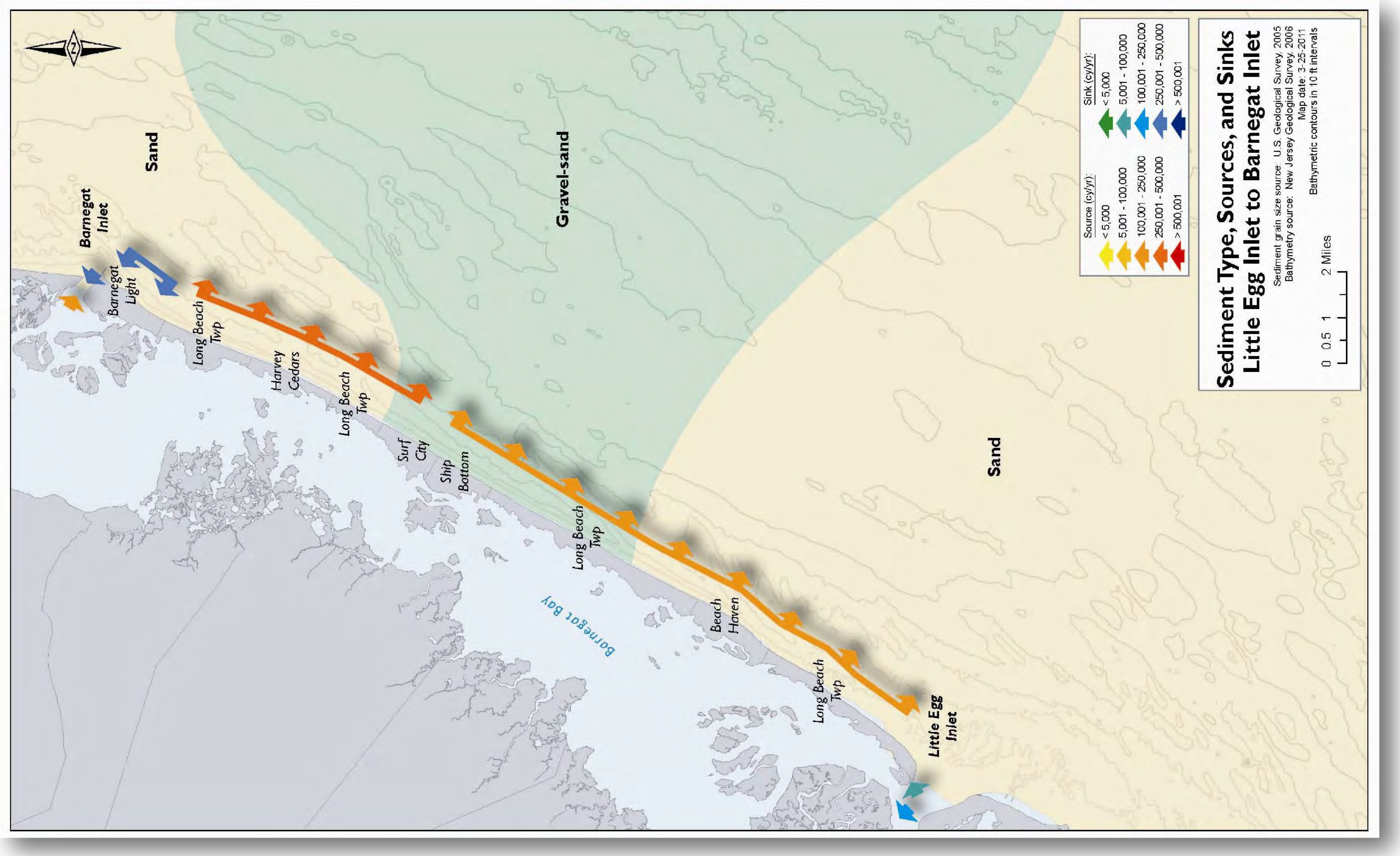


Figure 29. Sediment Sources and Sinks in Reach 6.

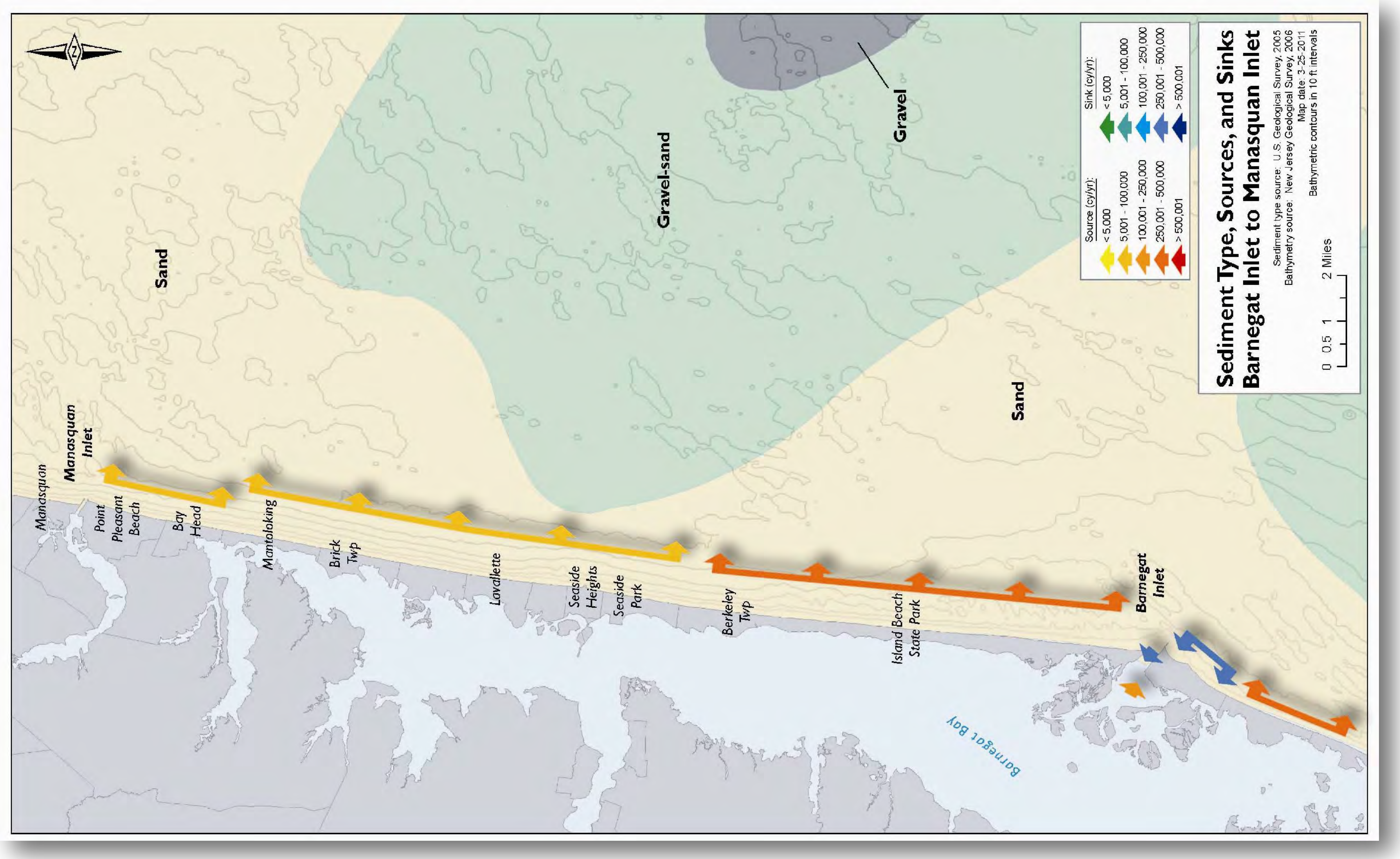


Figure 30. Sediment Sources and Sinks in Reach 7.

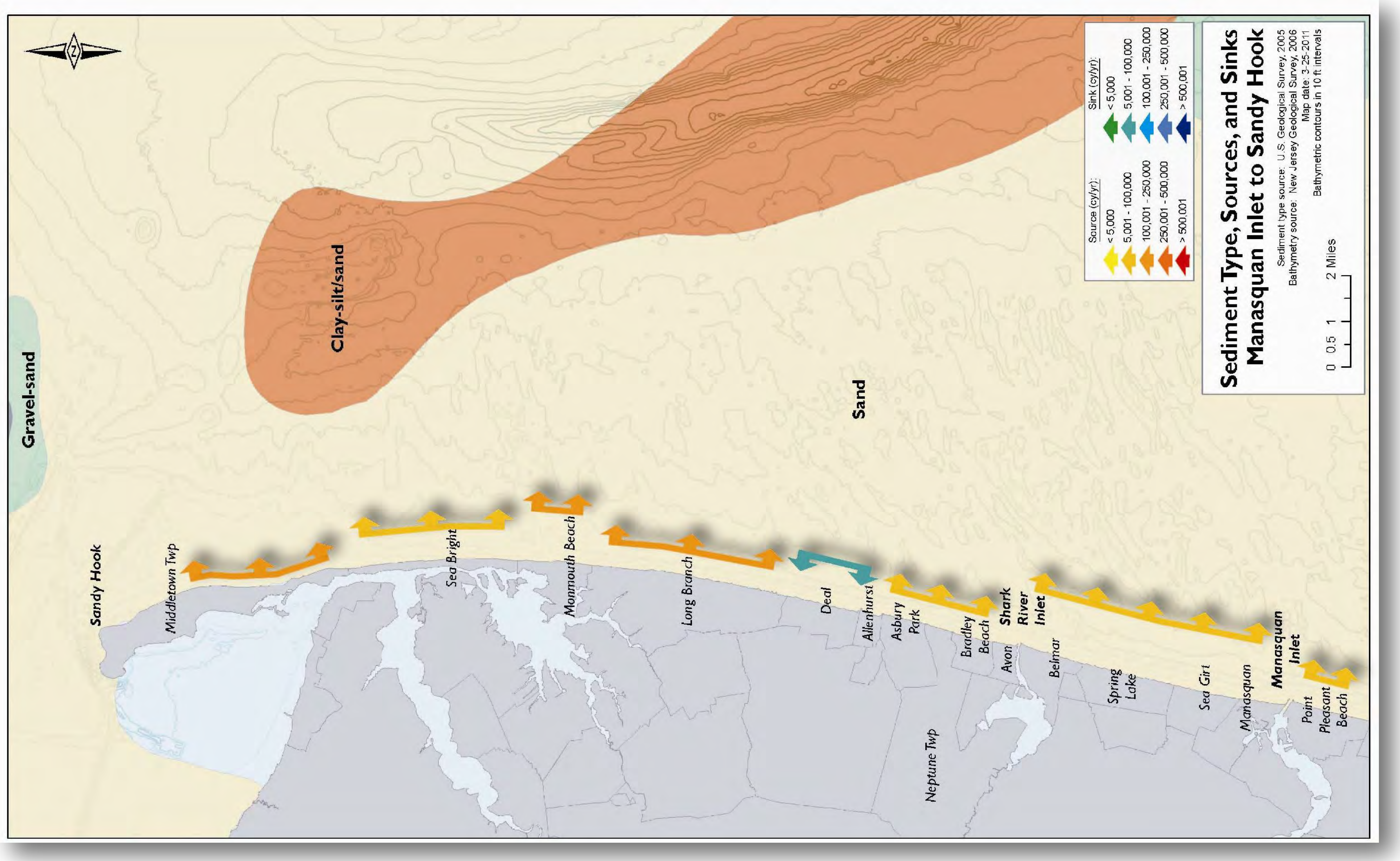


Figure 31. Sediment Sources and Sinks in Reach 8.

Sediment Transport and Inlet Bypassing

The direction and quantity of sediment transported along the NJ coastline by waves and currents serves as an important factor in shaping the coastal geomorphology of the region. Results from the Philadelphia (USACE-NAP, 2006) and New York District (USACE-NAN, 2006) sediment budget studies were combined to summarize longshore sediment transport rates and directions for the NJ shoreline. Sediment transport patterns along the coastline and around tidal inlets are illustrated in Figures 20 through 25. Inlet bypassing was assumed to be equal to the rate of transport entering the updrift side of each sub-region. Transport rates and directions were determined by calculating the net volume of material entering and exiting the sub-regions within each study Reach. For example, the Philadelphia District study for the north end of Ludlam Island shows an annual transport of 395,000 cubic yards moving to the south and 55,000 cubic yards moving to the north. The net transport pattern then becomes 340,000 cy/yr towards the south (volume entering – volume exiting).

Changes in the rate of longshore sediment transport affect beach erosion and accretion patterns. An increase in the longshore transport rate in the same direction results in beach erosion, whereas a decrease in the rate causes accretion. A divergence of longshore sediment transport accelerates beach erosion, where the transport patterns move sediment away from both sides of a nodel point. Conversely, a convergence of longshore sediment transport causes beach accretion, where sediment is transported into a particular stretch of beach from both sides. Both cases occur along the New Jersey shoreline. A brief summary of the longshore sediment transport and inlet bypassing patterns for each study Reach is provided below.

- **Reach 1: Cape May Point to Cape May Inlet** – The dominant direction of transport is east to west (Figure 32). Approximately 62,000 cubic yards of sediment bypasses Cape May Inlet from the north and enters the Cape May City sub-region. Rates of transport increase significantly from east to west as the beaches erode and supply sand to the littoral system. Net transport exiting the Cape May Point sub-region is shown to be 178,000 cy/yr.
- **Reach 2: Cape May Inlet to Townsends Inlet** – The dominant direction of transport is to the south, with approximately 251,000 cubic yards of material bypassing Townsends Inlet and entering the northern end of Reach 2 (Figure 32). Rates of transport nearly double along the length of Seven Mile Beach, increasing to 450,000 cy/yr in the community of Stone Harbor. To the south, Hereford Inlet receives significant quantities of sediment from Stone Harbor beaches and bypasses nearly one-third (142,000 cy/yr) to North Wildwood. Transport rates increase towards the center of Five Mile Island (Wildwood and Wildwood Crest), and decrease sharply at the south end of Reach 2.

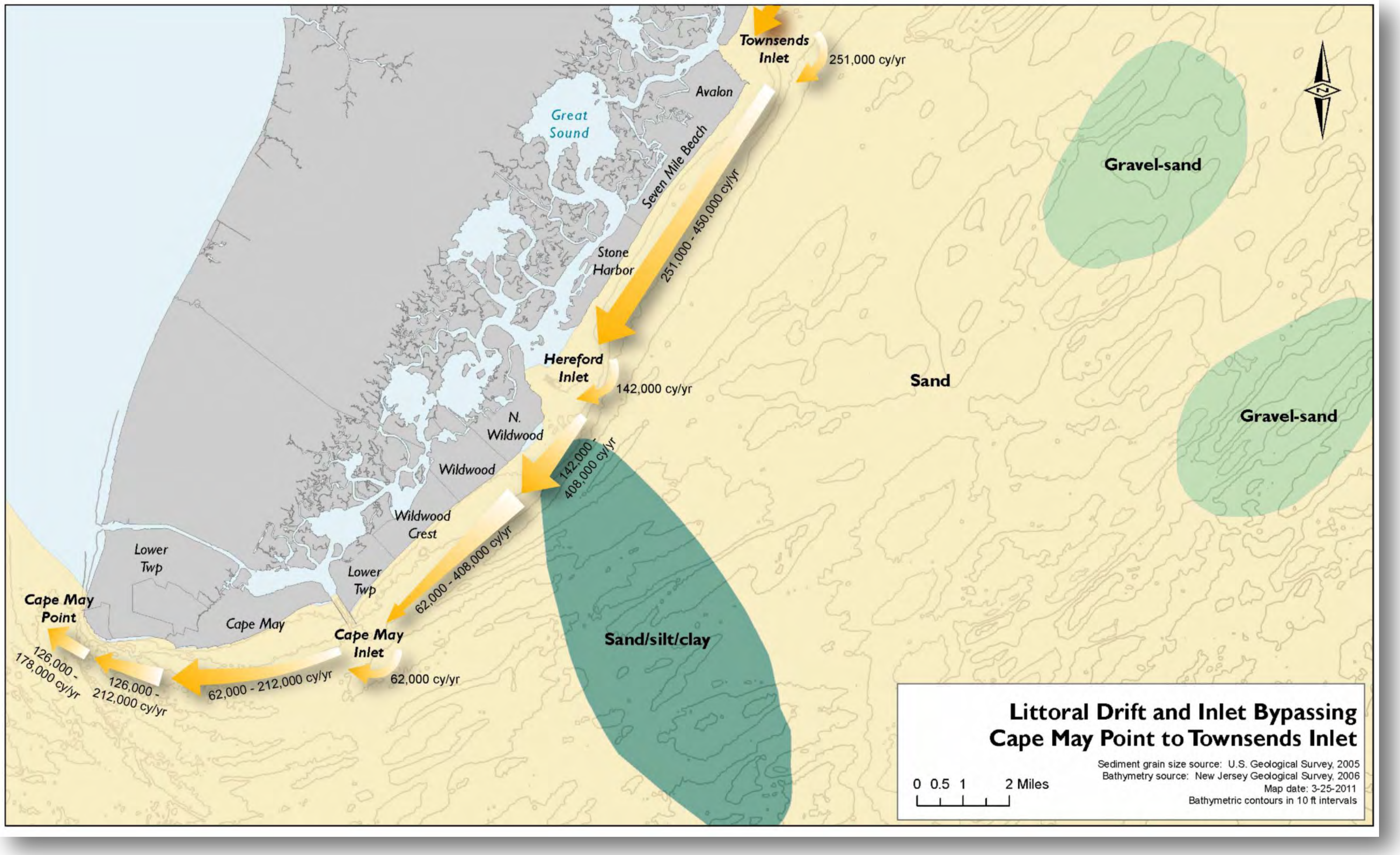


Figure 32. Sediment Transport Patterns in Reaches 1 and 2.

- **Reach 3: Townsends Inlet to Great Egg Harbor Inlet** – Net directions of longshore transport in Reach 3 are generally from north to south, with the exception of a nodal zone at the upper end of Ocean City where net transport is reversed (Figure 33). Transport rates on the barrier beach south of the nodal zone are relatively consistent, ranging between 229,000 and 305,000 cy/yr. Corson Inlet is shown to be a source of sediment to the littoral system, bypassing a greater volume of material (340,000 cy/yr) to the Ludlam Island sub-region than enters from the northern barrier. A gradual increase in the rate of transport continues from north to south along Ludlam Island, with 445,000 cy/yr being supplied to Townsends Inlet.

  Transport north of the nodal zone in Ocean City is predominantly to the north at a rate of 296,000 cy/yr (Figure 33). This material is supplied to Great Egg Harbor Inlet. Additional sediment is delivered to the inlet from the north, where the net transport rate from Absecon Island is 241,000 cy/yr. This information suggests that Great Egg Harbor Inlet serves as a sediment sink by trapping large quantities of material in the flood- and ebb-shoal systems.

- **Reach 4** – The dominant direction of longshore transport in Reach 4 continues to the south (Figure 33). Approximately 40,000 cubic yards of sand per year enters the sub-region from Absecon Inlet. Transport rates increase to 241,000 cy/yr towards the end of the reach in the community of Longport at Great Egg Harbor Inlet.

- **Reach 5** – Net directions of longshore transport in Reach 5 are from north to south (Figure 34). An exception occurs in the vicinity of North Brigantine Island where a nodal zone causes a reversal in transport to the north. Below the nodal zone transport rates along North Brigantine Island increase sharply from 55,000 to 395,000 cy/yr. Continuing to the south, Brigantine Inlet bypasses just over one-half of the material (168,000 cy/yr) to South Brigantine Island. Transport rates along the southern end of Reach 5 increase gradually to 260,000 cy/yr just north of Absecon Inlet.

  Net transport north of the nodal zone at North Brigantine Island is to the north at a rate of 55,000 cy/yr (Figure 34). This material is supplied to Little Egg Inlet. Additional sediment is also transported into Little Egg Inlet from the northern beaches at a rate of 265,000 cy/yr. The inlet forms a sink by removing sediment from the littoral system.

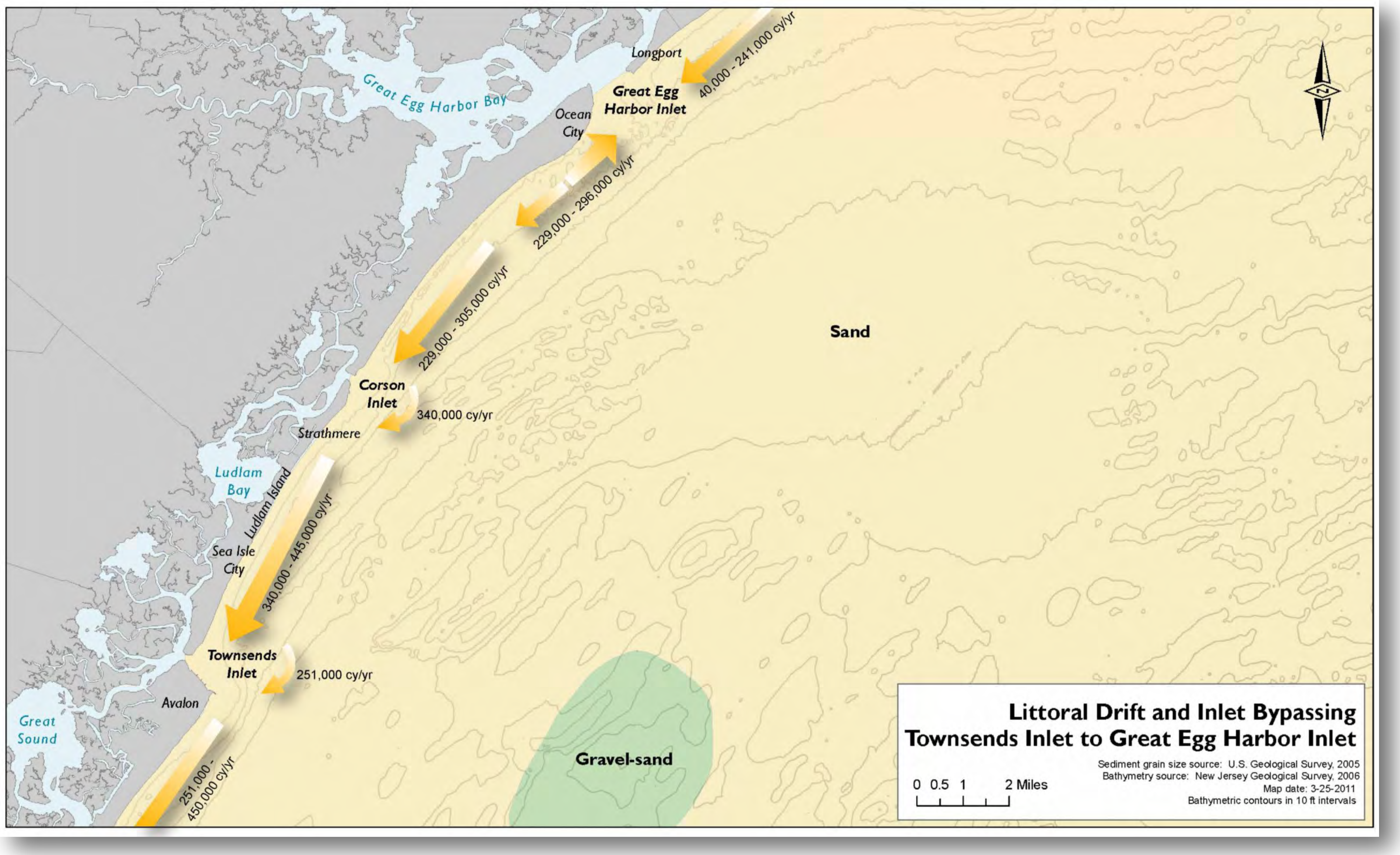


Figure 33. Sediment Transport Patterns in Reach 3.

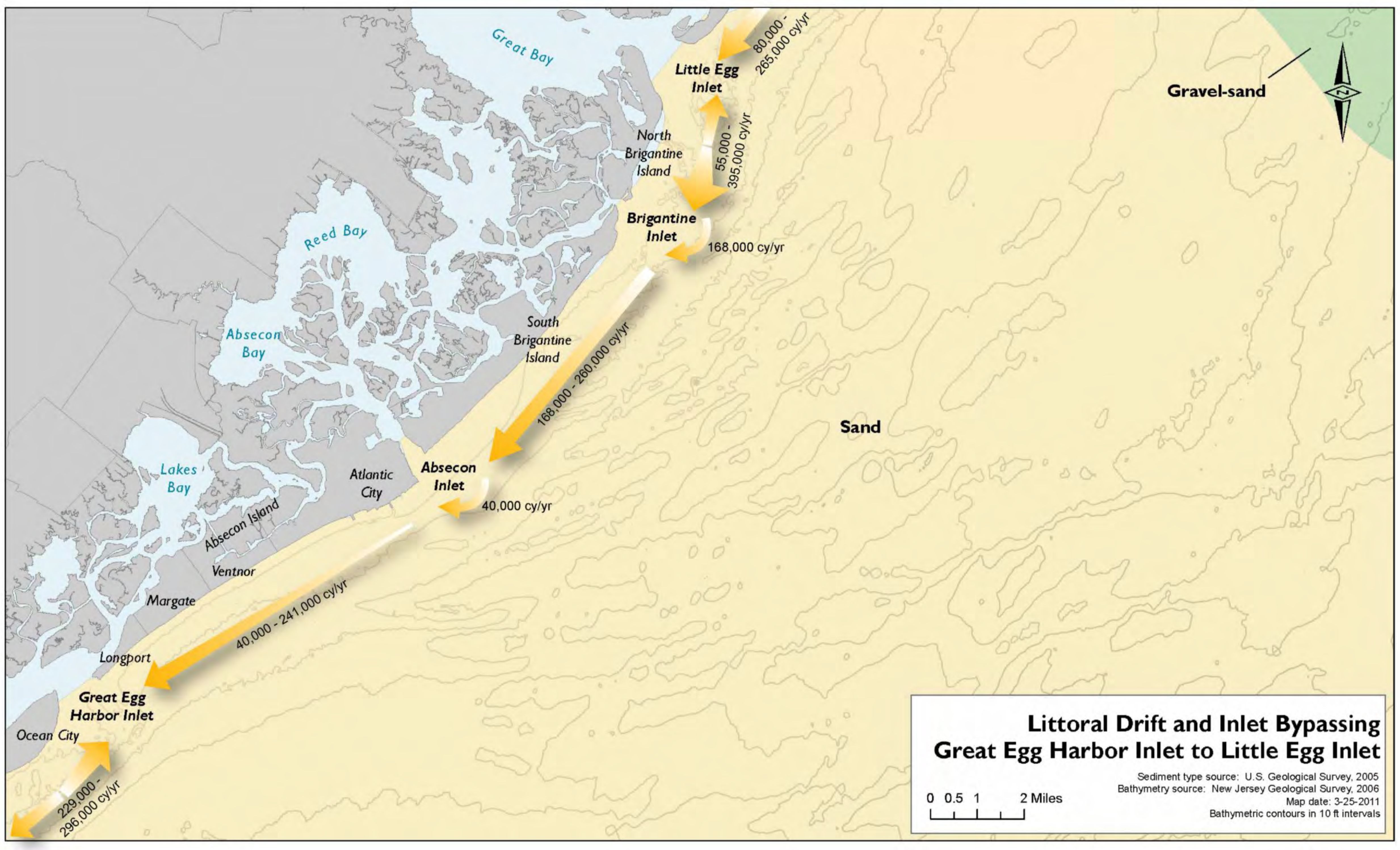


Figure 34. Sediment Transport Patterns in Reaches 4 and 5.

- **Reach 6: Little Egg Inlet to Barnegat Inlet** – Reach 6 forms a transition zone along the NJ shoreline where transport directions more frequently alternate (Figure 35). South of Harvey Cedars, net transport is to the south. Rates gradually increase from 80,000 cy/yr at Harvey Cedars to 265,000 cy/yr at Beach Haven and Long Beach Township (south) near Little Egg Inlet. A nodal zone at Harvey Cedars forms an area of net northerly transport extending into Long Beach Township (north) and the community of Barnegat Light. Transport rates to the north double over this short stretch of beach from 80,000 cy/yr to 190,000 cy/yr. A second nodal zone occurs at the northern end of Barnegat Light where net southerly transport from Barnegat Inlet supplies approximately 147,000 cubic yards of sand per year.

- **Reach 7: Barnegat Inlet to Manasquan Inlet** – Net directions of longshore transport along the South portions of Reach 7 are to the south, while net transport along the Northern beaches is to the north (Figure 36). As such, Reach 7 contains the regional nodal point along the NJ coastline dividing southward flowing sediment from northward flowing sediment. The nodal zone is located near the center of Island Beach State Park. Net transport south of the nodal zone is to the south, delivering approximately 270,000 cubic yards of sediment per year to Barnegat Inlet. As a result, shoreline change along Island Beach south of the nodal point is consistently erosional as material is transported towards Barnegat Inlet. Immediately north of the inlet the shoreline switches to accretionary as the eroded material accumulates. Northerly transport north of the nodal zone gradually increases from 15,000 cy/yr to 160,000 cy/yr at Point Pleasant Beach near Manasquan Inlet. Shoreline change in this region is predominantly erosional with increasing rates of beach loss towards the north.

- **Reach 8: Manasquan Inlet to Sandy Hook** – Net directions of longshore transport in Reach 8 are to the north (Figure 37). Manasquan Inlet bypasses approximately 135,000 cubic yards of sediment per year to beaches at the southern end of Reach 8. Transport increases steadily through the communities Asbury Park and Allenhurst, where rates reach 232,000 cy/yr. A slight decrease in the transport rate takes place in the vicinity of Deal, which results in net deposition of sand as shown in Figure 19. Further north between Long Branch and Sandy Hook, rates of sediment transport increase sharply from 232,000 cy/yr to 627,000 cy/yr.

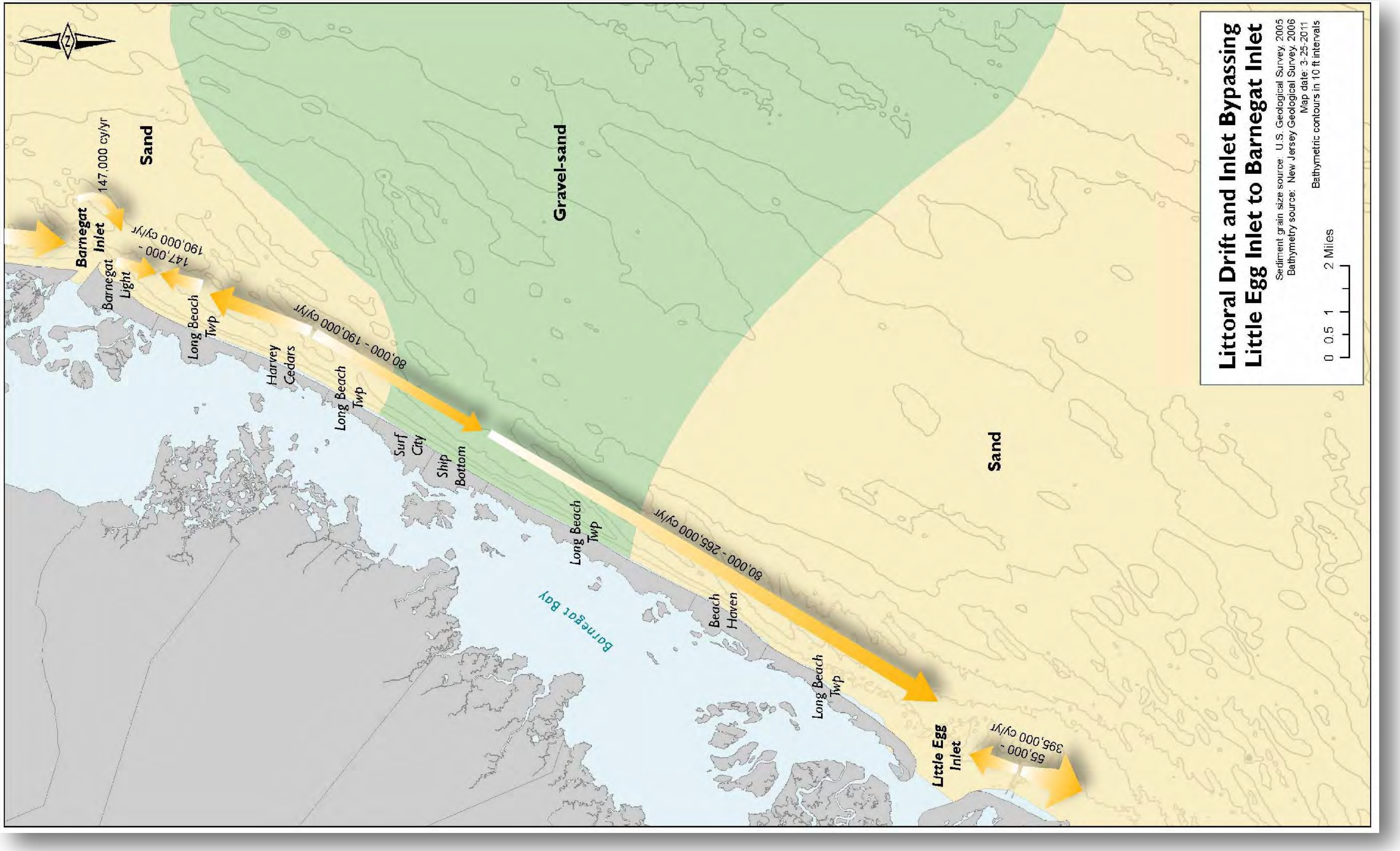


Figure 35. Sediment Transport Patterns in Reach 6.

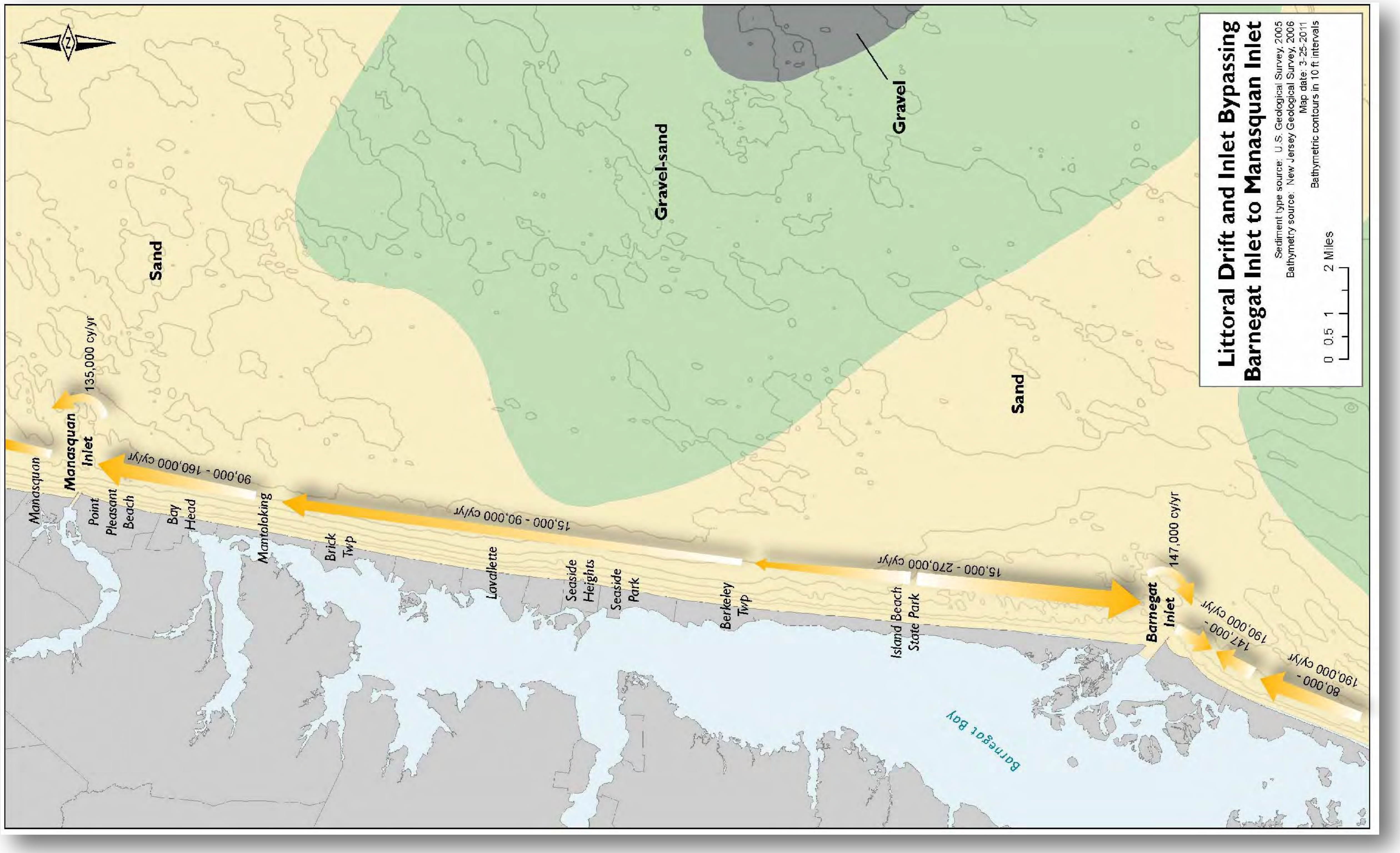


Figure 36. Sediment Transport Patterns in Reach 7.

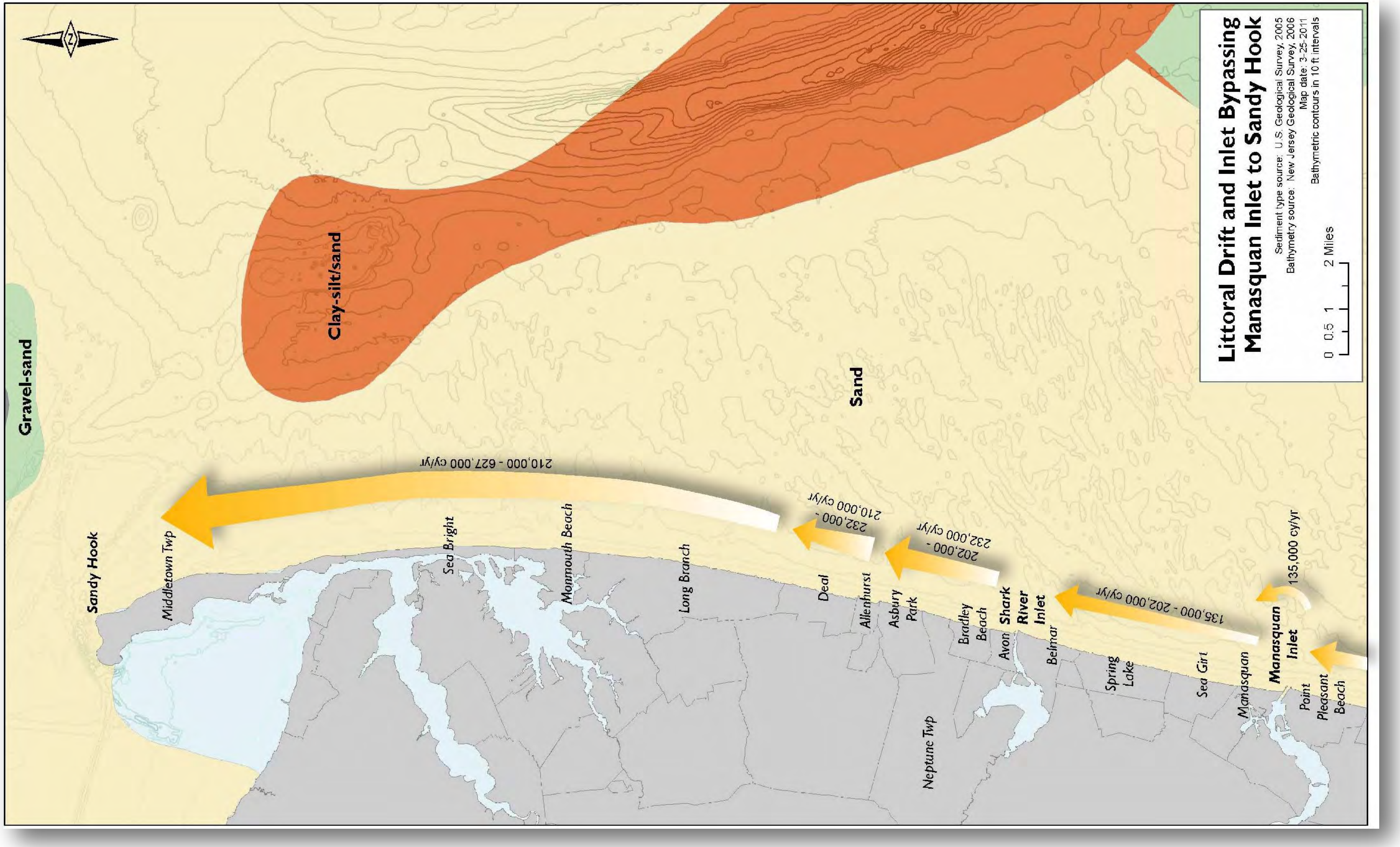


Figure 37. Sediment Transport Patterns in Reach 8.

RSM OVERVIEW

This section provides an introduction to the Regional Sediment Management (RSM) approach, and how it relates to the New Jersey Alternative Long-Term Nourishment (NJALTN) study. A tiered approach is defined as the basis for classifying specific alternatives that can be implemented in New Jersey to advance RSM strategies. Criteria are established for selecting alternatives to advance the primary objectives of the NJALTN study, namely to maximize the benefits of the investment through cost savings, reductions in sand requirements, and minimizing of environmental impacts.

Regional Sediment Management Defined

RSM is a system-based approach for managing and solving sediment-related problems by designing solutions that support a regional strategy. RSM addresses sediment management within a watershed or coastal system-, not just at the coast or along the shoreline. RSM defines system-wide sediment budgets as the basis for projects that optimize sediment to enhance the littoral system and minimize costs of managing sediment. Through RSM, the USACE is appropriated funding that addresses sediment management on a regional basis and helps implement projects not constrained by specific project, municipal, or State boundaries.

Managing sediments along the United States coast has historically been a difficult and costly challenge. As early as the 1800's, the War Department managed ports within the United States to maintain navigation for ships of war and commerce. Over time, the US Army Corps of Engineers (USACE) assumed responsibility for maintaining federal navigation channels and larger ports. As the US population concentrated at the shores, USACE also was assigned responsibility for mitigating effects of navigation channels and associated shore protection structures. Jetties and breakwaters were built to maintain the position of navigation channels, maintain the location of tidal inlets, slow channel shoaling, and/or provide protection to ships entering and leaving harbors. These structures, by design, impacted the movement and distribution of sediment, requiring USACE to manage large volumes of sand.

The process of dredging and maintaining the nation's ports requires the USACE to handle between 250 to 350 million cubic meters of sand annually at a cost of over $700 million. Until recently, the USACE was directed to approach each project separately and designed dredging, disposal, and mitigation strategies based on individual project needs. To minimize expenditure of public tax dollars, the driving strategy directed by Congress was to implement the least cost alternative, which potentially impacts the coastline. For instance, if the least cost alternative is to dispose dredged sediment offshore, the downdrift system may experience erosion if sand is removed from the littoral system. Sand is often placed offshore and outside the littoral system because it constitutes the lowest cost. The least cost solution is often mandated by Congress, and separate project funding pipelines help perpetuate the project-by-project decision-making, which can lead to duplicated efforts and inefficiencies as a result of not being able to combine project resources. The USACE realized these problems and began considering managing sediment on a regional, as opposed to an individual project basis. Thus, the term and concept of Regional Sediment Management (RSM) was initiated at the USACE.

The Coastal Engineering Research Board (CERB) was the first to embrace the concept of RSM. In 1996 CERB introduced the RSM initiative followed by a demonstration project at the Mobile District in 2000. There are now RSM projects in every coastal District, along with several inland Districts responsible for major rivers, harbors, and/or estuarine systems.

RSM has the potential to improve efficiencies by implementing the following five basic tenants:

- RSM involves making local project decisions in the context of the sediment system and forecasting the long-range implications of management actions.
- RSM recognizes sediment as a resource – sand and sediment processes are important components of coastal and riverine systems integral to economic and environmental vitality.
- RSM engages many stakeholders. Many federal and non-federal sediment management activities potentially have system-wide effects.
- RSM recognizes that sediment management actions have potential economic and ecological implications beyond a given site, beyond originally intended effects, and over long time scales (decades or more).
- RSM is a Corps-wide approach implemented through coordinated activities using several Corps authorities.

USACE understands the need to manage sediment as a valuable resource and to evaluate sediment budgets on a regional basis. The USACE can implement RSM because it is responsible for the planning, design, and construction process for federal coastal civil works projects. However, there are many harbors and large reaches of shoreline not within the USACE's responsibility, which introduces challenges for addressing sediment problems and/or needs on a regional basis. To address this issue, the USACE makes available the studies and data collected along each of the littoral cells studied under RSM. This provides State and local governments and other stakeholders data required to make informed decisions related to dredging and disposing of sediment to advance a particular project, and to benefit a region. States and local governments must also, therefore, embrace the concept of RSM for it to be viable.

RSM and the NJ Alternative Long-term Nourishment Study

The New Jersey Alternative Long-Term Nourishment Study recommends methods to manage New Jersey's coastal projects on a regional basis to ensure maximum benefits are achieved from the federal investment. Other primary purposes of the Study include reducing long-term periodic nourishment requirements and costs, reducing use of sand resources, and minimizing environmental impacts. These goals are consistent with the RSM approach, and the primary stakeholder needs (i.e., federal government through USACE, the

NJDEP, and local New Jersey municipalities). Implementing RSM on the State and local level has challenges, given the large scale of littoral cells relative to typical municipal jurisdictional boundaries, potentially large investment associated with regional shore protection strategies, and local political considerations. To optimize federal investment in the New Jersey coastline and improve the practices of local stakeholders, RSM strategies provide the driver for this Feasibility Report.

The primary purposes of this Feasibility Report, therefore, are to:

- Consolidate existing information for federal, state, and other decision-makers;
- Identify and prioritize alternatives that can be implemented by USACE, NJDEP, and local communities to achieve NJALTN objectives; and
- Define the path forward for implementing the alternatives.

Tiered Approach and Criteria for Classifying and Evaluating Alternatives

A key element of this Feasibility Report is to identify specific projects, project enhancements, and studies that can be implemented. These actions are presented as tiered recommendations. Within the sixteen (16) federally authorized shore protection and navigation projects for the NJ coast, there are numerous opportunities to enhance existing projects, combine projects, and refine elements of projects to achieve Study objectives, namely cost reduction, limiting use of sand resources, and minimizing environmental impacts. This Feasibility Report identifies and evaluates the benefits and limitations of a full range of alternatives. Each proposed alternative and/or strategy is categorized into a specific tiered recommendation, defined as:

- Tier 1 recommendations are achievable in the short-term within existing authorizations. It is expected that individual analyses (e.g., economic, cost justification) could be performed and documented in a Memorandum for Record (MFR) to provide justification for implementation. Following the justification, recommendations would be approved and implemented at a District level. Construction general funds could be used to conduct the analyses and implement (design and construct) the strategies. The majority of strategies identified in this System Optimization Report (SOR) are classified as Tier 1.
- Tier 2 recommendations are achievable within existing authorities, but require either documentation (position paper or Value Engineering Study) or a decision document (Engineering Design Report [EDR] and Limited Reevaluation report [LRR]). Recommendations will be approved at the District level (EDR) or the Division level (LRR). Construction general funds could be used to conduct analyses and implement strategies.
- Tier 3 recommendations require a new congressional authority (i.e., WRDA), or study (i.e., Chief's Report of General Reevaluation Report) to implement strategies. The existing December 17, 1987 authority for the New Jersey Shore Protection Authority can be used to

perform feasibility analyses for selected strategies identified in the SOR. Recommendations will be approved at Headquarters and Congressional level.

The alternatives are prioritized based on a number of criteria, including:

- Authorization requirements and ability to implement within existing project authorizations
- Project constraints
- Cost impacts on a short- and long-term basis and opportunity for cost savings
- Service life
- Other benefits
- Tier level

Specific recommendations are included to advance each alternative. This Feasibility Report includes suggestions for supplemental work (e.g., localized sediment budget enhancements, modeling, or data collection) with the intent to produce technical information to advance the Study objectives. For all tiered recommendations identified, a path forward is defined that can be implemented within the USACE procedures.

BROAD REGIONAL STRATEGIES

To advance RSM strategies for federally-authorized projects in New Jersey, there are strategies that should be applied to the coastline as a whole. This section defines and recommends broad regional strategies for the NJ coastline that are more general in nature. Broad regional strategies involve system-wide approaches, and likely span multiple projects or benefit sediment management practices along the New Jersey coastline. Where appropriate, information is included in this chapter to demonstrate how the action advances the goals of the NJ Alternative Long-Term Nourishment Study, namely to reduce costs, reduce sand requirements, and minimize environmental impacts. Some broad regional strategies require upfront investment, and do not have a quantitative known cost advantage currently (e.g., system wide monitoring), but are expected to pay dividends in the future in the form of greater understanding of coastal processes and multiple uses of monitoring data that can advance an adaptive management approach to shoreline protection.

Eight (8) broad regional strategies for RSM are presented in this section. The strategies are summarized in Table 4, which provides a preliminary evaluation according to the alternatives analysis criteria. These broad regional strategies are intended to supplement data collection and analyses to optimize design of existing authorized shore protection projects. The strategies also provide a mechanism for long-term data collection, monitoring project performance, and refining designs and construction templates through an adaptive management approach that allows future projects to be refined based on performance of prior projects. This information is intended to benefit the understanding of site-specific processes (e.g., hotspots and nodal points) that influence beach nourishment along the New Jersey coastline. There also may be a need to optimize performance on a scaled-back template, considering the potential for limited future funding that may alter how/when authorized projects can be constructed and maintained.

Wave/Sediment Transport Modeling

Extensive nourishment projects along the New Jersey coast reveal unique erosion patterns, which in some cases have resulted in unexpectedly high erosion rates that have reduced storm damage protection while increasing nourishment maintenance costs and sand requirements. These areas are termed erosional hotspots. Given the breadth of the New Jersey nourishment program, long-term commitment, near certainty that hotspots will persist in known areas, and likelihood that new hotspots will develop and be revealed in areas not yet nourished (but authorized), there is a need to apply technologies to better understand and mitigate them. Hotspots result from unique site-specific coastal processes related to wave energy focusing, wave-current interactions near inlets, and other factors. To develop effective remedies to hotspot maintenance, a more thorough understanding of the local coastal processes is required. This can be obtained through application of refined wave and sediment transport models coupled with field data collection and observations. The models can be used to better understand the driving causes for hotspot erosion, develop alternatives to mitigate the erosion, and refine engineering designs. Regional shallow wave transformation and sediment transport modeling provides site-specific design criteria, along with insight on local coastal processes that contribute to hotspot erosion. The models can help to develop mitigation strategies, such as advance nourishment/overfilling or sand stabilization structures.

In addition to managing erosional hotspots, there are other factors associated with the New Jersey shore protection program that warrant a detailed understanding of site-specific coastal processes, including:

- Many of the authorized eleven (11) shore protection projects and the five (5) navigational projects interact with each other. A deeper understanding of the interactions should be applied to improve performance while reducing sand maintenance requirements and cost.
- The shore protection projects generally have 50-yr project lifetimes with multiple periodic nourishment cycles. Monitoring data collected during these projects will reveal future trends of performance. Given the uncertainty in coastal engineering design, project performance will vary from expectations in certain areas. Having a set of modeling tools to adapt over time will provide a greater understanding of the coastal processes and facilitate an adaptive management approach whereby maintenance of authorized projects can be optimized based on performance of prior projects.
- Potential shortages of federal and local funds to construct projects as authorized will require projects to be selected that maximize benefits while minimizing cost. Models should be applied to simulate various alternative construction templates to maximize performance.

Although substantial materials have been published related to coastal processes and beach nourishment performance along the New Jersey coastline, a gap exists in the knowledge of regional and site-specific coastal processes related to wave energy focusing and sediment transport rates. Coastal engineering project design should be optimized from a performance and cost perspective through rigorous analysis of the prevailing coastal processes. Understanding site-specific wave and sediment transport processes, coupled with historic beach change (and project performance) data would result in more efficient design of beach nourishment templates and coastal structure alternatives. In the case of New Jersey, where there is a long project history, a detailed understanding of waves, inlet currents, sediment transport and a refined local sediment budget would also help optimize future projects based on the well-documented performance of past projects. In this regard, refined coastal processes modeling should be considered part of an overall adaptive management approach. For example, the proposed design configuration for beach nourishment at hotspots, and the impacts of engineering structures such as groins, should be optimized based on the performance of past projects and a greater understanding of prevailing coastal processes.

Table 4. Broad Regional Strategies Criteria Matrix

		Criteria						
		1. Authorization	2. Constraints	3. Cost Savings	4. Service Life	5. Other Benefits	6. Priority	7. Tier Level
Broad Regional Strategy	**Wave/Sediment Transport Modeling**	NJALTN Study	Funding	Provide greater understanding of coastal processes to refine design and reduce sand requirements/cost	Extend design life of nourishment, particularly at hotspots and vicinity of nodal points	Improve storm damage protection; provide design basis for modifying designs, incorporating overfill and/or structural solutions to complement existing nourishment projects; provide information to minimize environmental impacts	2	1
	Regional Geomorphic Change Analysis	NJALTN Study	Funding	Provide greater understanding of coastal processes to refine design and reduce sand requirements/cost	Optimize nourishment placement to extend design life	N/A	2	1
	Improved,Updated and Living Sediment Budget	NJALTN Study	Funding	Provide greater understanding of coastal processes to refine design and reduce sand requirements/cost	Optimize nourishment placement to extend design life	Long-term commitment to understanding evolving coastal processes, sea level rise impacts, influence of adjacent projects as basis for future project planning	3	1
	Enhanced Monitoring Program	Refinement to Authorized Project(s)	Funding	Refine design based on performance of prior projects to optimize performance, reducing sand requirements and cost	Apply adaptive management strategy to refine designs, optimized nourishment placement, and extend service life based on prior project performance	Understand true cost-effectiveness of projects as compared to intended design life; offer greater understanding of coastal processes near inlets, where uncertainty is significant	1	1
	Sediment Needs Vs. Availability	NJALTN Study	Funding	N/A	Ensure adequate sand resources are available to achieve intended service life	Provide proactive basis for identifying and permitting new borrow sites	1	1
	Dredge Diversity Assessment	NJALTN Study	Funding; Dredge Industry Procurement Standards	Provide dedicated government equipment for rapid response/less mobilization to reduce construction cost	Provide flexible equipment for proactive maintenance (e.g., pump directly on beach; bypassing/backpassing/forepassing) to extend service life	Boost regional beach building dredge fleet	1	1
	Environmental Demonstration Studies	Refinement to Authorized Project(s)	Funding; Environmental permit conditions	N/A	N/A	Provide data and scientific rationale to streamline environmental permitting process for future projects and borrow site approval; provide information to minimize environmental impacts	2	2
	Breach Contingency Plan	Refinement to Authorized Project(s)	Funding; Environmental permit conditions	N/A	Provide contingency actions that can be implemented to heal short-term damage and extend overall service life	Provide actions to prevent further erosion of sensitive habitats	3	2

Wave Climatology and Transformation Modeling

The impact of waves in the nearshore environment, specifically on highly populated shorelines that serve significant recreational and/or economic benefits is one of the key reasons to understand wave propagation and transformation for site-specific areas. Impacts to nearshore processes and shoreline change are highly dependent on the offshore wave climate and the transformation of waves from deep water to the shoreline. Subsequently, as waves interact with the coastline, wave-induced currents play a role in sediment transport and shoreline change. As such, a key component in understanding erosion and accretion along the coastline is a determination of the wave field, both offshore and in the nearshore region.

The coastline of New Jersey represents a complex coastal setting where the offshore bathymetry, sand bars, tidal shoals, and shoreline orientation influence wave heights and directions at the beach. Before an effective solution can be determined, wave modeling is required to simulate refraction, diffraction, shoaling and breaking of waves. Wave refraction and diffraction produce an uneven distribution of wave energy along the coast that can affect sediment transport rates. This process results in areas of increased erosion ("hot spots") and variations in the pathways of sediment transport. Wave modeling allows for quantitative predictions of these processes.

A regional, spectral wave model should be utilized to propagate water waves over the irregular bathymetry and provide "state-of-the-art" nearshore wave predictions. The spectral approach makes it possible to model more accurately the actual sea surface, comprised of a variety of waves traveling in different directions with different frequencies, phases, and heights. By simulating the different wave components, accurate nearshore statistical parameters are calculated and used as input for localized sediment transport, and alternatives analysis modeling. The wave model needs to be validated to local wave measurements (if available) to ensure modeling results accurately predict reality.

One of the primary advantages of wave modeling is the ability to simulate multiple scenarios. Models can be used to determine the effect that various changes have on the wave climate (e.g., groin configurations, varying beach nourishment templates, offshore borrow site dredging). The models can also be used to simulate a range of wave conditions and to determine the resulting impacts on the shoreline (e.g., storm events, seasonal variations). Numerical wave modeling is a key component in understanding changes in wave height, wave direction, areas of increased energy concentration, structural design, sediment transport, and ultimately proper shoreline management. Figure 38 shows example wave modeling results used to evaluate a variety of beach restoration alternatives.

Sediment Transport Modeling

To evaluate and assess shore protection alternatives along the New Jersey coast, the sediment transport dynamics must also be quantified, including sediment transport directions and volumes of cross-shore and longshore transport. The components of sediment transport

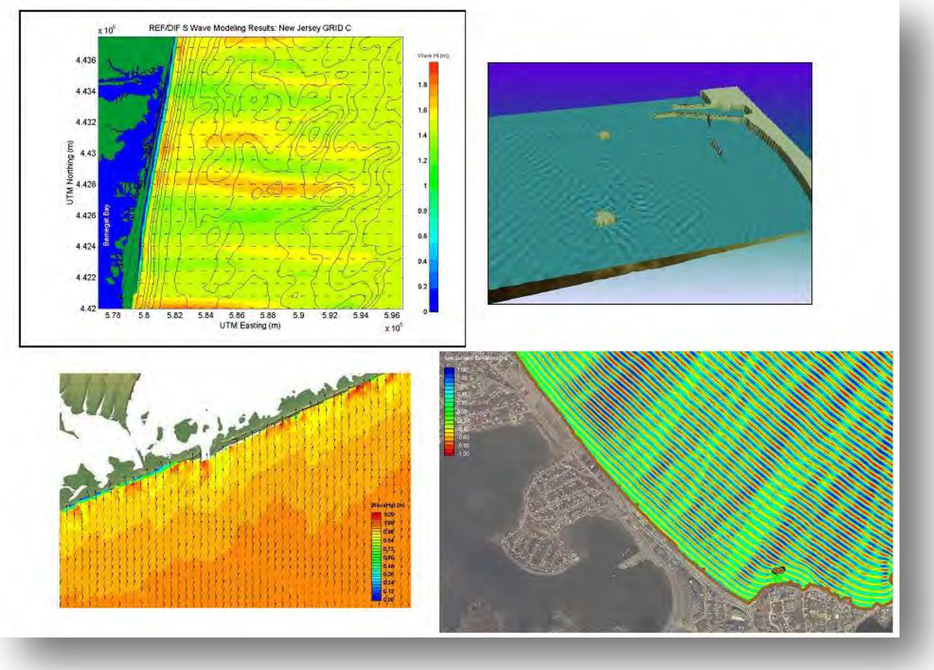


Figure 38. Examples of wave modeling results used to assess a variety of coastal settings in the completion of successful beach erosion and alternative analysis studies.

can be evaluated through the use of numerical modeling. The goal of sediment transport modeling is to provide a physical representation of alongshore currents and sediment transport driven by breaking waves, so that estimates of alongshore sediment flux can be integrated across the surf zone. This tool is ideally suited to evaluate the influence of various shore protection alternatives on sand movement and shoreline evolution. For example, the expected lifetime of beach nourishment and the influence of groins on shoreline evolution can be quantified.

Various sediment transport modeling tools are available, including one-line models (e.g., GENESIS), wave-current tools (e.g., CMS), and physics-based models that utilize wave model output and wave-current distributions. Physics-based sediment transport models consist of a hydrodynamic component to estimate wave-induced currents, and a sediment transport component to quantify the amount of sediment moved.

Physics-based models have the capability to simulate variable rates of longshore transport across the surf zone (i.e., typically transport is focused in the nearshore swash zone and in the breaker zone). Traditional one-line models are not capable of making this distinction, which can be a key factor in engineering design. For instance, the length and height of shore-perpendicular coastal structures (i.e., groins) can, and should be, fine-tuned to a site-specific transport regime. Lacking this type of information, specification of the offshore length of a groin (which adds substantially to cost as the quantity of construction materials increases with depth) is based on incomplete and inaccurate assumptions.

Figure 39 shows an example of alongshore variations in sediment transport as computed by a physics-based transport model. The influence of spatially-varying bathymetry and wave parameters on the longshore sediment flux is demonstrated. The left plot shows nearshore bathymetry and the middle plot depicts the modeled wave field (red contours show focused wave energy and blue contours show energy shadow zones). The right hand plot is proportional to the rate of longshore sediment transport. The varying rate of longshore transport helps to identify localized hot-spots of erosion. Where the direction of transport is constant but the rate is increasing, more sand is transported out of a region than transported in, and erosion occurs. Likewise, if there is a nodal point where the direction changes, there is a divergence of sand and erosion occurs. These types of details should be investigated for typical, seasonal, and storm conditions and factored into the overall design process for shore protection.

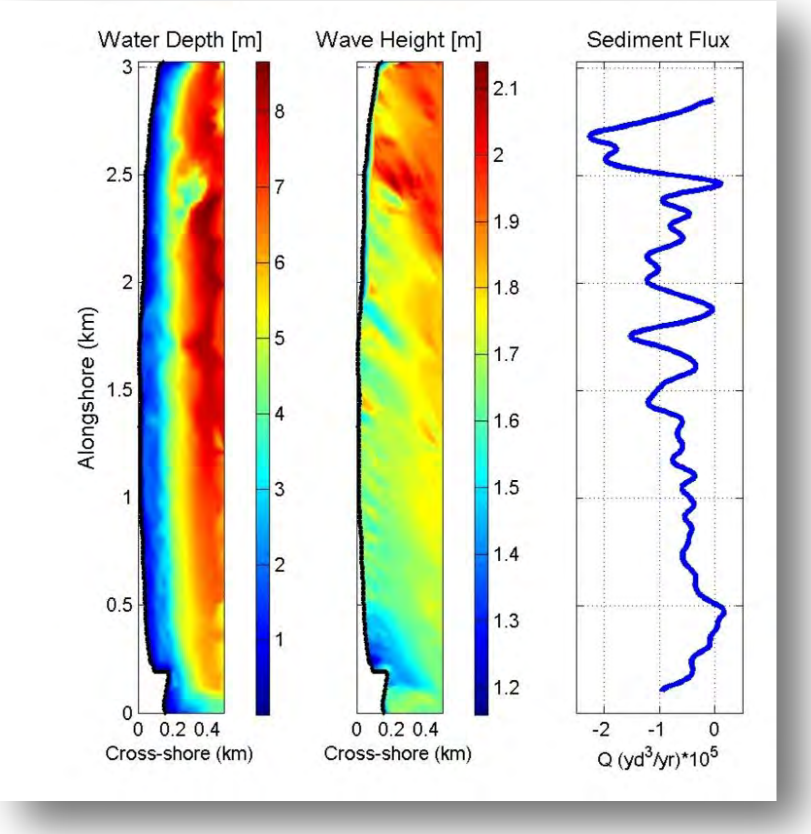


Figure 39. Example of sediment transport results (Q) and the flow of sand along the beach.

Longshore sediment transport is primarily controlled by long-term average wave conditions, while cross-shore sediment transport is mostly governed by infrequent storm events. Storm waves shape the cross-shore profile based on a number of parameters including wave height, wave steepness, and the median grain size of the beach. Since the profile shape is sensitive to water level, storm surge has an important impact on overall cross-shore transport.

The cross-shore component of sediment transport must be coupled with longshore estimates from physics-based models to develop a complete picture of nearshore transport. A numerical model based on the concept of equilibrium beach profiles should be utilized to quantify cross-shore sediment transport. The concept of equilibrium beach profiles is well-established in coastal engineering literature, and assumes the profile maintains a particular shape based on sediment characteristics. In addition, this type of model assumes the wave breaking characteristics are related to the profile shape. The combined use of longshore and cross-shore sediment transport modeling allows potential nourishment designs and other shoreline stabilization measures to be refined with confidence.

Case Study - Coastal Processes at Hotspots at the Atlantic City, Ocean City and Avalon Beach Nourishment Projects

Improved understanding of coastal processes will benefit future project performance at documented hotspot erosion areas such as Atlantic City, Ocean city, and Avalon. Details on application of these strategies are presented in the site-specific authorized project strategy sections of this report. Beach nourishment projects in Atlantic City, Ocean City, and Avalon have erosional hotspots near adjacent inlets, which require more frequent nourishment. It has been hypothesized that the hotspots are associated with nodal points south of the nearby inlet. The hotspot in Atlantic City is associated with the nodal point south of Absecon Inlet; the hotspot in Ocean City is associated with Great Egg Harbor Inlet; and the hotspot in Avalon is associated with Townsends Inlet.

Nodal points are locations where the net longshore transport is equal to zero (i.e., northward transport balances southward transport), although neither the northward rate nor southward rate is zero. Gross transport can be significant at these nodal points. Converging nodal points occur where the transport is toward the node, and diverging nodal points occur where transport is away from the node (Figure 40). Converging nodes are generally at inlets where sand enters from both directions. At diverging nodes transport is northward some distance north of the node, and southward some distance south of the node. Nodal points can be defined as "instantaneous" or "long-term." An instantaneous node is a point where transport is zero at an instant in time. The location of an instantaneous diverging node can migrate up and down the beach with changes in incident wave direction. For some wave conditions the instantaneous node can disappear. A long-term node is a point where the average or net transport is zero. The location of a long-term node is based on the wave climate rather than on wave conditions at an instant in time.

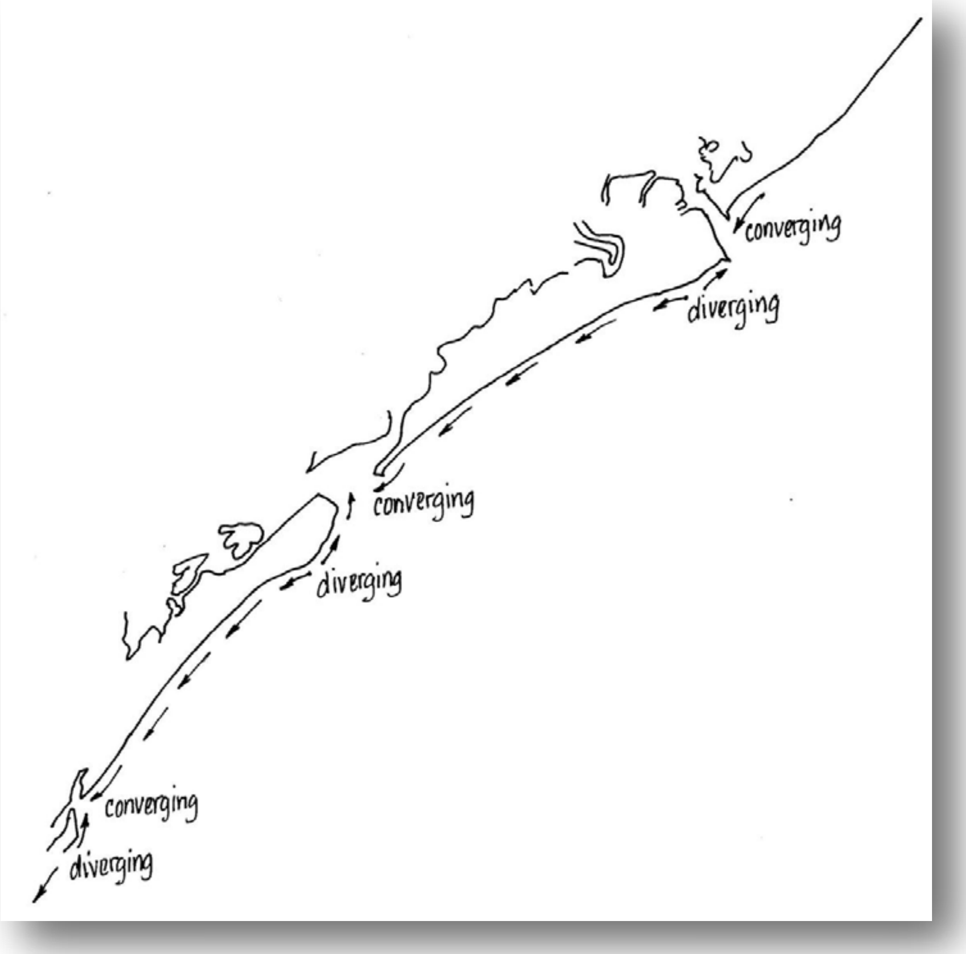


Figure 40. Converging and diverging nodal point.

Converging nodes and diverging nodes typically alternate along a shoreline. A converging node (at an inlet) is associated with an adjacent diverging node (downdrift of the inlet). The locations of the long-term, diverging nodes at Atlantic City, Ocean City and Avalon should be estimated from wave and sediment transport models, combined with site-specific data (e.g., currents, refined shoreline change analysis, dye studies) as appropriate. Identifying more detailed characteristics regarding the sediment transport nodes, including their potential seasonality, could further inform where sand should be bypassed.

Regional Geomorphic Change Analysis

Historical shoreline and bathymetric data along the coastline provide important information on regional changes in geomorphology. Over time, the shoreline and nearshore areas evolve in response to a combination of natural coastal processes and anthropogenic activities. The interaction between waves, tides, currents, winds, storms, sea level rise, and available sediment supply result in a natural evolution of the coastline. Concurrently, anthropogenic activities such as dredging, beach nourishment, and coastal engineering structures, influence the geomorphology.

Analysis of historical shoreline and nearshore bathymetric change is a necessary component to understanding the complex cause and effect relationships that form the New Jersey coastline. An integrated approach should be developed to identify patterns of sediment transport and quantify net rates of change along the coastline by combining analyses of regional geomorphic change with broad regional strategy #1 (wave and sediment transport modeling). This approach provides the technical basis and analytical data needed to develop regional sediment management recommendations that maximize the benefits of shore protection activities, while reducing costs and sand requirements.

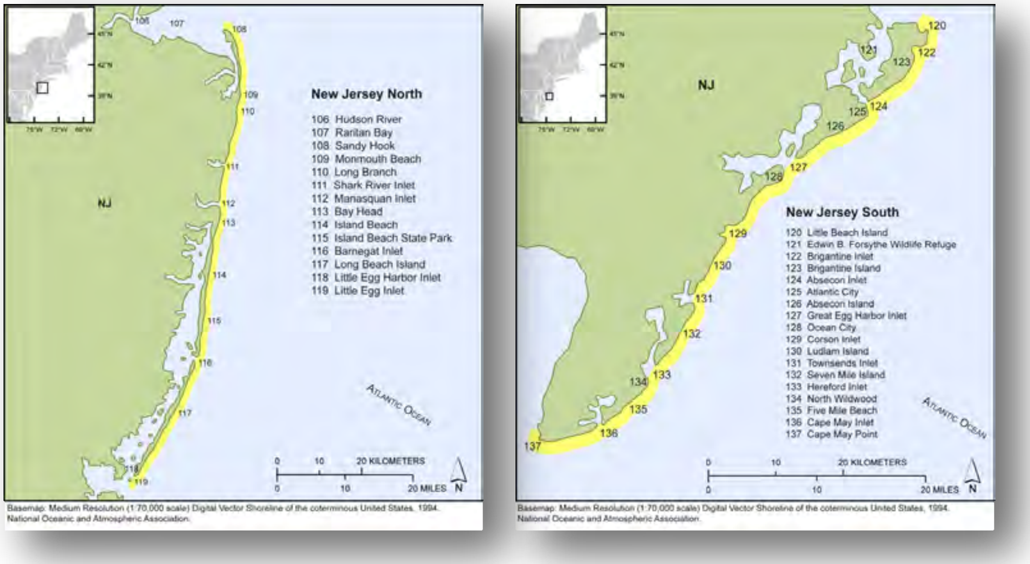
Shoreline Change

A comprehensive analysis of historical shoreline change should be performed for the Atlantic Ocean shoreline of New Jersey. The analysis should consider various time scales, both long- and short-term, so the influence of anthropogenic activities can be identified, and natural background rates of change are quantified. Targeting different time intervals and comparing areas of the coastline less heavily influenced by anthropogenic activities will help to identify impacts of existing and future shoreline management alternatives.

A number of studies have developed historical shoreline position data; however, a quantitative assessment of shoreline change integrating impacts of anthropogenic activities along the New Jersey coastline has not been performed. This type of analysis will quantify background rates of shoreline change, and provide necessary data to calibrate the sediment transport model (broad regional strategy #1). This approach will improve use of the sediment transport model as a predictive tool for evaluating regional and localized sediment management strategies.

Historical shoreline data are available from sources including a shoreline dataset in ArcGIS format that spans the time period from 1836-42 to 1977 (NJDEP, 1991). The dataset provides eleven (11) different Atlantic Ocean shorelines from the years 1836-42, 1855, 1866-68, 1871-75, 1879-85, 1899, 1932-36, 1943, 1951-53, 1971, and 1977. The earliest shorelines were derived from historic US Coast and Geodetic Survey T-sheets, and the more recent shoreline data were interpreted from aerial photography. Although the dataset provides valuable information on early shoreline positions, rates of change have not been computed, and information covering the more recent 34-year period since 1977 is not included.

The US Geological Survey National Assessment of Shoreline Change considered all of the shorelines in the NJDEP dataset, plus a more contemporary shoreline from 2000 (Himelstoss et al., 2010). The USGS study computed long- and short-term rates of change using linear regression techniques for southern and northern sections of New Jersey (Figure 41). Although this study included a contemporary shoreline from 2000, incorporation of additional shorelines post 1977 are needed to resolve the background erosion rates over the past 34 years when anthropogenic activities have had a greater influence on shoreline change.



Basemap: Medium Resolution (1:70,000 scale) Digital Vector Shoreline of the coterminous United States, 1994. National Oceanic and Atmospheric Association.

Basemap: Medium Resolution (1:70,000 scale) Digital Vector Shoreline of the coterminous United States, 1994. National Oceanic and Atmospheric Association.

Figure 41 North and south regions of the New Jersey coastline included in the USGS shoreline database.

Additional sources of shoreline data covering the past 30 to 50 years should also be identified and incorporated into the shoreline change analysis. Potential data sources include aerial photography available from the private sector and/or state and federal governments, as well as modern day LIDAR data. With aerial photography data sources, the position of mean high water must be interpreted and digitized from the photos. The photos also need to be geo-referenced to a common coordinate system and horizontal datum. In the case of LIDAR data, the elevation of mean high water must be identified and extracted as a shoreline position.

The Richard Stockton College of New Jersey Coastal Research Center has been collecting beach profile data of the Atlantic facing coastline since 1986. The dataset includes annual measurements at 100 shore perpendicular transects in the fall since 1986, and biannually in the fall and spring since 1994. These data provide another source of information on shoreline change that should be used in combination with the NJDEP and USGS historical shoreline positions to document the impacts of anthropogenic activities on shoreline evolution. The data should be used to identify the elevation and location of mean high water at each profile (Fig. 42). The x,y coordinates of reference markers at each profile should then be used to map the location of mean high water for each of the surveyed datasets. The temporal resolution of the Stockton College beach profile data is sufficient to isolate effects of coastal management activities such as beach nourishment and coastal engineering structures. Although the spatial resolution is much coarser than shoreline positions obtained from surveys or aerial photographs, the data would be valuable in identifying beach nourishment performance.

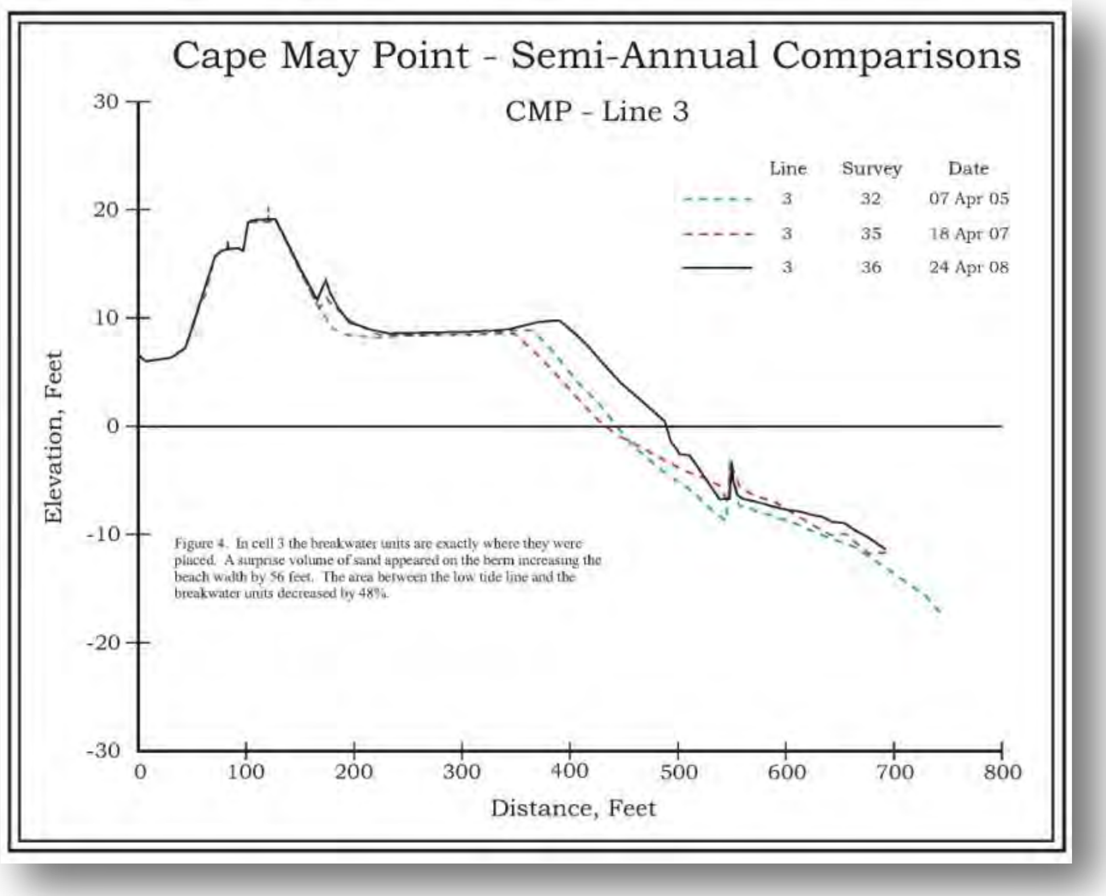


Figure 4. In cell 3 the breakwater units are exactly where they were placed. A surprise volume of sand appeared on the berm increasing the beach width by 56 feet. The area between the low tide line and the breakwater units decreased by 48%.

Figure 42. Example of Stockton College beach profile data collected at Cape May Point.

An update of the existing studies of shoreline change for the New Jersey coast with more recent data covering the past 30 to 50 years is needed to improve understanding of shoreline response to natural processes and anthropogenic activities. For example, Figure 43 shows results from the USGS study for northern New Jersey with long-term rates of change from the 1800s to 2000 as compared with short-term rates of change from 1977 to 2000. Based on the long-term data, the Monmouth and Long Branch sections of the coast show net erosion, while the short-term data show the accretionary effects of large-scale beach nourishment conducted during the 1990s. Without breaking the data into discrete time intervals, it is not possible to evaluate the effects of short-term temporal activities like beach nourishment.

Existing studies for New Jersey contain valuable information on the early evolution of the coast, but more recent changes since the late 1970s, when human activities to manage the shoreline have been more prevalent, are not documented adequately. Improving temporal resolution of shoreline and geomorphic evolution will allow analysis of long- and short-term time scales so the influence of anthropogenic activities can be identified, natural background rates of change can be determined, and shoreline management activities can be optimized.

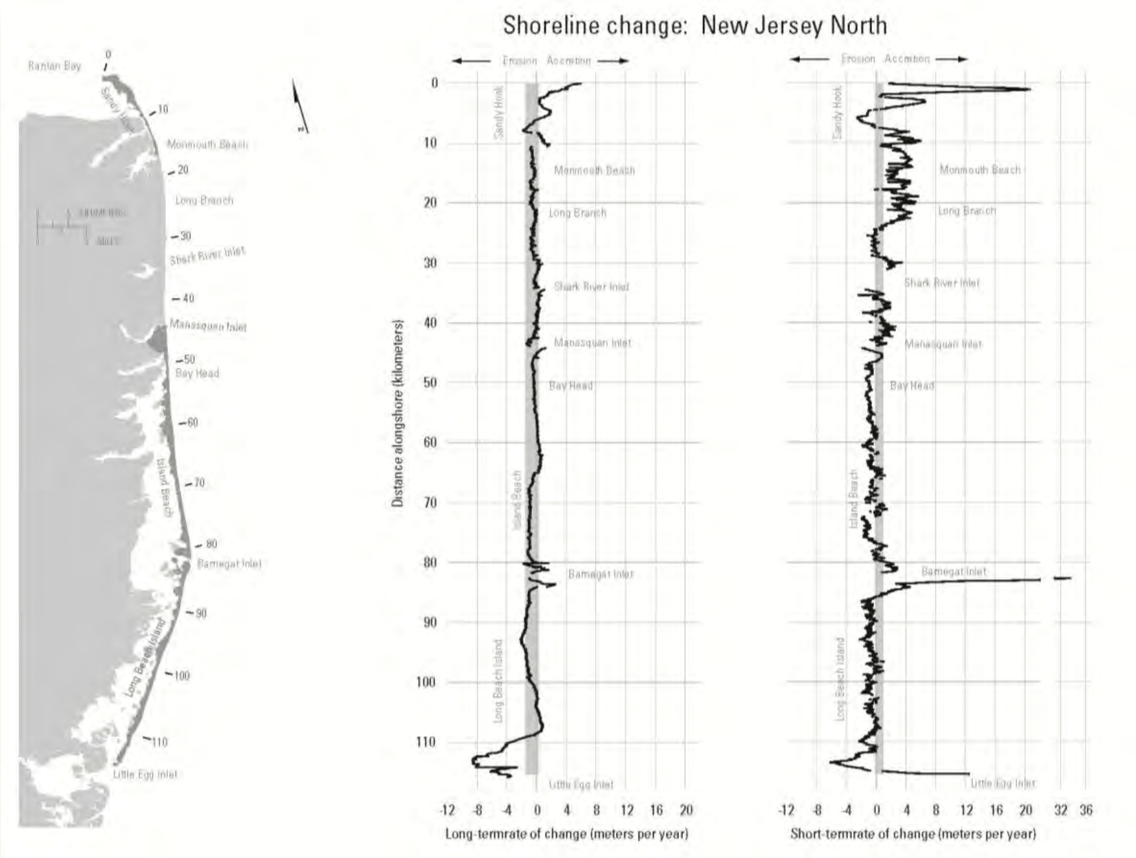


Figure 43. USGS assessment of shoreline change for northern New Jersey, comparing long- and short-term rates of change (from Hapke, et al., 2010).

Nearshore Bathymetric Change

Temporal and spatial changes in nearshore bathymetry along the New Jersey coastline should be evaluated as part of a regional geomorphic change analyses. The analysis should consider high resolution bathymetric surveys in the vicinity of tidal inlets, and data collected farther offshore to delineate potential dredge material borrow sites. Comparison of survey data from different time periods will determine changes in sediment volume for specific regions of the coast. An example of a bathymetric change analysis from the 1800s to the mid-1900s for southern New Jersey is illustrated in Figure 44. The data show areas along the coastline with higher sedimentation rates that should be integrated into a regional sediment management plan. This information should be used in combination with the shoreline change data to refine sediment transport patterns and rates. The volume data should also be used to identify inlet ebb shoal areas with high sedimentation rates as candidate borrow sites. Surveys of existing borrow sites should be compared over time to determine infill rates so design life and potential for reuse of the borrow sites can be refined. An existing historical bathymetric change study for the Cape May to

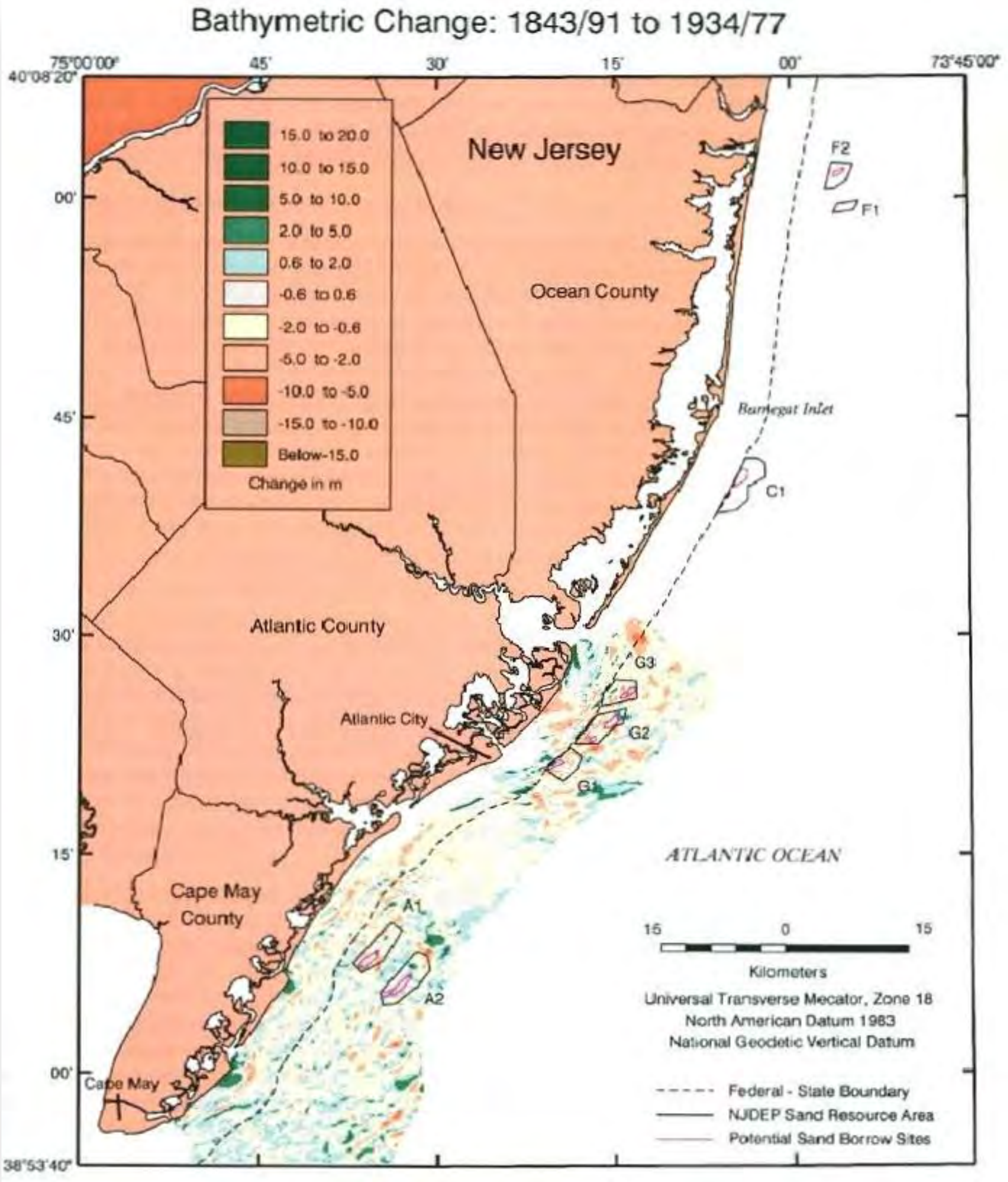


Figure 44. Example of bathymetric change analysis for southern New Jersey, showing areas of sediment accumulation in relation to potential offshore borrow sites (from Byrnes, et. al., 2000).

Hereford Inlet region by the USACE provides a basis for updated analyses of this type (USACE, 2006a).

Improved and "Living" Sediment Budget

The existing sediment budgets developed by NAP (USACE-NAP, 2006) and NAN (USACE-NAN, 2006) provide the basis for establishing an updated, living sediment budget. Results from broad regional strategies #1 (wave and sediment transport modeling) and #2 (updated shoreline change analysis) should be applied to resolve uncertainties in the existing sediment budgets. There are unresolved components of the existing sediment budgets related to offshore losses and sea level rise, hotspot erosion, and at tidal inlets. There also are inconsistencies between the existing shoreline change data and the sediment budget information. For example, short-term shoreline change for the Manasquan to Sandy Hook area shows beach accretion while the budget shows this area as a sediment source.

With ongoing shoreline and bathymetric surveys used to compute volumes of shoreline change, quantities of sand removed by dredging projects, and beach nourishment quantities added to the system, information exists to update the sediment budget regularly incorporating the latest data and observational trends. The sediment budget should be refined routinely as new projects are implemented and new monitoring data collected; hence, providing a "living" sediment budget. On a regional basis, the refined sediment budget will help quantify the overall net deficit of sand to be compensated through beach nourishment. On a localized scale, the refined sediment budget will help locate site-specific features (e.g., hotspots and nodal points), and account for inlet influences on adjacent beaches and the overall coastal system. Long-term refinements of the sediment budget will determine whether repeated re-nourishment is offsetting historic sand deficits, stabilizing the coastal system, and reducing future sand requirements. The living sediment budget would facilitate an overall adaptive management approach for maintaining the shoreline, building on past successes and refining if prior efforts have not met expectations.

Sediment transport modeling should be used to supplement and refine rates in the existing sediment budgets, including associated estimates of sediment sources and sinks, transport rates and directions, and localized hotspot features. Figure 45 presents a typical example of a conceptual sediment budget, including sediment sources, sinks, and transport pathways quantified in a refined sediment budget. The existing USACE sediment budgets would provide the basis for the refinement.

Updates to the existing USACE sediment budgets should incorporate the effects of sea level rise to account for offshore losses of sediment. An example application of this type of analysis is described in the following section. A second example of a simplified approach for refining the sediment budget at Great Egg Harbor Inlet is also provided below.

Wave and sediment transport modeling recommended as broad regional strategy #1 would provide detailed transport rates and directions along the coast to refine the existing sediment budgets. Supplemental monitoring data and analyses (broad regional strategy #4) also would quantify sources and sinks of sediment for input to the living sediment budget. The sediment budget should be integrated into a user-friendly database to help inform decisions relative to how much, how often, and where authorized shore protection projects would need renourishment. This way, investment in ongoing monitoring would quantitatively guide future projects.

Sediment Budget Refinement: Estimated Sand Loss Due to Sea Level Rise

One element not yet resolved within the existing sediment budgets for Jersey is sand losses due to sea level rise. The increase in water level lifts the active

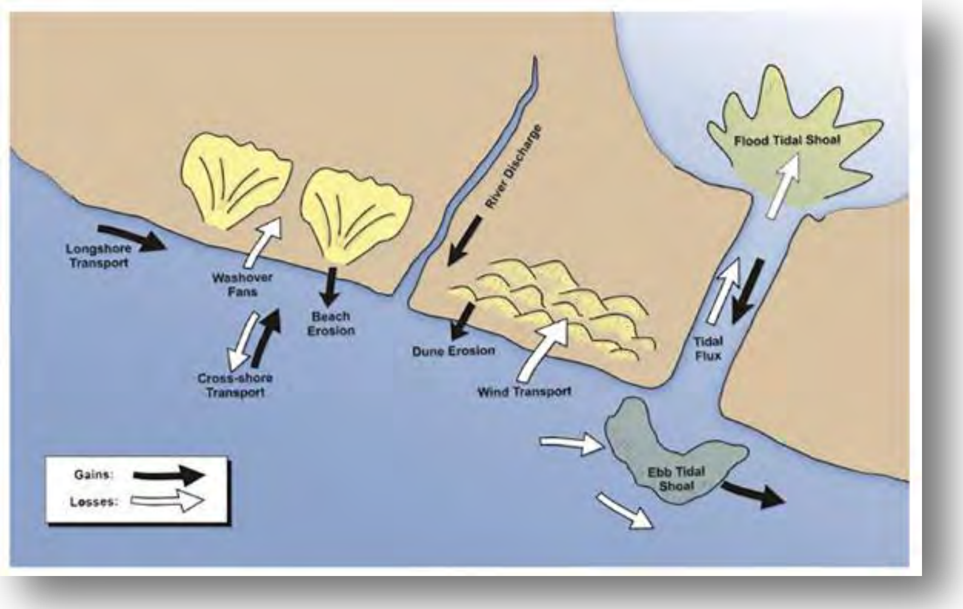


Figure 45. Example of the principal contributions to a sediment budget. (Komar, 1998)

beach profile and removes a volume of sand, causing offshore transport from the beach. Bruun (1962) indicated the volume of sand lost is equal to the change in water level times the distance offshore to the closure depth. This is the water depth beyond which there is no significant wave-induced sediment motion (Weggel, 1979). Hallermeier (1978) developed a procedure to estimate the closure depth based on wave climate.

For this preliminary analysis, a representative closure depth of 30 feet is assumed for the New Jersey coast. Therefore, the annual loss of sand is equal to the annual rate of sea level rise multiplied by the distance to the 30 foot depth contour. NOAA (2011) presents rates of sea level rise at three locations in New Jersey: Sandy Hook, Atlantic City, and Cape May. The tidal records at these three locations are presented in Figures 46 through 48. The rates of rise shown at the top of each figure range from 3.90 to 4.06 mm/yr.

For the present analysis, the distance offshore of the 30 foot contour and the alongshore spacing were scaled from USGS topographic maps. Figure 49 shows the variation in offshore distance along the coastline. In general, the distance is between 4,000 and 8,000 feet south of Corson Inlet, and then increases to a maximum of 15,000 feet near Little Egg Inlet. The distance to the 30 foot contour decreases dramatically north of Little Egg Inlet, averaging around 2,000 feet along the shoreline north to Sandy Hook.

The rates of sea level rise between the three NOAA tide stations were interpolated for intermediate locations along the coast, and multiplied by the distance to the 30 foot contour to obtain local volumetric erosion rates (Figure 50). The rate is about 75 cu ft/yr between Cape May and Townsends Inlet. From Townsends Inlet to Little Egg Inlet, the rate increases to about 175 cu ft/yr. It then drops to 40 cu ft/yr on Long Beach Island. North of Barnegat

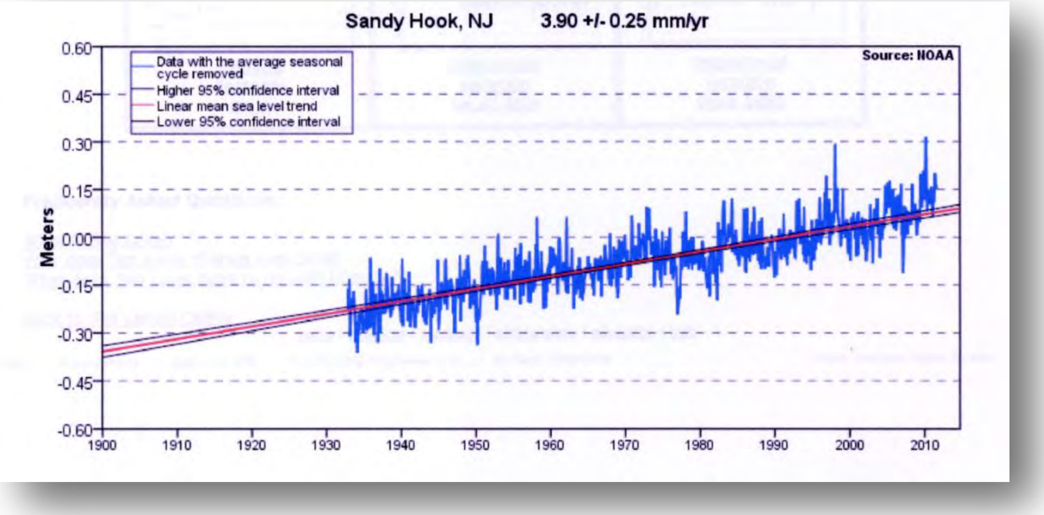


Figure 46. Sea level record at Sandy Hook, New Jersey.

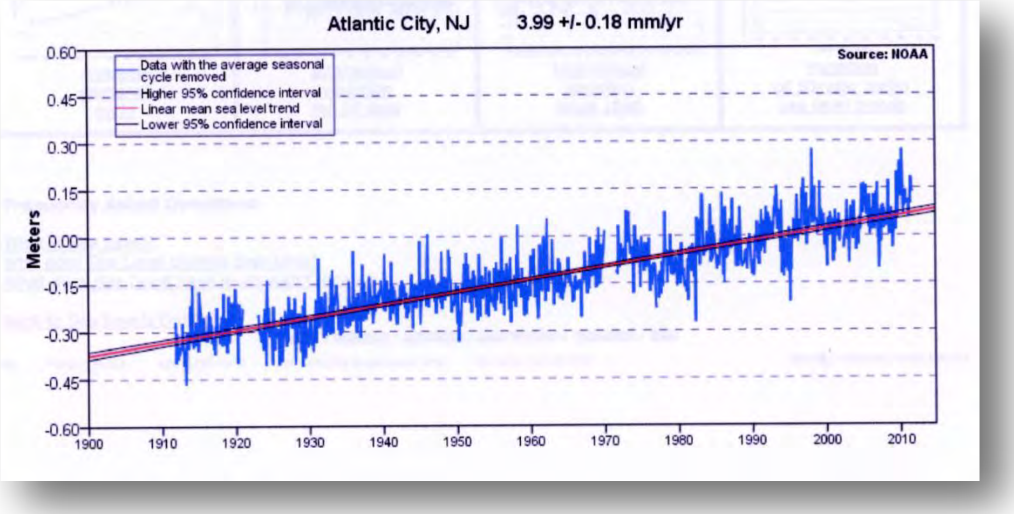


Figure 47. Sea level record at Atlantic City, New Jersey.

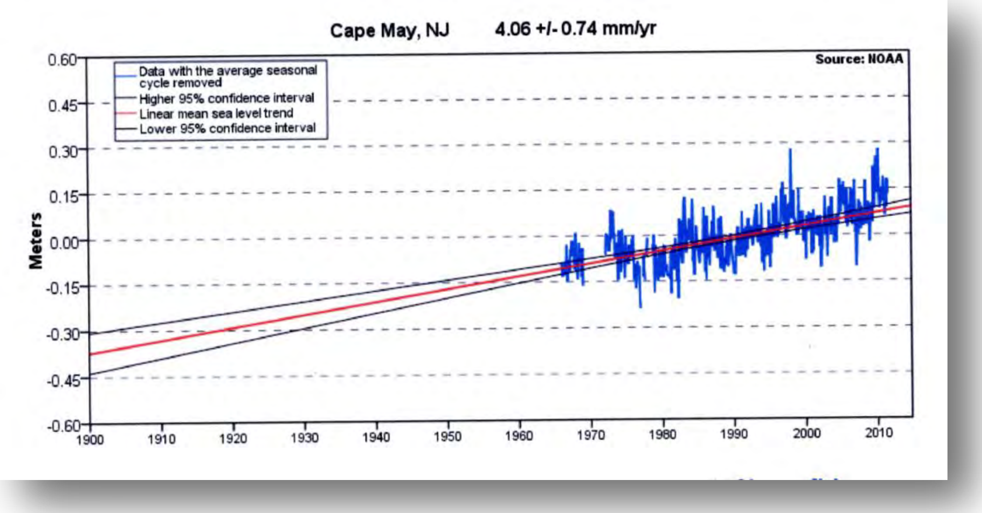


Figure 48. Sea level record at Cape May, New Jersey

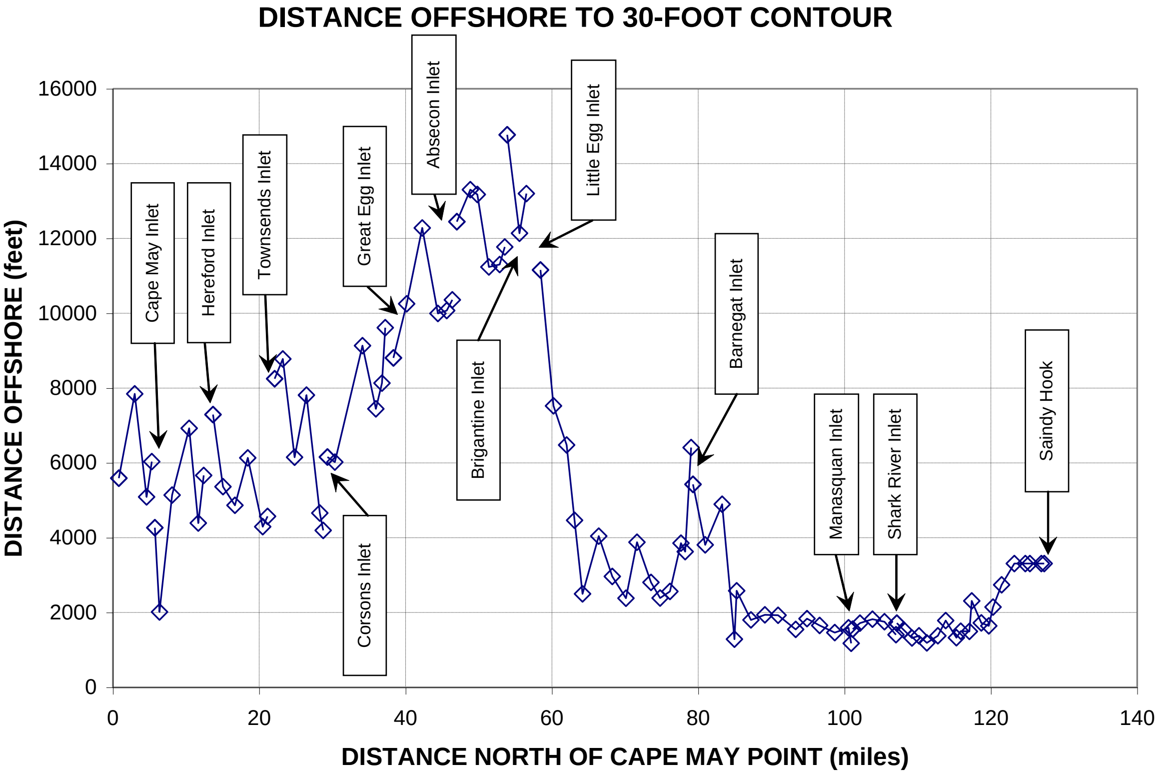


Figure 49. Distance the 30 foot contour as a function of distance along the New Jersey shoreline.

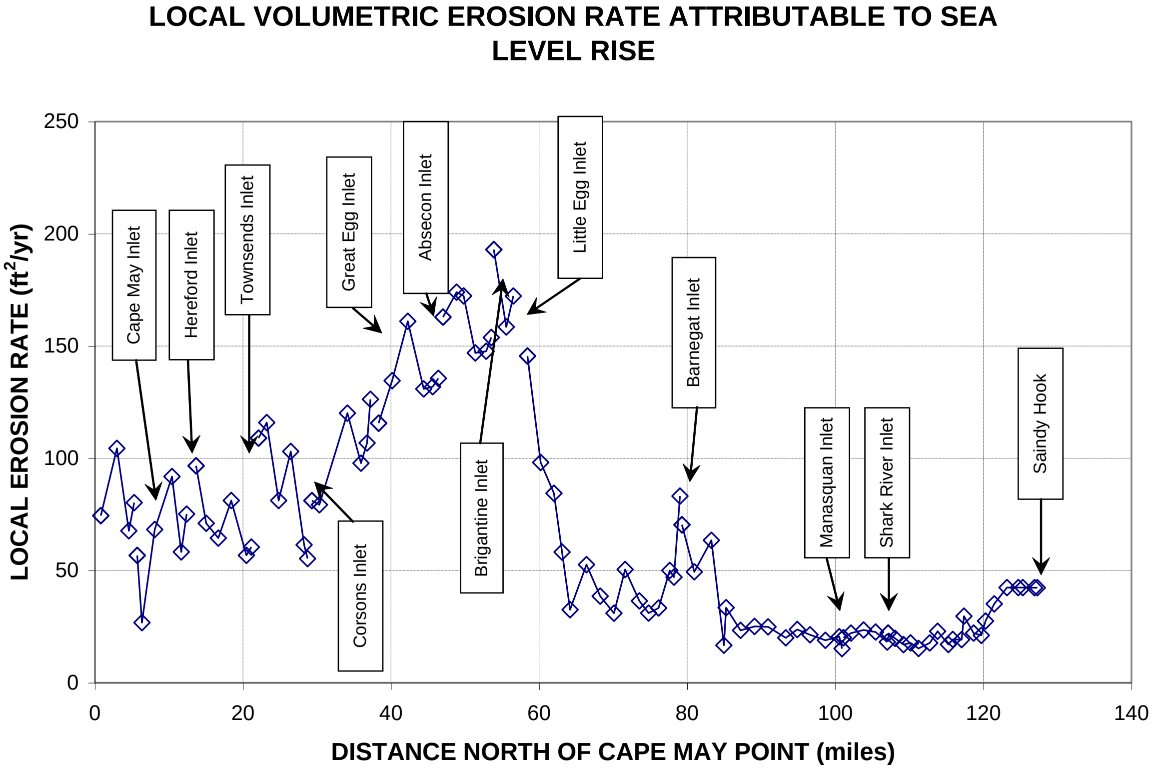


Figure 50. Local volumetric erosion rates attributable to sea level rise as a function of distance along the New Jersey shoreline.

Inlet, the rate is about 25 cu ft/yr and increases to about 45 cu ft/yr just south of Sandy Hook.

Local volumetric erosion rates from Figure 50 were converted to shoreline recession rates by dividing by the closure depth of 30 feet (assuming a uniform profile shift). Figure 51 shows the annual shoreline recession rates along the New Jersey coastline attributable to sea level rise. Between Cape May and Townsends Inlet the recession is about 2.5 ft/yr. Between Townsends Inlet and Little Egg Inlet the rates increase to about 6.0 ft/yr. North of Little Egg Inlet they drop from 5.0 ft/yr to about 1.5 ft/yr along Long Beach Island. North of Barnegat Inlet rates of erosion drop to approximately 0.7 ft/yr, and then increase near Sandy Hook to about 1.5 ft/yr.

Table 5 lists the total volume of sand removed from the active beach profile due to sea level rise for various shoreline reaches. The total loss from this analysis is approximately 1.625 million cubic yards annually. This is a significant fraction of the annual sand deficit for the system, and should be incorporated into the sediment budget and overall planning process.

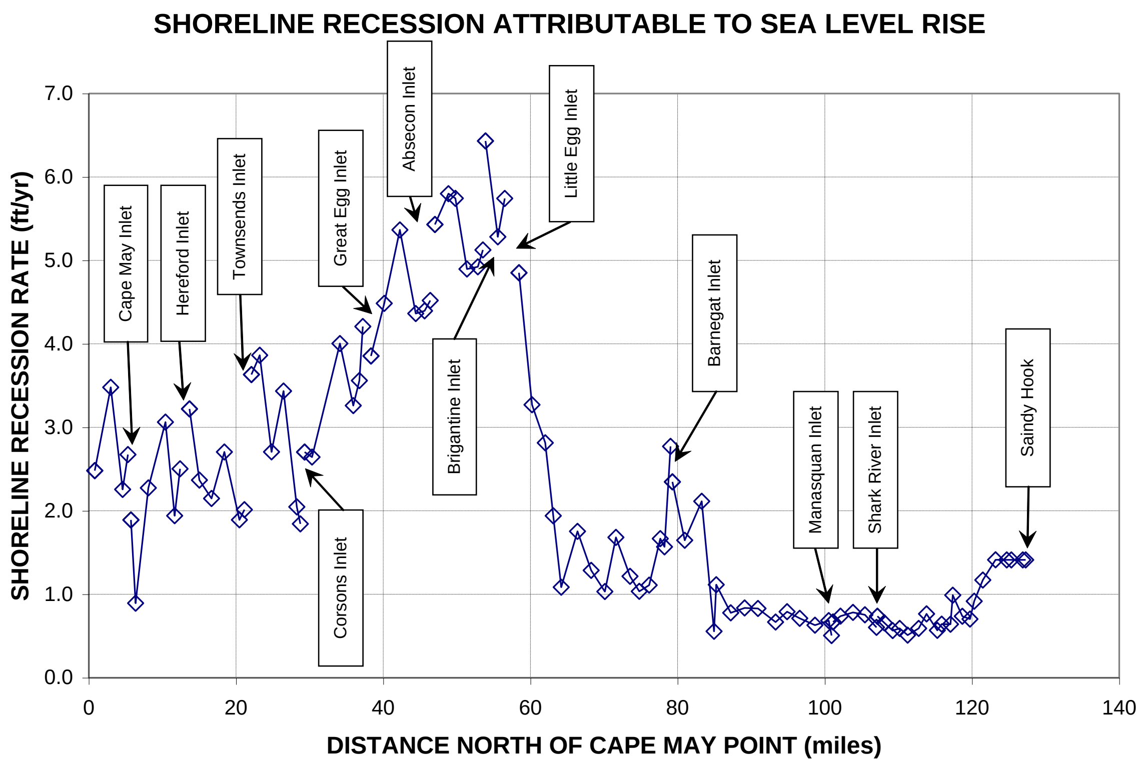


Figure 51. Shoreline recession attributable to sea level rise as a function of distance along the New Jersey shoreline.

Table 5. Sediment Loss Attributable to Sea Level Rise.

Shoreline Region	Shoreline Reach	Sediment Loss (cy/yr)
Cape May Point to Cape May Inlet	1	81,400
Cape May Inlet to Hereford Inlet	2	87,900
Hereford Inlet to Townsends Inlet	2	116,200
Townsends Inlet to Corson Inlet	3	129,600
Corson Inlet to Great Egg Inlet	3	160,200
Great Egg Inlet to Absecon Inlet	4	230,500
Absecon Inlet to Brigantine Inlet	5	214,800
Brigantine Inlet to Little Egg Inlet	5	94,700
Little Egg Inlet to Barnegat Inlet	6	247,300
Barnegat Inlet to Manasquan Inlet	7	131,600
Manasquan Inlet to Shark River Inlet	8	25,800
Shark River Inlet to Sandy Hook	8	105,600
TOTAL		1,625,600

Sediment Budget Refinement: Great Egg Harbor Inlet Sediment Budget

A living sediment budget should also be updated at strategic locations, such as tidal inlets, which significantly impact the adjacent shorelines and the overall coastal system. Inlet sediment budgets should be developed for key locations along the New Jersey coast, with results used to update the overall living sediment budget. An example preliminary sediment budget for Great

Egg Harbor Inlet has been prepared based on limited available information. The analysis reveals the need for enhanced monitoring data to resolve uncertainties.

Figure 52 shows the variability of historic shoreline locations for Great Egg Harbor Inlet between 1842 and 1920. The inlet moved generally northeastward, building Ocean City's inlet shoreline on the south while eroding Longport's beaches to the north. Longport subsequently armored its inlet shoreline to manage erosion and to control northeastward migration of the inlet. Variability in the inlet location is typical of unjettied/uncontrolled inlets, which trap longshore transport. The trapped sand can be held in the inlet and eventually bypassed during episodic events such as channel thalweg shifts. Sand may also be bypassed on the seaward edge of the ebb shoal.

The following preliminary sediment budget for Great Egg Harbor Inlet illustrates the procedures and data requirements necessary to perform an inlet sediment budget. The analysis was performed for the period 1965 to 1984 when inlet bathymetric data are available. Three (3) sediment budget cells were established for estimating sediment transport: a) Longport cell - Absecon Island beach from Great Egg Harbor Inlet to a point about 16,000 feet north of the inlet near the boundary between Margate and Ventnor; b) Inlet cell - Great Egg Harbor Inlet itself; and c) Ocean City cell - Ocean City beach from the inlet to a point about 28,000 feet south of the inlet at 45th Street. The cells and components of the sediment budget are shown in Figure 53.

The components of the budget include: a) wave-driven longshore sand transport into and out of each cell; b) offshore losses due to a long term increase in sea level; c) natural sand bypassing from the inlet to the Longport and Ocean City cells; d) nourishment placed on Ocean City beaches during the 1965-1984 time period; e) volumetric changes on Ocean City and Longport beaches, and f) sediment volume stored in the Great Egg Harbor inlet shoals. Of these components, the sand quantities bypassing the inlet and a coefficient for longshore sand transport are unknown and must be computed.

Longshore sand transport rates were estimated using tabulated wave hindcast data developed by the Corps of Engineers under the Wave Information Study (WIS). The WIS data are available for the 20 year period from 1956 through 1975, including about 11 years that coincide with the sediment budget period. Average longshore transport rates computed using data from WIS stations 61, 62, and 63 were assumed to apply to the 1965-1984 time period. Transport rates were calculated from the WIS wave data using the formula,

$$Q_\ell = k\frac{0.44\rho g^{1/2}H_b^{5/2}}{16(\rho_S-\rho)a'}\sin(2\theta_b) \qquad (1)$$

in which Q_ℓ = longshore sand transport rate, k = calibration coefficient usually assumed to be 1.0, g = acceleration of gravity, H_b = breaking wave height, ρ_s = sediment mass density, ρ = fluid mass density a' = solids fraction of the in situ sediment, and θ_b = angle of the breaking wave with respect to the

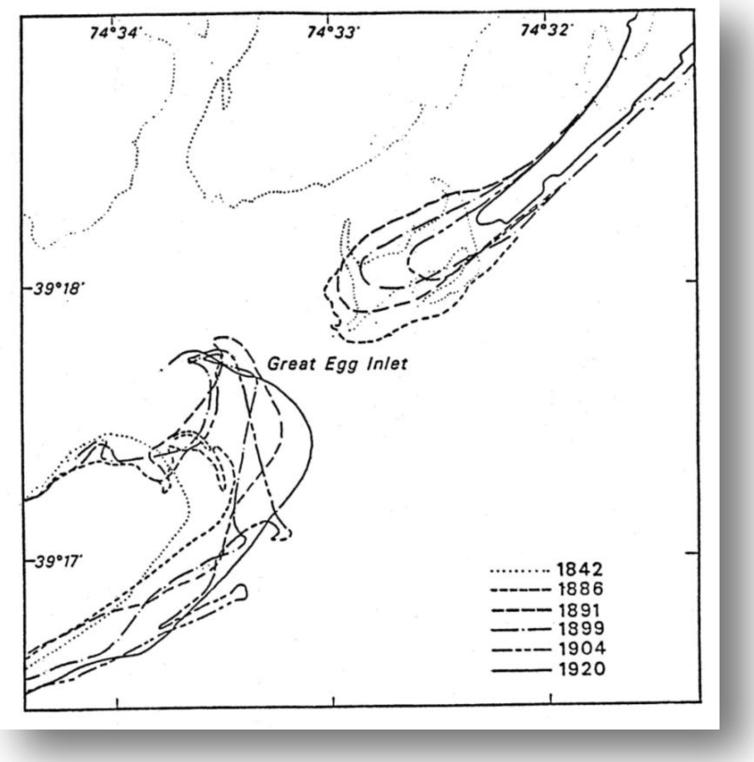


Figure 52. Historic shorelines at Great Egg Harbor Inlet, 1842 to 1920 (Fitzgerald, 1981).

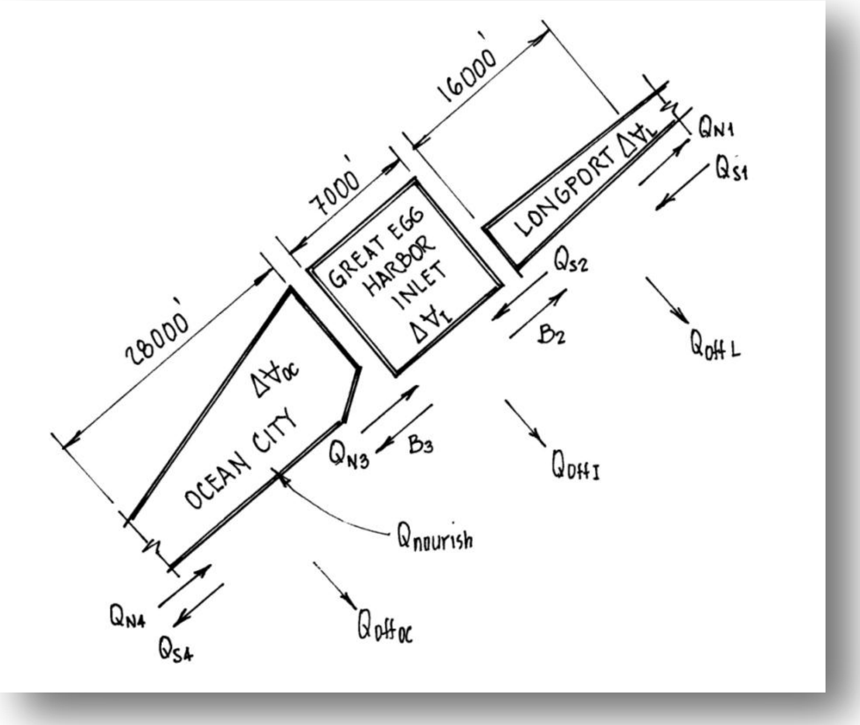


Figure 53. Sediment budget cells and components for Great Egg Harbor Inlet.

shoreline. The breaking wave height and angle were determined by assuming straight and parallel bottom contours. The longshore transport rates determined for the cell boundaries are shown in Table 6.

Table 6. Longshore Transport Rates at Sediment Budget Boundaries

Transport Rate Location (see Figure 53)	Transport Rate (1,000 cy/yr)
Q_{N1}	791.4
Q_{S1}	596.0
Q_{S2}	687.5
Q_{N3}	494.9
Q_{N4}	715.7
Q_{S4}	704.3

Long-term offshore sediment losses due to sea level rise were estimated using the Bruun (1962) rule. As discussed previously, this method relates losses due to sea level rise with the local closure depth and the distance offshore to the closure depth. Cross-shore profiles at one location in Longport and three in Ocean City were used to establish the closure depth (Weggel, 1979). Long-term sea level rise was assumed to be 3.99 mm/yr based on tidal records from Atlantic City (Figure 47). Results of the analysis are summarized in Table 7. Average erosion rates attributable to sea level rise are approximately 2.5 feet per year in Ocean City. This corresponds to a unit loss per foot of beach of approximately 73 cf/yr in the Longport cell and 100 cf/yr in the Ocean City cell. Total volume losses for the beach cell equal 43,300 cy/yr and 103,700 cy/yr, respectively.

Table 7. Offshore Sand Losses Due to Sea Level Rise.

Profile	Location	Closure depth (ft MLW)	Distance to closure contour (ft)	Recession rate (ft/yr)	Volume loss (cf/ft-yr)
GE-1	Longport	-21.2	5,600	2.33	72.7
93	18th St OC	-26.2	7,800	2.80	101.4
95	36th St OC	-28.2	7,320	2.49	95.1
96	45th St OC	-28.2	8,320	2.83	108.1

Volumetric changes on the beaches in Longport and Ocean City were calculated using beach profile surveys from July 1965 and May 1984. Profiles were adjusted to close at their seaward ends, generally at the 30 foot MLW depth contour. The volume change per unit length of shoreline was determined as the area between the 1965 and 1984 profiles, and the total loss or gain from a reach was determined by the average end area method. Profile lines, volume changes per unit length of beach, and total volume changes are summarized in Table 8. The analysis shows a gain of 53,200 cy/yr on beaches in the Longport cell and a loss of 132,100 cy/yr from beaches in the Ocean City cell.

Changes in sediment volume stored in Great Egg Harbor Inlet were determined from hydrographic surveys of the inlet collected in 1965 and 1984 (Figures 54-55). Contours showing bathymetric change (differences between contours) occurring during the 20 year period between surveys are shown in Figure 56. Erosion and accretion in the inlet is summarized in Figure 57, which shows areas computed above a given difference contour. For example, about 64 million square feet of the inlet above the zero contour experienced accretion, while 40 million square feet experienced erosion. The total accretion is the area under the curve above the zero line and the total erosion is the area below the zero line. Between 1965 and 1984 the inlet gained about 9.06 million cubic yards and lost 4.39 million cubic yards for a net accumulation of 4.67 million cubic yards, or 236,500 cy/yr.

Beach nourishment in the sediment budget area during the period 1965 to 1984 took place in the Ocean City cell. The history of beach areas nourished and the volumes placed is summarized in Table 9. During the sediment budget period from 1965 to 1984, the average annual rate of nourishment was 197,100 cy/yr.

Table 8. Volume Change on Longport and Ocean City Beaches Between July 1965 and May 1984.

Profile	Location	Area Change (sq ft)	Distance Between Profiles (ft)	Volume Change (1000 cy/yr)
GE-1	Longport	+1,741	14,260	+23.3
GE-2	Longport jetty	+16,175	1,780	+29.9
			TOTAL	**+53.2**
GE-9	Seaspray Road	-10,000		
GE-10	Surf & Beach	-13,214	1,600	-30.5
91	North Street	-574	2,320	-27.4
92	8th Street	+333	4,340	-1.0
93	18th Street	-6,149	6,280	-34.2
94	27th Street	-2,247	4,960	-39.0
95	36th Street	+1,823	5,040	-2.0
96	45th Street	-1,405	5,220	+2.0
			TOTAL	**-132.1**

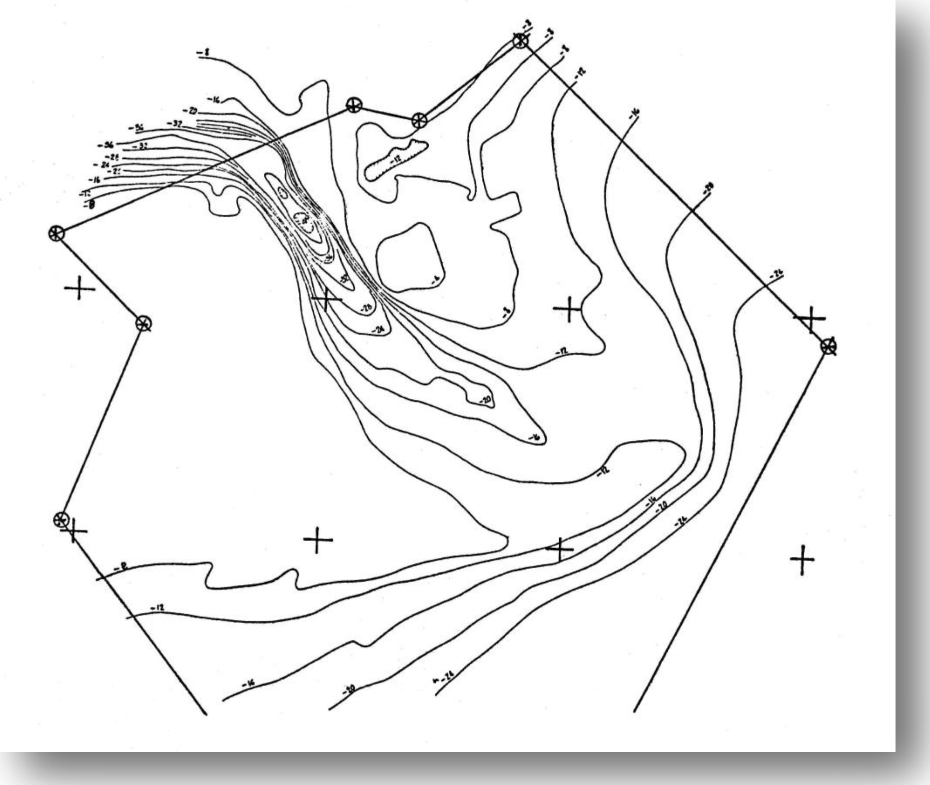


Figure 54. Contours at Great Egg Harbor Inlet from 1965 survey.

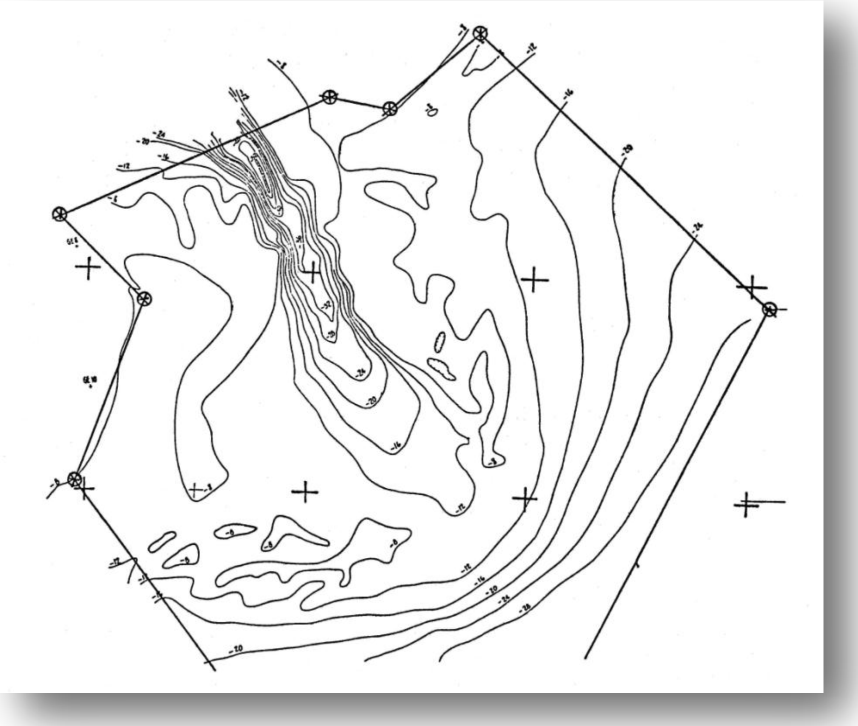


Figure 55. Contours at Great Egg Harbor Inlet from 1984 survey.

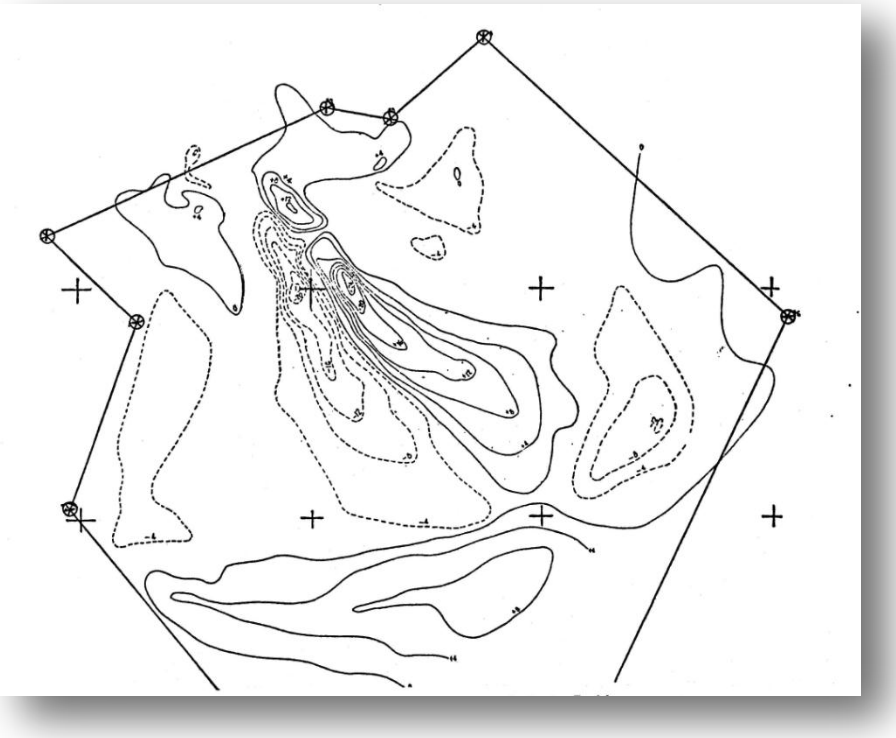


Figure 56. Contour differences at Great Egg Harbor Inlet from 1965 to 1984 (dashed contours indicate erosion, solid contours indicate accretion).

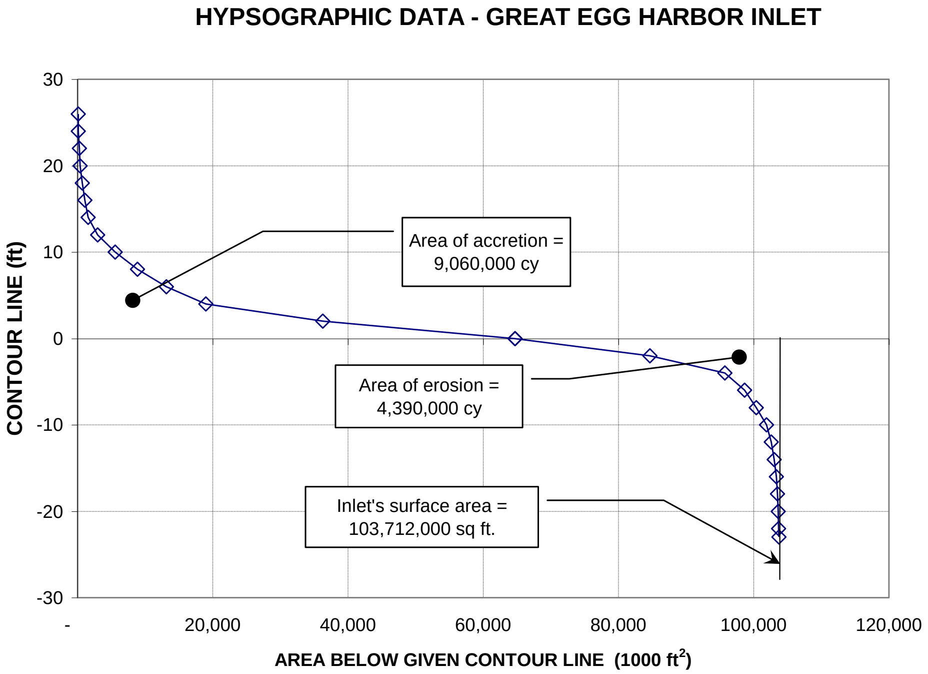


Figure 57. Hypsographic plot of accretion and erosion areas in Great Egg Harbor Inlet between 1965 and 1984.

Table 9. Nourishment of Ocean City Beaches Between 1952 and 1982.

Year	Volume (1000 cy)	Cumulative Volume (1000 cy)	Location
1952	2,550.0	2,550.0	Surf Rd. – 12th Street
1959	1,618.0	4,168.0	Atlantic Ave. – 15th Street
1962	278.0	4,416.0	Atlantic Ave. – 19th Street
1970	475.3	4,891.3	13th – 16th Streets
1971	237.9	5,129.2	16th – 23rd Streets
1972	243.7	5,672.8	5th – 10th Streets
1973	347.3	6,020.2	5th – 10th Streets
1974	167.5	6,187.7	5th Street south 16th Street north 16th Street south
1975	167.8	6,355.5	5th Street north 16th Street south
1976	81.7	6,437.2	5th Street north North end (emergency)
1977	169.9	6,607.1	North end (emergency)
1978	120.7	6,727.8	North end (emergency) St James – St Charles 5th Street
1979	84.5	6,812.3	5th Street
1980	193.1	7,005.4	5th Street south 6th Street
1981	25.8	7,031.2	5th Street
1982	1,277.1	8,308.3	Morningside – 20th Street

Average annual rate over 31 years = 268,000 cy/yr.
Average annual rate between 1964 and 1983 = 197,100 cy/yr.

With the individual components of the sediment budget resolved, the total budget for each of the three (3) cells was then solved according to the following equations:

Longport cell

$$kQ_{S1} - kQ_{N1} - Q_{S2} + B_2 - Q_{offL} = \Delta V_L \quad (2)$$

Great Egg Harbor Inlet cell

$$kQ_{S2} - B_2 + kQ_{N3} - B_3 - Q_{offI} = \Delta V_I \quad (3)$$

Ocean City cell

$$kQ_{N4} - kQ_{S4} + B_3 - kQ_{N3} - Q_{offOC} + Q_{nourish} = \Delta V_{OC} \quad (4)$$

Assuming B_2, B_3 and k are unknowns, eq. (2) becomes,

$$596.0k - 791.4k - 687.5k + B_2 - 43.1 = 53.2 \quad (5),$$

eq. (3) becomes,

$$687.5k - B_2 + 494.9k - B_3 = 236.5 \quad (6),$$

and eq. (4) becomes,

$$715.7k - 704.3k + B_3 - 494.9k - 105.3 + 197.1 = -132.1 \quad (7).$$

Solving for B_2, B_3 and k yields the following:

$$k = -0.469$$

$$B_2 = -244.6$$

$$B_3 = -450.7$$

The negative value of k indicates that directions for the longshore transport rates are opposite, and only about half the assumed values. For the Longport cell the calculations show,

Q_{N1} = -0.469 * 791.4 = -371,200 cy/yr to the south, and

Q_{S1} = -0.469 * 596.0 = -266,900 cy/yr to the north.

Likewise,

Q_{S2} = -0.469 * 687.5 = -322,400 cy/yr from the inlet north to Longport, and

B_2 = -244,600 cy/yr from Longport south into the inlet.

The budget indicates that the Longport cell gains sand from the inlet in the amount 77,800 cy/yr (322,400 cy – 244,600 cy).

At the south end of Ocean City,

Q_{N4} = -0.469 * 715.7 = -335,700 cy/yr to the south, and

Q_{S4} = 0.469 * 704.3 = -330,300 cy/yr to the north.

The amount of sand moving into the inlet from Ocean City is given by,

Q_{N3} = -0.469 * 494.9 = –232,100 cy/yr from the inlet south to Ocean City, and

B_3 = -450, 700 cy/yr from Ocean City north into the inlet.

Therefore approximately 218,600 cy/yr moves from the Ocean City cell into the inlet.

The preceding sediment budget is limited by the data, and as for all sediment budget calculations, care should be used in interpreting the results. The present budget is valid only for the 1965–1984 time period, and is suggestive of the prevailing wave climate at the time. Net transport directions compare well with the USACE sediment budgets prepared for the 1986 to 2003 time period (USACE-NAP, 2006; USACE-NAN, 2006). The transport rates between the two budgets differ, although this could be explained by variations in wave climatology between the time periods investigated. Additionally, with the ongoing Ocean City and Ludlam Island beach nourishment projects, conditions are significantly different today. An analysis using more recent data or more sophisticated methods would lend insight into the cause of nourishment losses from the north end of the Ocean City Project.

Enhanced Monitoring Program

Substantial efforts have been devoted to collecting data along the New Jersey shoreline to document beach profile change and monitor beach nourishment project performance. Bi-annual surveys by Richard Stockton College at 100 profiles provide the backbone for the present monitoring program. These profiles should continue, and be supplemented as follows:

- Complementary profiles should be surveyed according to standard methods, equipment, and horizontal/vertical datums to provide greater spatial resolution at strategic locations, including at erosional hotspots and on vulnerable barrier beaches. Specific locations and spacing should be specified depending upon available resources; however, candidate areas would include erosional hotspots at northern Ocean City and Avalon, as well as Cape May City.

- Enhanced beach profile data analysis according to standard protocols should be performed including:
    - Extrapolate shoreline position to populate an annual archive of measured shorelines for subsequent shoreline change analysis.
    - Calculate volume change at each profile, and integrate across the shoreline, and across each shore protection project area.
    - Compare beach profile volume change to expected beach nourishment performance and identify areas where the project performs or does not perform as planned. This information should be used to evaluate sand volume requirements as compared to scheduled maintenance quantities. If warranted, maintenance schedules should be updated using the beach profile information. If future sand volumes and/or budgets are limited, this information should be used to determine where nourishment should be directed to improve future performance (.g., adaptive management).

In addition to the complementary beach profiling and enhanced analysis, there is a need for supplemental data related to waves, currents, and bathymetric change:

- Offshore wave data (e.g., seaward of the closure depth ~30-35 feet deep) at key locations should be collected to quantify wave energy impacting the coastline. Also, nearshore wave data at strategic locations (e.g., ~20 feet deep) should be obtained to quantify wave focusing from offshore to nearshore, especially offshore of erosional hotspots. For example, a one-year wave data collection program at critical locations (3-4) along the New Jersey coastline would define transformed wave conditions for authorized Shore Protection Projects. Corresponding nearshore data should be collected for a minimum of 3 months, focused on traditionally high-energy times of year. Bottom-mounted wave ADCP instrumentation or surface buoys would be appropriate, and measurement of directional spectra is essential. The data would refine design criteria, and provide boundary condition and calibration information for wave and sediment transport models necessary for refinement of sediment budgets and optimization of shore protection project design.
- Supplemental sediment sampling is required at the inlets to evaluate opportunities to expand dredging footprints within the navigation channels. For example, there is potential to substantially expand dredged quantities from Barnegat Inlet for nourishment of Long Beach Island if the sand compatibility can be demonstrated, and if the potential environmental impacts can be managed. Other inlets should also be evaluated. Collection of current data is needed to understand sediment transport patterns and rates, particularly in the vicinity of tidal inlets adjacent to beach nourishment projects. This information will further quantify rates and pathways in the sediment budgets as the basis for improving project design and maintenance. The most desirable area is Great Egg Harbor Inlet at the north

end of Ocean City, where sediment transport due to tidal currents and/or wave-current interactions potentially influence adjacent beach erosion. Other inlets could also be evaluated, as needed.

Bathymetry data in the tidal inlets and offshore borrow sites is required to effectively quantify inlet sediment budgets, and develop accurate estimates of sand volume availability in approved borrow sites. A program of surveys for each inlet and borrow area once every ten (10) years is preferred, supplemented by pre- and post-dredging surveys. Key areas would include Hereford Inlet, Townsends Inlet, Corson Inlet, and Great Egg Harbor Inlet. Since these inlets are not authorized navigation projects, routine bathymetric surveys of the channel and ebb shoal areas area collected. A time series of bathymetric data at these inlets would quantify sedimentation patterns and rates, and aid the identification of potential borrow sites for nourishment of adjacent beaches. Targeted nearshore bathymetric surveys offshore of erosional hotspots would lend greater insight to sediment transport processes, and provide data necessary to refine shore protection solutions in these areas.

Last, a geo-referenced database is recommended as a living tool to monitor and track beach nourishment history and status. Existing records are fragmented regarding the quantities, dates, sources, and locations of nourishment projects completed. Having a single point of reference that can be easily updated would facilitate the overall planning process. The database could be developed as a shared effort between authorized projects as part of the ongoing monitoring process. Funds could be pooled from individual projects as a refinement to the monitoring plan. If needed, existing authorities should be modified to provide dedicated appropriations for development of a database. A dedicated database manager should be defined, and the database should include an updated annotated bibliography of reference materials, monitoring survey metadata, and links to quality controlled data sets.

Sediment needs versus sediment availability and borrow area development

This broad regional strategy focuses on the overall available sand volumes needed to maintain the authorized project design templates compared to the available sand resources in identified sand borrow sites. Marine spatial planning strategies were implemented that consider the proximity of permitted borrow sites and navigation channels to the authorized beach nourishment projects. The analysis shows an overall surplus of sediment for the New Jersey beach nourishment program. However, there are local deficits where offshore sand resources are distant from the beaches in need of nourishment. An alternatives analysis shows expanded sediment requirements and identifies priority sand resources needed to supplement existing borrow sites.

Authorized Project Needs

A 2007 analysis by USACE NAP evaluated future sand requirements for authorized projects based strictly on design quantities, estimated renourishment quantities, and anticipated renourishment intervals. The analysis accounted for the time period elapsed from the 50-year design horizon for each project. Table 10 summarizes future estimated quantities per project as of 2007. Total future requirements, including beaches under jurisdiction of USACE NAN, are estimated to be 178,352,000 cubic yards. Adding the 38,404,000 cubic yards already placed on beaches for initial construction, and 9,553,000 cubic yards for periodic nourishment up to 2007, the total sand quantity authorized for the 50-year project is nearly 226,309,000 cubic yards.

Historic Nourishment Rates

Historic volumes of sand placed on New Jersey beaches from the 1960s to 2010 were analyzed to determine nourishment rates and resources utilized. Data were obtained from the USACE NAP, USACE NAN, and New Jersey Bureau of Coastal Engineering records. The data were sorted according to shoreline Reaches 1 through 8. Annualized nourishment rates were calculated from trend lines fit to the cumulative rate of nourishment for each Reach. For instance, Figure 58 presents the cumulative rate of nourishment for the Reach from Cape May Point to Cape May Inlet. The slope of the trend line estimates the nourishment rate for the Reach in cubic yards per year. The data show an historic rate of nourishment for the Cape May Point to Cape May Inlet Reach of 142,000 cy/yr.

A similar linear regression analysis was used to compute historic nourishment rates for the remaining shoreline Reaches north to Sandy Hook. Results are summarized in Table 11, including nourishment rates per mile of shoreline. The Ocean City shoreline between Corson Inlet and Great Egg Harbor Inlet shows the highest historic nourishment rate per mile at 49,000 cy/yr-mi. The lowest annualized rate per mile of 2,700 cy/yr-mi occurs in the area from Shark River Inlet to Manasquan Inlet. Extrapolation over a 50-year project life for the entire New Jersey shoreline suggests a requirement of 97,000,000 cubic yards of nourishment material. This volume is less than the estimated quantity based on authorized project volumes, mainly because the actual nourished quantities have lagged behind the authorized design volumes due to funding limitations.

Future Nourishment Rates

Future nourishment rates were computed by supplementing the historical data with expected renourishment quantities and cycles over the remaining lifetimes of the authorized projects. Periodic renourishment quantities and cycles in the authorized project plans were used to extend the historical estimates. A 50-year project life was used from the time of the initial nourishment. Figure 59 presents an example of the extended cumulative nourishment rates for the Cape May Point to Cape May Inlet Reach. The slopes of the linear trend lines were used to estimate future nourishment rates.

Table 10. Sand Requirements for Authorized Shore Projects in New Jersey

Shoreline Reach	Authorized Shore Protection Project	Initial Construction Volume (cy)	Years Remaining*	Renourishment Interval	Periodic Renourishment Volume (cy)	Future Sand Requirement (cy)
8	Sandy Hook to Barnegat Inlet, NJ; Section I: Sea Bright to Ocean Twnsp. Section II: Asbury to Manasquan	14,800,000 (I) 7,200,000 (II)	33 (I) 38 (II)	6 (I) 6(II)	3,500,000 (I) 2,600,000 (II)	21,000,000 (I) 15,600,000 (II)
7	Manasquan Inlet to Barnegat Inlet, NJ	10,689,000	50	4	961,000	23,182,000
6	Barnegat Inlet to Little Egg Inlet, NJ	6,700,000	50	7	1,900,000	20,000,000
5	Brigantine Inlet to Great Egg Harbor Inlet: Brigantine, NJ	Completed	50	6	312,000	2,496,000
4	Brigantine Inlet to Great Egg Harbor Inlet: Absecon, NJ	Completed	47	3	1,591,000	25,456,000
3	Great Egg Harbor Inlet and Peck Beach, NJ (Ocean City Beachfill)	Completed	35	3	1,100,000	13,200,000
3	Great Egg Harbor Inlet to Townsends Inlet, NJ - Peck	1,603,000	50	3	403,000	8,454,000
3	Great Egg Harbor Inlet to Townsends Inlet, NJ - Ludlam	5,146,000	50	5	1,820,000	23,346,000
2	Townsends Inlet to Cape May Inlet, NJ	Completed	47	3	746,000	11,936,000
2	Hereford Inlet to Cape May Inlet, NJ	Unavailable	50	Unavailable	Unavailable	Unavailable
1	Cape May Inlet to Lower Township (Cape May City Beachfill)	Completed	34	2	346,000	5,882,000
1	Lower Cape May Meadows, Cape May Point, NJ	Completed	48	4	650,000	7,800,000
					TOTAL	**178,352,000**

* As of 2007

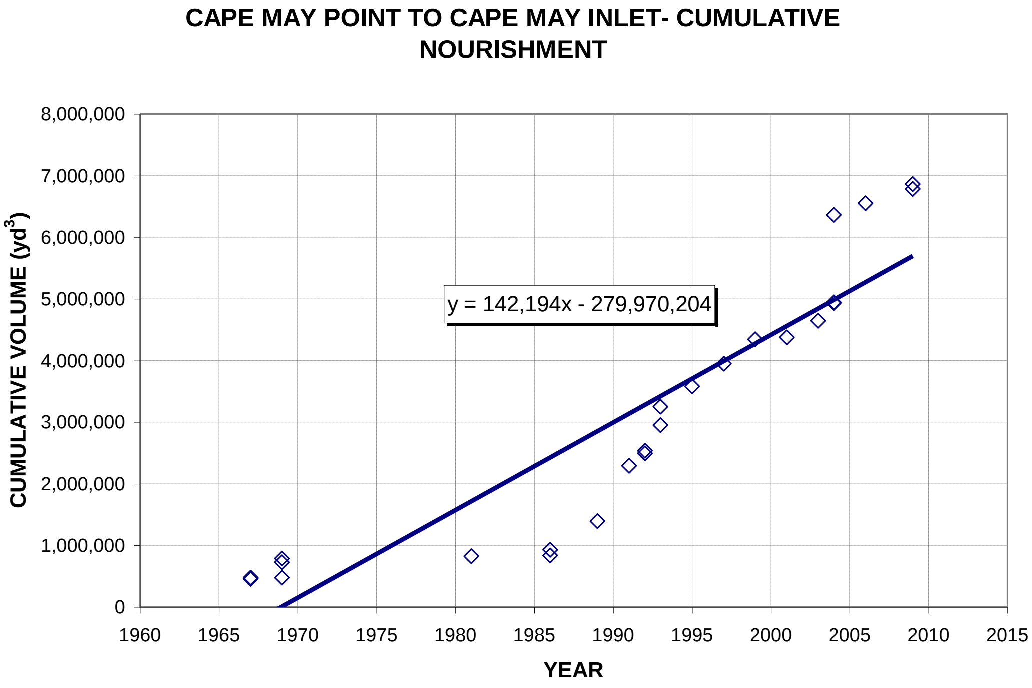


Figure 58. Cumulative historic nourishment between Cape May Point and Cape May Inlet.

Table 11. Historic Nourishment Rates for New Jersey Shoreline Reaches.

Shoreline Reach	Shoreline Region	Historic Nourishment Rate (cy/yr)	Shoreline Length (mi)	Historic Nourishment Rate Per Mile of Beach (cy/yr-mi)
8	Sandy Hook to Shark River	488,636	19.3	25,226
8	Shark River to Manasquan Inlet	15,927	5.8	2,727
7	Manasquan Inlet to Barnegat Inlet	107,331	23.3	4,610
6	Barnegat Inlet to Little Egg Inlet	238,739	20.3	11,766
5	Brigantine Inlet to Absecon Inlet	54,478	4.4	12,353
4	Absecon Inlet to Great Egg Inlet	141,547	7.9	17,872
3	Great Egg Inlet to Corson Inlet	400,319	8.1	49,361
3	Corson Inlet to Townsends Inlet	147,893	6.3	23,438
2	Townsends Inlet to Hereford Inlet	160,584	6.3	25,329
2	Hereford Inlet to Cape May Inlet	39,830	7.0	5,666
1	Cape May Inlet to Cape May Point	142,264	6.2	23,020
TOTAL =		**1,937,548**	**115.0**	**18,306**

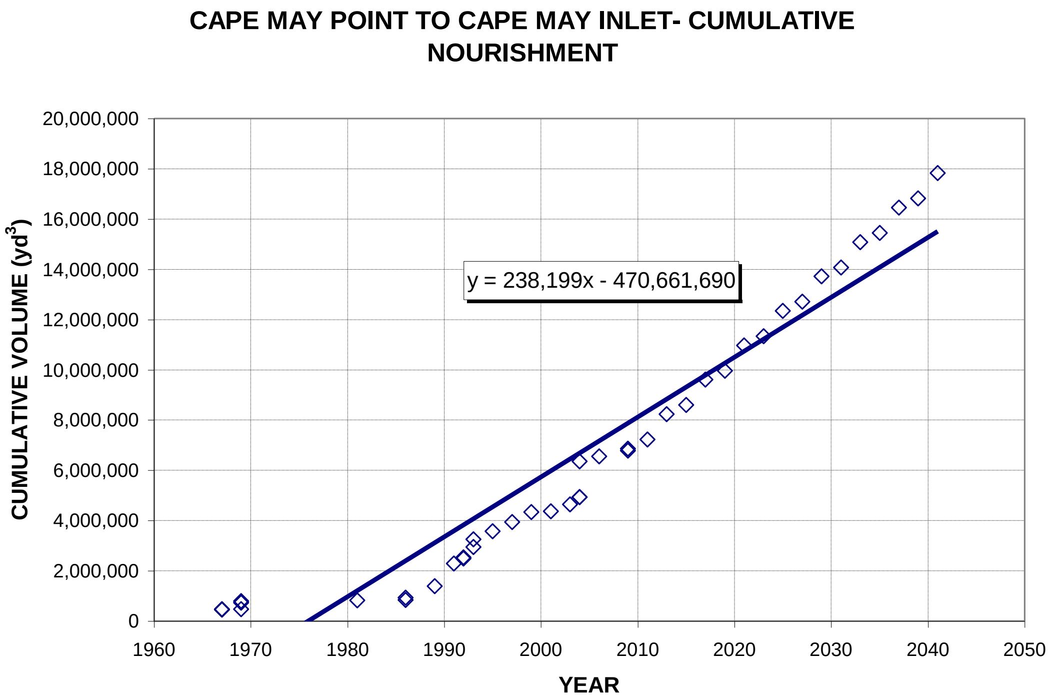


Figure 59. Cumulative future nourishment between Cape May Point and Cape May Inlet.

Table 12 presents the projected annual nourishment rates for the shoreline regions. Total sand requirements are projected to be nearly 3 million cubic yards per year for the entire state of New Jersey, or approximately 149 million cubic yards for the 50-year project life. The maximum projected nourishment rate per mile is 57,763 cy/yr-mi at Ocean City. The lowest is 5,666 cy/yr-mi for Hereford Inlet to Cape May Inlet.

Figure 60 compares historic and projected rates of nourishment on a per mile basis for the entire coastline. The data illustrate relative differences in nourishment quantities, with the area between Hereford and Absecon Inlets receiving the most sand. Figure 61 presents a comparison of historic nourishment rates per mile of shoreline with estimated losses due to sea level rise (from Table 5). The sea level rise losses do not include sediment transported to adjacent inlets, or losses off Cape May Point or Sandy Hook. Sediment moved from the beach to the inlets may at times be recovered during episodic events that transport material to downdrift shorelines, or by natural bypassing across the inlet ebb shoals.

In most locations, nourishment rates exceed offshore loss rates (Figure 61), which confirms that continued nourishment can help stem beach erosion. Exceptions occur at Brigantine and Absecon Islands, where losses have exceeded historic nourishment rates. The higher future planned nourishment rate, particularly at Absecon Island will help mitigate the loss of sand due to sea level rise; however, long-term net erosion is to be expected at Brigantine unless the planned future nourishment volume is increased. Whether sand sources from known borrow sites can meet the long-term project requirements is evaluated separately below.

Table 12. Future Nourishment Rates for New Jersey Shoreline Reaches.

Shoreline Reach	Shoreline Region	Projected Nourishment Rate (cy/yr)	Shoreline Length (mi)	Projected Nourishment Rate Per Mile of Beach (cy/yr-mi)
8	Sandy Hook to Shark River	629,345	19.3	32,491
8	Shark River to Manasquan Inlet	128,441	5.8	21,993
7	Manasquan Inlet to Barnegat Inlet	228,620	23.3	9,820
6	Barnegat Inlet to Little Egg Inlet	296,700	20.3	14,623
5	Brigantine Inlet to Absecon Inlet	53,832	4.4	12,207
4	Absecon Inlet to Great Egg Inlet	352,288	7.9	44,481
3	Great Egg Inlet to Corson Inlet	468,459	8.1	57,763
3	Corson Inlet to Townsends Inlet	325,158	6.3	51,531
2	Townsends Inlet to Hereford Inlet	220,422	6.3	34,767
2	Hereford Inlet to Cape May Inlet	39,830	7.0	5,666
1	Cape May Inlet to Cape May Point	238,199	6.2	38,544
TOTAL		**2,981,294**	**115.0**	**29,444**

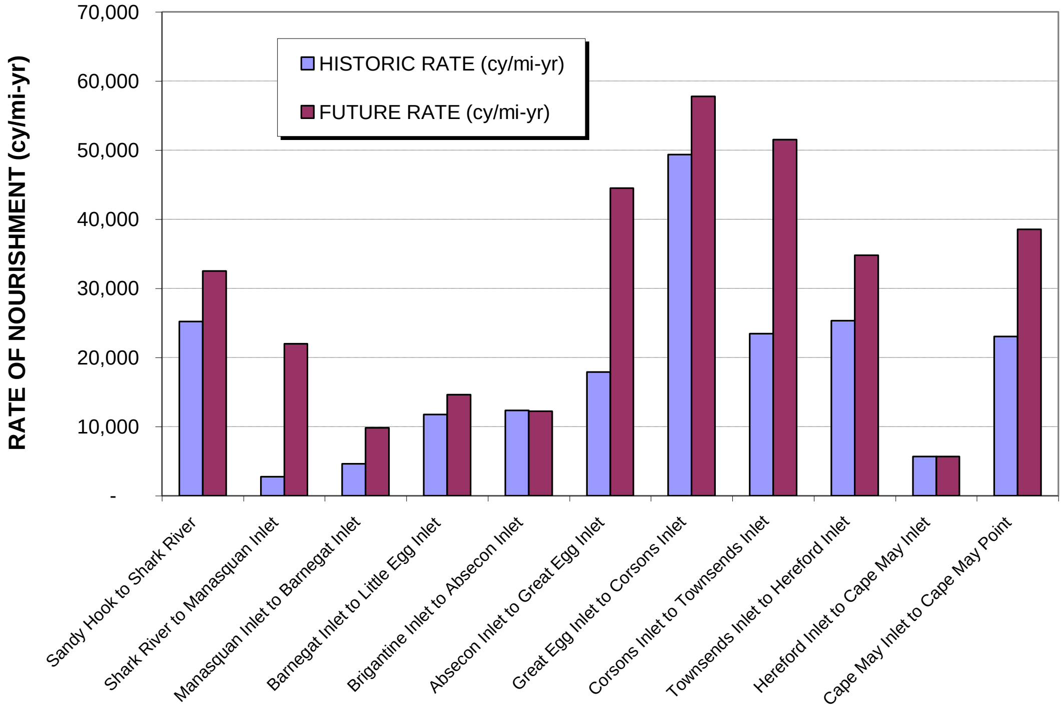


Figure 60. Comparison of historic and projected rates of nourishment per shoreline mile for various shoreline regions

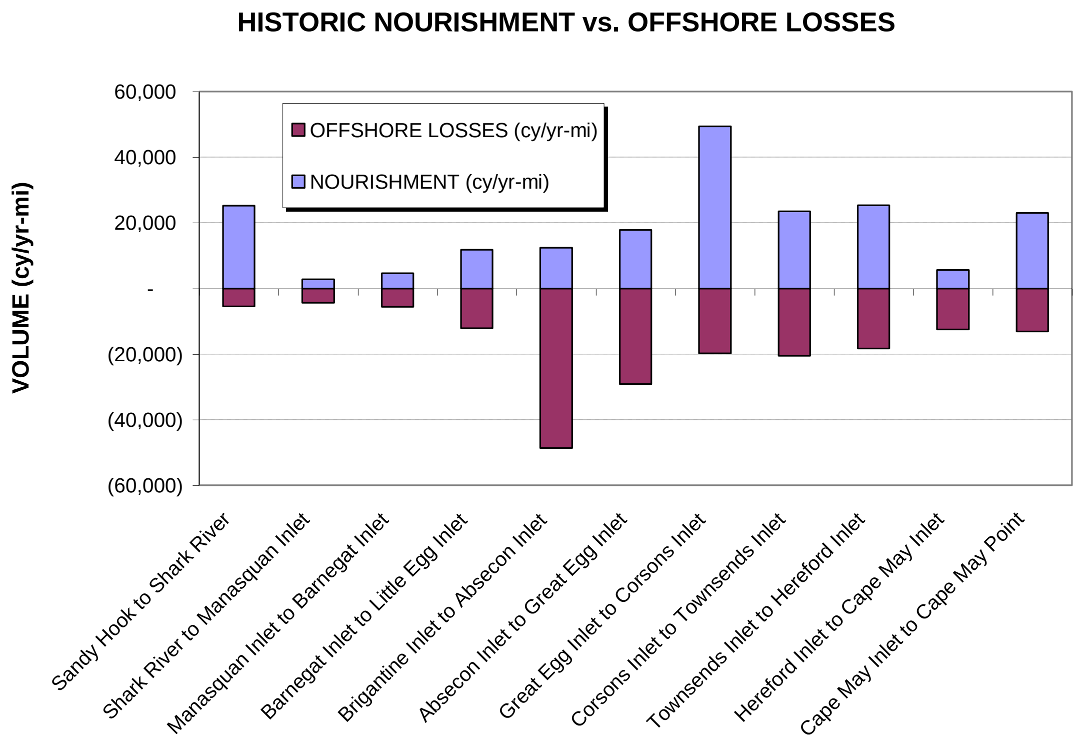


Figure 61. Historic nourishment rates compared with estimated losses due to sea level rise.

Sediment Availability within Identified Borrow Sites

A spatial analysis of sand available for beach nourishment in existing and potential borrow areas was performed using existing data provided by the USACE NAP and NAN. The analysis determined a "range of availability" using a distance from the centroid of the known borrow areas to the shoreline. A five-mile radius from the centroid was used to determine the likely shoreline region where the borrow sand would be used. The five-mile radius was assumed to be a representative transport distance for a hopper dredge. Thus, a borrow area farther from shore would produce a smaller "range of availability", while an area in an inlet or closer to shore would produce a longer "range of availability".

Known borrow areas were located on a map, and a five-mile arc was constructed from the borrow area centroids. The locations where the arcs intersected the shoreline were used to identify the "range of availability". For example, an arc from the centroid of the Townsends Inlet borrow area intersects the shoreline 2.6 miles north of Hereford Inlet and 5.2 miles north of Townsends Inlet, giving a "range of availability" of 10 miles (Figure 62).

The annualized capacity of each borrow area was obtained by dividing the estimated volume in the borrow area by 50 years. The annual volume per mile was computed by dividing by the length of each shoreline region. Table 13 summarizes the borrow areas, distance from shore, projected volume, and the shoreline length within the "range of availability". The analysis assumes more than one borrow area can be used for a particular shoreline region. Thus, the contribution of each borrow area is summed across overlapping shoreline regions within the "range of availability." The cumulative annual volume available for each shoreline region is then calculated as the sum of the individual contributions to the region from each borrow site in the range.

Figure 63 presents the results of the analysis for the shoreline reach between Cape May Point and Cape May Inlet. The amount of sand available in authorized and/or permitted borrow areas as a function of shoreline location is illustrated, along with the amount available if potential borrow areas are considered. Also shown is the cumulative amount of sand available as measured from the inlet at the southerly end of the reach. The slope of the cumulative line at a given location provides the annual amount of sand available for that shoreline location from existing and potential borrow areas. For example, on Figure 63 the slope between Mile 0 and Mile 3.0 considering both existing and potential borrow areas is about 34,100 cy/yr-mi or 6.5 cy/yr per foot of beach. The slope between Mile 3.0 and Mile 4.8 is 77,200 cy/yr-mi or 14.6 cy/yr per foot of beach. This is because additional borrow areas contribute sand to the "range of availability," specifically the high capacity potential borrow areas K and $K_{extension}$. Relaxation of the five-mile assumption for the borrow site analysis would move the boundary between the two slopes southward.

A similar mass balance analysis was used to compute borrow area capacities for the remaining shoreline reaches north to Sandy Hook. Table 14 presents the amount of borrow sand available for each shoreline reach, as well as the volume per unit length of shoreline.

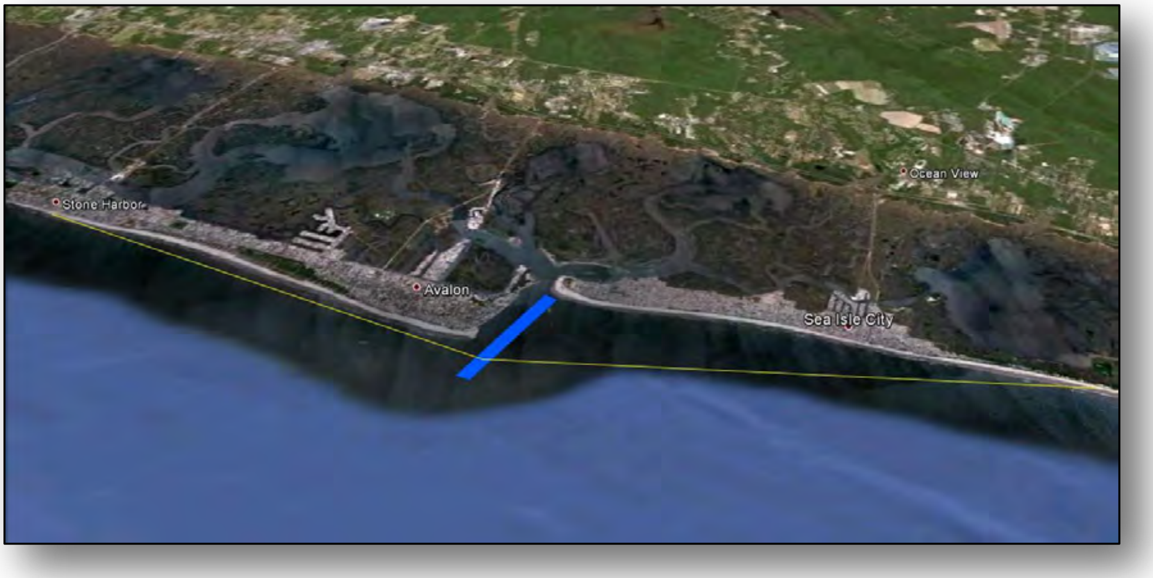


Figure 62. Location of Townsend Inlet borrow area showing shoreline intercepted by a 5-mile radius drawn from the centroid of the borrow area.

Table 13. Borrow Area Designations and Capacities

Borrow Area Designation	Distance from Shoreline (mi)	Borrow Area Status	Projected Capacity (1,000 cy)	Annualized Capacity (1000 cy/yr)(1)	Shoreline Length (mi)(2)	Volume Per Unit Shoreline Length (cy/yr-mi)	Range of Availability (5-mile radius)
M2	1.40	Potential	N/A	0.0	5.8	0	Cape May Point to 0.2 mi. S of Cape May Inlet
P2	1.20	Potential	N/A	0.0	6.7	0	Cape May Point to 0.68 mi N of Cape May Inlet
CM4	1.05	Existing	4,450	89.0	8.3	10,678	Cape May Point to 2.13 mi N of Cape May Inlet
CM1	1.50	Existing	2,200	44.0	8.3	5,279	Cape May Point to 1.91 mi N of Cape May Inlet
P1	1.30	Existing	1,336	26.7	7.7	3,489	Cape May Point to 2.36 mi N of Cape May Inlet
CM5	1.40	Existing	2,841	56.8	7.7	7,420	Cape May Point to 1.46 mi N of Cape May Inlet
K	3.75	Potential	7,177	143.5	5.7	25,346	3.15 mi. S of CMI to 2.8 mi N of Cape May Inlet
$\mathbf{K}_{\mathbf{extension}}$	3.75	Potential	5,008	100.2	5.7	17,691	3.15 mi. S of CMI to 2.8 mi N of Cape May Inlet
Cape May Inlet		Existing	3,000	60.0	8.3	7,248	Cape May Point to 5.06 mi. N of Cape May Inlet
WW/WC	0.00	Potential	2,256	45.1	8.3	5,413	1.14 mi. S of CMI to 1.8 mi N of Hereford Inlet
OS1	0.50	Potential	13,016	260.3	8.3	31,233	1.37 mi. S of CMI to 1.35 mi. N of Hereford Inlet
OS2	N/A	Potential	9,493	189.9	N/A	N/A	N/A
Hereford Inlet - A1	0.70	Existing	1,300	26.0	8.3	3,119	1.35 mi. N of CMI to 4.5 mi. N of Hereford Inlet
Hereford Inlet - A2	0.95	Existing	800	16.0	8.3	1,920	2.25 mi. N of CMI to 5.47 mi N of Hereford Inlet
Hereford Inlet - Maine	0.90	Existing	1,950	39.0	8.33	4,679	1.76 mi. N of CMI to 5.18 mi. N of Hereford Inlet
Hereford Inlet - NJDEP	0.50	N/A	N/A	N/A	8.33	N/A	1.24 mi. N of CMI to 4.61 mi. N of Hereford Inlet
Townsends Inlet	0.50	Existing	3,500	70.0	10.00	7,000	2.6 mi. N of Hereford Inlet to 5.24 mi. N of Townsends Inlet
L1	2.75	Existing	16,100	322.0	9.16	35,142	6.19 mi. N of Hereford Inlet to 0.9 mi. N of Corson Inlet
L2	3.75	Potential	24,859	497.2	8.33	59,650	6.41 mi N of Hereford Inlet to centerline of Corson Inlet

Borrow Area Designation	Distance from Shoreline (mi)	Borrow Area Status	Projected Capacity (1,000 cy)	Annualized Capacity (1000 cy/yr)(1)	Shoreline Length (mi)(2)	Volume Per Unit Shoreline Length (cy/yr-mi)	Range of Availability (5-mile radius)
L3	3.10	Existing	21,861	437.2	8.33	52,457	0.97 mi. N of Townsends Inlet to 3.33 mi. N of Corson Inlet
M3	2.30	Potential	23,166	463.3	9.17	50,514	3.04 mi. N of Townsends Inlet to 6.3 mi. N of Corson Inlet
M8	4.00	Existing	6,500	130.0	8.33	15,597	4.5 mi. N of Townsends Inlet to 5.74 mi. N of Corson Inlet
Corson Inlet	0.45	Existing	1,000	20.0	10.00	2,000	1.35 mi. N of Townsends Inlet to 5.4 mi. N of Corson Inlet
OC-A	1.20	Existing	16,000	320.0	10.00	32,000	2.72 mi N of Corson Inlet to 5.28 mi. N of Great Egg Inlet
Gardens	1.25	Potential	19,439	388.8	10.00	38,878	3.08 mi. N of Corson Inlet to 5.62 mi. N of Great Egg Inlet
AC - B&C	1.30	Existing	11,000	220.0	9.69	22,716	3.15 mi. N of Great Egg Inlet to 4.38 mi. N of Absecon Inlet
Absecon Inlet - A thru F	0.70	Existing	1,900	38.0	9.85	3,856	3.48 mi. N of Great Egg Inlet to 5.4 mi. N of Absecon Inlet
G1	2.40	Potential	14,618	292.4	8.11	36,053	6.41 mi. N of Great Egg Inlet to centerline Brigantine Inlet
Brigantine Inlet - B2	0.70	Existing	2,700	54.0	9.70	5,565	1.35 mi N of Absecon Inlet to 6.25 mi. N of Little Egg Inlet
LBI E	0.85	Existing	9,350	187.0	10.00	18,700	4.05 mi. N of Little Egg Inlet to 15.07 mi. N of Little Egg inlet
LBI D1	3.15	Existing	12,000	240.0	8.33	28,795	11.7 mi. N of Little Egg Inlet to 20.47 mi. N of Little Egg Inlet
LBI D2	4.05	Existing	12,000	240.0	7.08	33,880	13.72 mi. N of Little Egg Inlet to centerline of Barnegat Inlet
LB Twp - B	1.69	Existing	3,640	72.8	9.77	7,451	13.72 mi N of Little Egg Inlet to 2.7 mi. N of Barnegat Inlet
Barnegat Inlet	0.45	Existing	12,040	240.8	10.00	24,080	15.64 mi N of Little Egg Inlet to 5.17 mi. N of Barnegat Inlet

Borrow Area Designation	Distance from Shoreline (mi)	Borrow Area Status	Projected Capacity (1,000 cy)	Annualized Capacity (1000 cy/yr)(1)	Shoreline Length (mi)(2)	Volume Per Unit Shoreline Length (cy/yr-mi)	Range of Availability (5-mile radius)
Berkeley Twp - A	2.27	Existing	11,200	224.0	10.00	22,396	2.61 mi . N of Barnegat Inlet to 12.94 mi. N of Barnegat Inlet
Berkeley Twp - E	2.50	Potential		0.0	9.59	0	3.41 mi. N of Barnegat Inlet to 13.51 mi. N of Barnegat Inlet
Berkeley Twp - D	2.04	Potential	3,750	75.0	10.00	7,500	5.45 mi N of Barnegat Inlet to 15.78 mi. N of Barnegat Inlet
Mantoloking - B	1.60	Existing	6,300	126.0	9.91	12,714	14.07 mi. N of Barnegat Inlet to 0.58 mi. N of Manasquan Inlet
Manasquan - A	1.72	Existing	11,200	224	9.43	23,754	15.3 mi. N of Barnegat Inlet to 8.56 mi. N of Manasquan Inlet
Belmar BA-1 (3)	2.82	0	0	0	8.39	0	0.60 mi. N of Barnegat Inlet to 3.08 mi. N of Shark River Inlet
Belmar BA-2 (3)	1.69	0	0	0	9.52	0	
Belmar BA-3 (3)	1.55	0	0	0	9.85	0	
Belmar BA-4 (3)	1.38	0	0	0	9.91	0	
Belmar BA-5 (3)	2.32	0	0	0	9.36	0	
Belmar BA-6 (3)	4.49	0	0	0	4.90	0	0.70 mi N of Manasquan Inlet to 2.82 mi. N of Shark River
Belmar BA-7 (3)	3.40	0	0	0	7.56	0	
Seabright A	1.41	Existing	23,100	462.0	10.00	46,200	9.64 mi. N of Shark River to Sandy Hook
Seabright B	2.09	Existing	14,862	297.2	10.00	29,720	10.1 mi. N of Shark River to Sandy Hook
Seabright C	2.23	Existing	7,038	140.8	9.59	14,682	9.28 mi. N of Shark River to 19.97 mi. N of Shark River
Sandy Hook	0.47	N/A	N/A	0.0	5.00	N/A	15.27 mi. N of Shark River to Sandy Hook

(1) Assumes 50 years
(2) Assumes 5-mile radius from centroid of borrow area
(3) Belmar borrow areas have been depleted
N/A – Information not available

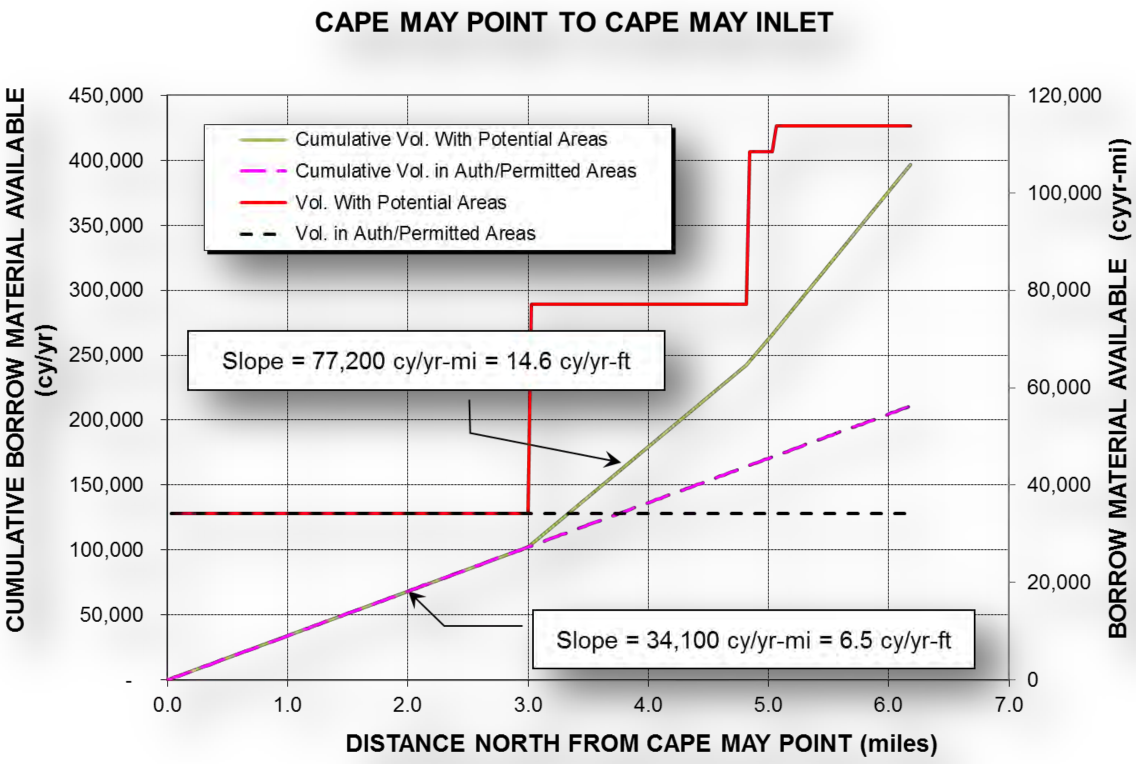


Figure 63. Cumulative volume of sand available for beaches between Cape May Point and Cape May Inlet in borrow areas within a five-mile radius.

Figure 64 compares the availability of sand from authorized/permitted and potential borrow areas for the entire Atlantic Ocean coastline of New Jersey. The figure shows reaches of shoreline where little or no sand is available within a 5 mile range of availability. For example, in the areas around miles 50 to 60 near the south end of Long Beach Island, and miles 103 to 115 in the vicinity of Shark River Inlet, there is no borrow sand within 5 miles of the beach. This suggests that nourishment of these areas would benefit from the identification of new borrow areas, or that sand will need to be transported for distances exceeding 5 miles. While use of potential borrow areas identified by the USACE increases the amount of sand available (mostly in areas where large amounts of sand are already available), it does not close the gaps along the shoreline where sand supplies are limited.

Figure 65 presents the cumulative amount of borrow material available per year for New Jersey's ocean coastline. The slope of the curve is the volume per year per mile available locally. Authorized and permitted borrow areas can provide about 4.9 million cy of sand per year. If potential borrow areas are included that volume increases to just over 7.0 million cy per year. In total, the identified authorized or permitted borrow sites would potentially supply some 243,100,000 cy of sand for the 50-year project, and up to 351,650,000 cy if all potential sites are accessible.

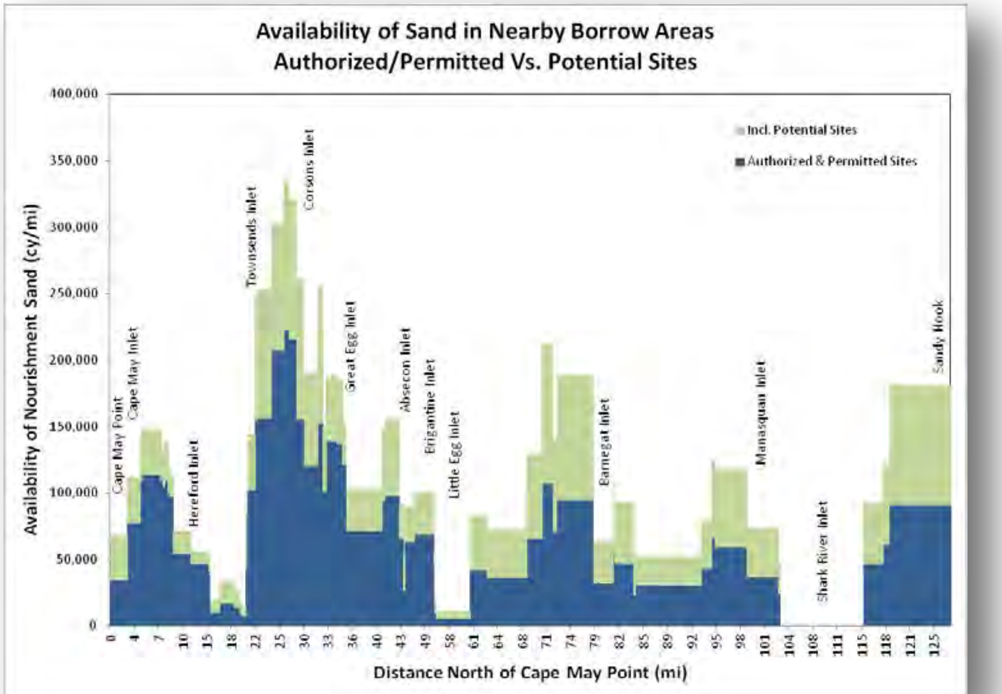


Figure 64. Availability of nourishment sand from authorized, permitted and potential borrow sites within 5 miles of beach.

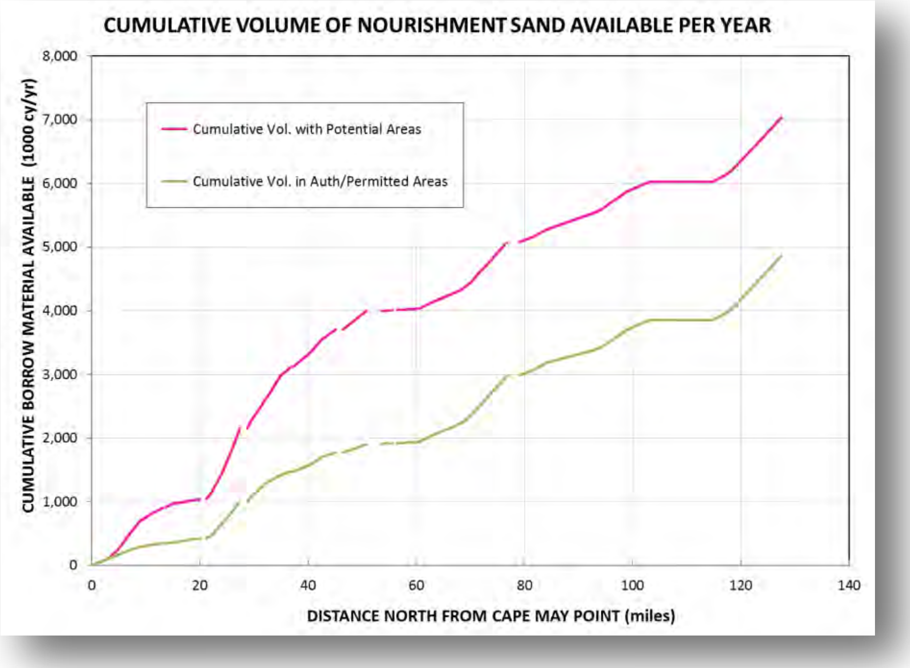


Figure 65. Cumulative volume of nourishment sand available as a function of distance north of Cape May Point.

Table 14. Summary of Borrow Sand Volume Available for Each Shoreline Region.

Shoreline Reach	Shoreline Region	Reach Length (miles)	Volume Authorized/ Permitted Areas (1000 cy/yr)	Volume per Mile Authorized/ Permitted Areas (cy/yr-mi)	Volume Including Potential Borrow Areas (1000 cy/yr)	Volume per Mile Including Potential Borrow Areas (cy/yr-mi)
8	Sandy Hook(1) to Shark River Inlet	19.32	1,009	52,247	1,009	52,247
8	Shark River Inlet(1) to Manasquan Inlet	5.84	28	4,823	28	4,823
7	Manasquan Inlet to Barnegat Inlet	23.28	840	36,061	917	39,408
6	Barnegat Inlet to Little Egg Harbor Inlet	20.29	1,067	52,569	1,067	52,569
5	Little Egg Harbor Inlet to Brigantine Inlet	2.06	12	6,038	12	6,038
5	Brigantine Inlet to Absecon Inlet	4.41	134	30,272	292	66,304
4	Absecon Inlet to Great Egg Harbor Inlet	7.92	295	37,226	589	74,373
3	Great Egg Harbor Inlet to Corson Inlet	8.11	476	58,702	962	118,680
3	Corsons Inlet to Townsends Inlet	6.31	574	90,943	1,115	176,679
2	Townsends Inlet to Hereford Inlet	6.34	80	12,679	128	20,268
2	Hereford Inlet to Cape May Inlet	7.03	137	19,433	515	73,222
1	Cape May Inlet to Cape May Point	6.18	211	34,119	397	64,194

(1) Data not available for several large borrow areas.

Overall Sediment Supply Compared to Need

Total sand requirements for the 50-year project are estimated to be 226,309,000 cy of clean, beach-compatible sand. Based strictly on the time remaining, the renourishment frequency, and renourishment volume estimates in the authorized project design templates, a conservative estimate of future sand requirements is 178,352,000 cy. An inventory of identified borrow sites reveals that the estimated volume of available sand in the existing authorized or permitted borrow sites combined is 243,120,000 cy. This volume increases to 351,630,000 cy with use of potential borrow sites identified along the New Jersey coast.

Although there is an adequate supply of sand identified on a state-wide basis, there are limitations for accessing the sand. Primary limitations include spatial constraints for transporting sand from the borrow site to the beach nourishment project, along with environmental constraints for obtaining permits. Federal funding to cost-share beach nourishment projects also has been a limiting factor, accentuating the need for readily accessible sand resources in close proximity to the nourishment sites.

Table 15 summarizes the sand requirements and available resources by shoreline reach. Although there is an overall abundance of sand in the identified borrow sites, there are certain reaches and projects lacking adequate sand resources.

- Reach 1 between Cape May Point and Cape May Inlet has a shortfall of (-3,142,000) cy with authorized or permitted sites. However, when potential borrow sites are included there is a surplus of 6,158,000 cy of sand.
- Reach 2 between Cape May Inlet and Townsends Inlet has a shortfall of (-1,086,000) cy with existing authorized or permitted borrow sites. This does not include possible sand needs between Hereford Inlet and Cape May Inlet, since this region is in the feasibility investigation stage. When potential borrow sites are added there is a surplus of 20,224,000 cy.
- Reach 4 between Great Egg Harbor Inlet and Absecon Inlet has a significant shortfall of (-10,716,000) cy within existing authorized or permitted borrow sites. When potential borrow sources are added there is a surplus of 3,994,000 cy.

Supplemental sand also is derived via infilling at certain borrow areas. Although additional data and analyses are needed to quantify the infilling rates, accumulated sand in the borrow areas could offset the shortfalls shown in Table 15, especially in shoreline reaches 1 and 2 where the deficits are relatively small.

Table 15. Summary of Sand Requirements versus Availability, not including needs for Hereford Inlet to Cape May Inlet.

Shoreline Reach	Shoreline Region	Authorized Projects	Volume of Nourishment Required (cy)	Volume Authorized/ Permitted Areas (cy/50 yr)	Volume Difference w/out Potential Areas (cy/50 yr)	Volume Including Potential Borrow Areas (cy/50 yr)	Volume Difference Incl. Potential Source (cy/50 yr)
8	Manasquan Inlet to Sandy Hook	Sandy Hook to Barnegat Inlet, NH; Sections I and II – Sea Bright to Manasquan	36,600,000	51,880,000	15,280,000	51,880,000	15,280,000
7	Barnegat Inlet to Manasquan Inlet	Manasquan Inlet to Barnegat Inlet, NJ	23,182,000	41,980,000	18,798,000	45,870,000	22,688,000
6	Little Egg Harbor Inlet to Barnegat Inlet	Barnegat Inlet to Little Egg Inlet, NJ	20,000,000	53,330,000	33,330,000	53,330,000	33,330,000
5	Absecon Inlet to Little Egg Inlet	Brigantine Inlet to Great Egg Harbor Inlet: Brigantine Island, NJ	2,496,000	7,300,000	4,804,000	15,240,000	12,744,000
4	Great Egg Harbor Inlet to Absecon Inlet	Brigantine Inlet to Great Egg Harbor Inlet: Absecon Island, NJ	25,456,000	14,740,000	(-10,716,000)	29,450,000	3,994,000
3	Townsends Inlet to Great Egg Harbor Inlet	Great Egg Harbor Inlet to Townsends Inlet, NJ (Ludlam and Peck Beach); Great Egg Harbor and Peck Beach (Ocean City), NJ	45,000,000	52,500,000	7,500,000	103,860,000	58,860,000
2	Cape May Inlet to Townsends Inlet	Hereford Inlet to Cape May Inlet, NJ; Townsends Inlet to Cape May Inlet, NJ	11,936,000[1]	10,850,000	(-1,086,000[1])	32,160,000	20,224,000[1]
1	Cape May Point to Cape May Inlet	Lower Cape May Meadows, Cape May Point, NJ; Cape May Inlet to Lower Township, NJ	13,682,000	10,540,000	(-3,142,000)	19,840,000	6,158,000
TOTAL			**178,352,000**	**243,120,000**	**64,768,000**	**351,630,000**	**173,008,000**

Dredge Diversity Assessment

The New Jersey Shore Protection Projects provide opportunity for a diverse dredging fleet, including the commercial dredge industry fleet, as well as USACE assets where appropriate. Opportunities also exist for dedicated backpassing and/or bypassing facilities (or mobile dredge), and perhaps for a hopper dredge with pump out capabilities. An evaluation of dredge options, capacity, scheduling, and efficiency is provided herein, along with recommendations.

Corps of Engineers' Dredge Fleet and Activities

The USACE is responsible for maintaining adequate depths in inland and coastal navigation channels. To maintain these channels, the USACE owns and operates several dredges. To preclude competing with commercial dredging companies, the number and capability of USACE dredges is limited. The current USACE fleet is shown in Table 16, including the type of dredge and current status.

Of the dredges listed, those historically available for coastal work in New Jersey because of their size and home port, are the *Curritcuk*, *Fry* and *Merritt*. The high capacity and large pumping rate dredges in the fleet are used to maintain river channels or large inlets/river mouths. The *Fry* and *Merritt* are side-cast dredges while the *Curritcuk* is a dragging suction arm, split-hull hopper dredge (Figure 66). Of the three dredges, only the *Curritcuk* was used to dredge New Jersey inlets during fiscal years 2011 and 2012, while the *Merritt* and *Fry* were used primarily in the Wilmington District. The *Murden*, a new split-hull, dragging suction arm dredge with double the capacity of the *Curritcuk* is planned for operations in FY 2012. During the last two fiscal years, the *Curritcuk* visited Cape May Inlet five times, Barnegat Inlet six times, Manasquan Inlet four times, and Shark River Inlet once. The total volume of sand removed from Cape May Inlet in the two-year period was 141,300 cy, in Barnegat Inlet 179,900 cy, in Manasquan Inlet 120,700 cy, and in Shark River Inlet 43,800 cy.

Regional sediment management requires placement of sand dredged from inlets on adjacent beaches. In most cases, sand that accumulates in inlets is derived from adjacent beaches, and offshore disposal deprives adjacent beaches of sand that would otherwise reside in the littoral system. Thus, offshore disposal contributes to erosion of the beaches. This erosion is often mitigated by sand dredged from offshore borrow areas, thus illustrating the need for direct pumping from inlets to adjacent beaches. Side casting in inlets can remove sand from the navigation channel, but does not remove it from the active inlet, nor does it place and on adjacent beaches. Additionally, ebb and flood currents often rework the sand and return it to the channel relatively quickly.

Table 16. USACE Dredge Fleet

Dredge Name	Home District	Dredge Type	Capacity (cy)	Status FY 2012
Currituck	Wilmington	Split-hull hopper	313	Active
Fry	Wilmington	Side caster		Inactive
Merritt	Wilmington	Side caster		Standby
Essayons	Portland	Hopper	6,000	Active
Hurley		Side caster		Inactive
McFarland	Philadelphia	Hopper	3,142	Standby
Potter		Side caster		Inactive
Sandwick		Water injection		Inactive
Wheeler	New Orleans	Hopper	8,000	Active
Wm A. Thompson		Cutter suction		Inactive
Wm. L. Goetz	St. Paul	Cutter suction		Inactive
Yaquina	Portland	Hopper	1,044	Active
Jadwin	Vicksburg	Dustpan		Active
Murden	Wilmington	Split-hull hopper	600 (est.)	Active

Figure 66. Photos of the USACE split-hull hopper dredge, Currituck.

In FY 2011 and 2012, New Jersey's inlets were served exclusively by the *Currituck* with disposal as sand bars in the nearshore zone with the expectation that sand would migrate onshore to nourish the beaches. Effectiveness of nearshore disposal depends on several factors including the wave environment and water depth where the sand is deposited. Generally, sand is more likely to move onshore to nourish the beach if it is placed very close to shore in shallow water, often not within the safe operating zone of a hopper dredge. The capacity of the Currituck is about 300 cy; thus, the average annual number of loads at Cape May Inlet in FY 2011 and 2012 was 235; at Barnegat Inlet, 300; at Manasquan Inlet 200; and Shark River Inlet 73. This equals a total of 808 round trips between the inlets and adjacent beaches during FY 2011-2012. Use of the newly commissioned *Murden* would reduce the number of runs to about 400, but would not ensure onshore sand movement. The increased draft of the *Murden* would require sand placement in deeper water, making it less likely to move onshore.

Hopper pump-out capability would improve the capability to deposit inlet sands to adjacent beaches; however, the USACE does not presently have this capability. It also seems unlikely that commercial dredging companies will seek to develop this capability because of the relatively small volumes to be dredged from most New Jersey coastal inlets. Alternatively, a small cutter-head pipeline dredge could achieve the same result by pumping sand directly from the inlet to the adjacent beach.

Dredging/Sand Transport Quantities

The demand for inlet dredging in New Jersey is summarized in Table 17, which presents annual quantities historically removed from each inlet for navigation channel maintenance. Although the table presents historical dredging quantities for Absecon Inlet, dredging is currently not required to maintain navigation. There is also an opportunity to dredge inlets not authorized as navigation projects to obtain beach nourishment sand.

Table 17. Historical Dredging Quantities from New Jersey Inlets

Inlet	Quantity Dredged (cy/yr)
Cape May	65,000
Absecon	114,300
Barnegat	241,000
Manasquan	52,200
Shark River	31,800

In addition to moving sand from inlets to adjacent beaches, backpassing projects are increasingly being planned or executed. Backpassing involves taking sand from an accreting beach and moving it back updrift, from whence it came, to sand-starved eroding beaches. Three such projects have been executed in New Jersey, twice at Avalon and, more recently at Cape May. Two others, at Brigantine and the Wildwoods, are being considered. A third backpassing operation at Avalon is also planned and has been permitted. The quantities backpassed or expected to be backpassed are summarized in Table 18.

Table 18. Backpassing Quantities and Costs

Location	Quantity (cy)	Cost per cy	Method
Avalon	57,000 (in 2005) 50,000 (in 2006) 60,000 (expected in 2012)	$5.91 $6.94	Truck Truck
Cape May	70,000 (in 2011)	$14.79	Hydraulic dredge
North Wildwood	100,000 to 200,000		
Brigantine	55,000		

Sand Transport Equipment Needs

The need to move sand from inlets to the beach and also to move sand updrift along a beach in backpassing operations indicates demand for a portable dredging system. Such a system might be deployable from either land or water to move sand from inlets to adjacent beaches and for backpassing operations. Clausner and Welp (2008) investigated several alternative systems to backpass at the Wildwoods. Mechanical systems were quickly eliminated due to interference with beach use and estimated cost of approximately $20 per cubic yard. A submersible mobile hydraulic pump deployed from a crane was studied in detail. Five sources of pumps were contacted; however, only two provided detailed responses. The systems were expected to backpass between 100,000 and 200,000 cy/yr. One system had an estimated cost of $410,000 for a diesel-driven pump, $66,000 for a production meter and $257,000 for a diesel-powered booster station for a total cost of $733,000. No information on operating costs was provided.

A second system touted average production rates of between 300 and 600 cy/hr depending on the pump and pipe diameter. One of these systems involved a 150 hp electric submersible agitator dredge pump discharging through a 12-inch pipeline and supported from a crane with a 120 to 160-foot boom. Power would be from a 300 kW generator. Skid-mounted, 400 hp booster pumps would be needed if the pumping distance exceeded about 1 mile. The cost was estimated at $10/cy. The other system had a maximum capacity of 600 cy/hr and discharged through a 14-inch pipeline. Skid- mounted, 500 hp booster pumps would be required about every mile.

Based on these systems, it would be possible to develop a mobile dredging system deployable either by land for backpassing or by water on a barge to maintain inlets while placing sand directly on an adjacent beach. Alternatively, a jet-pump system like that currently used for bypassing at Indian River Inlet, Delaware could be adapted to produce a mobile inlet maintenance and backpassing system.

<u>Environmental Demonstration Studies</u>

There are environmental resources, including fisheries, surf clams, benthic invertebrate community, and nesting shore birds, influencing implementation of shore protection projects. Two primary aspects of projects at New Jersey with sensitive environmental implications are related to dredging sand for beach nourishment, and incorporating supplemental measures (e.g., groins) to extend the design life of beach nourishment particularly in the vicinity of erosional hotspots. Targeted environmental studies at key location(s) to evaluate potential impacts would provide a means to implement trial pilot project(s). Well conceived environmental investigations also would provide insight on how to minimize potential environmental impacts at other locations; thus, facilitating environmental approvals at other site(s).

This section specifically addresses potential impacts to sensitive ecological receptors, and does not propose investigations of other potential environmental impacts related to circulation, water quality, and stability of adjacent beaches, which are assumed to be evaluated as part of the overall project alternatives analysis, planning, and design phases (i.e., assumes that an alternative would not be recommended for ecological impact analysis without first proving beneficial from a physical standpoint).

Expanded Dredging for Beach Nourishment

Dredging sand for beach nourishment directly impacts the seafloor and benthic invertebrates inhabiting the sediments. Although there can be site-specific concerns, direct impacts are generally well-studied in the mid-Atlantic, including research of recolonization patterns and recovery of benthic abundance and diversity. Impacts can generally be minimized through careful planning and upfront data collection, which may result in the need to harvest, relocate, or seed commercially valuable shellfish species. By avoiding direct impacts to submerged aquatic vegetation, hard bottom, and not creating excessively deep holes, the benthic community generally responds after dredging since the types of seafloor disturbances are analogous to the dynamic nature of the seafloor and exposure to sand wave movement and storm activity.

Dredging for beach nourishment also involves potential short-term impacts to finfish foraging, migration, and spawning activities, which are less well studied. Where shoals are quite shallow and/or intertidal, there is potential value for bird foraging as well. In New Jersey, there are vast sand resources available within the inlets (e.g., Barnegat Inlet, Great Egg Harbor Inlet) that would supplement the local source of beach-compatible sand in economical fashion. However, there are sensitive resources related to fisheries (i.e., winter flounder) and shore birds (i.e., terns). Targeted investigations of these potential impacts would facilitate environmental approvals. Recommended investigations include:

- **Phase 1**. Expanded observations for existing activities: Fish survey and bird observations to document response to existing approved dredging activities in Barnegat Inlet or Great Egg Harbor Inlet. Building a more detailed understanding of impacts (or lack thereof) associated with approved activities would provide the basis to evaluate expanding the footprint and dredge quantity for existing activities, at least for a pilot project. In the case of winter flounder, constraining the window within which spawning activities are expected would allow for an expanded dredge season.
- **Phase 2**. Observations for pilot activities: If, through Phase 1, the scope of existing dredging can be expanded in the form of a pilot project, then rigorous observations of the expanded project can help document potential impacts, and provide a basis for refining the project to minimize impacts. The pilot project may be extended at the particular site. Furthermore, conclusions at one location (e.g., Barnegat Inlet) may be transferrable to another location (e.g., Great Egg Harbor Inlet); thereby, providing a defensible basis for expanding dredging activities at other location(s) where sand is available and there is demand on beaches to maintain the authorized project template.
- **Phase 3**. Observations of ongoing expanded projects to ensure potential impacts are minimized.

Structures for Erosional Hotspot Protection

Localized hotspot erosion introduces the need for maintenance of a beach nourishment project that otherwise is maintaining the design template for the majority of the project footprint. Installing structures (e.g., groins or other) at erosional hotspots potentially extend the design life of the overall shore protection project. Potential impacts associated with structures include direct coverage of seafloor habitat, and sensitive species (e.g., nesting shorebirds on adjacent beaches such as piping plovers). Targeted monitoring activities include surveys of colonization and use on/adjacent to existing structures to demonstrate a positive habitat value. Expanded environmental monitoring of existing structures provides data needed to evaluate installation of new structures where engineering analysis reveals a benefit to the beach nourishment project, reducing sand requirements, cost and minimizing environmental impacts.

Breach Contingency Plan

A breach contingency plan is recommended at four (4) areas: North Beach/Harvey Cedars on Long Beach Island; Island Beach State Park; Strathmere (Whale Beach); and Lower Cape May Meadows. These areas experience severe erosion conditions prompting shore protection measures including beach nourishment to reduce imminent threat of storm damage. Developing breach contingency plans will facilitate rapid response to barrier island breaches. Rapid breach closure by using a breach contingency plan is in the Federal interest and more cost-effective when the time and volume of material needed to remedy the breach are reduced.

Current procedures to close a breach require a request from the State of New Jersey Administration following a declaration of emergency for federal assistance documenting State resources have been exhausted. Upon receipt of the Administration's request, the Corps prepares an advance measures report evaluating the feasibility of, and justification for, Federal participation in emergency works. This report is submitted to higher authority (NAD and HQUSACE) for review and approval. Approval of the advance measures report gives authority to the District to prepare Plans and Specifications and negotiate the PCAS with the Sponsor. It took the New York District of the Corps approximately six (6) months to award the contract and eleven (11) months to close the breach at Westhampton in 1992.

A Breach Contingency Plan should be developed to streamline the contracting and construction activities. The process for implementing a breach contingency plan includes reviewing previous response actions and determining whether similar actions could advance more expeditiously using innovative ideas to close a barrier island breach. Specific authorities to facilitate a breach closure should also be reviewed and identified. The Breach Contingency Plan would serve as the decision tool providing documentation and authority for future breach closures. The plan also would recommend a delegation of authority to the District to respond rapidly to breaches. The District would prepare a fact sheet in lieu of a report upon each breach occurrence. The fact sheet would declare existence of an emergency condition, and would provide specific details of the breach including condition, location and proposed solution. The Plan would also allow accelerate the dredging/trucking contracting process. Lastly, the Plan would propose to obtain authority for approval from NJDEP and not the State Administration, upon which the Corps could respond to the breach.

The "Fire Island to Montauk Point, Long Island, New York Breach Contingency Plan" (dated January 1996) is an example of such a plan for Long Island, specifically in the vicinity of Westhampton Beach.

Recommended Broad Regional Strategies

Eight recommended broad regional strategies are summarized in Table 19, including the recommended specific action, priority, and Tier level within the existing project authorization framework.

Table 19. Broad Regional Strategies: Action Items, Priorities and Tier-Level

	1. Recommendation		2. Priority	3. Tier Level
Broad Regional Strategy	**Wave/Sediment Transport Modeling**	Complete spectral wave model for NJ coast; Complete physics-based longshore sediment transport modeling for NJ coast; Use combined results to refine sediment budgets, optimize nourishment design, and minimize sand requirements/cost.	2	1
	Refined Regional Geomorphic Change Analysis	Update shoreline change and bathymetric change computations for NJ shoreline; develop consistent plan to incorporate ongoing monitoring data; Use results to refine "living" sediment budgets on a regular basis.	2	1
	Improved, Living Sediment Budget	Update existing USACE sediment budgets based on results of wave/sediment transport modeling and refined regional geomorphic change analysis; Develop user-friendly tool for "living" sediment budget that can be updated when new monitoring data are collected; Maintain "living" sediment budget and use results for adaptive management of shore protection projects to minimize sand requirements, cost, and environmental impacts.	3	1
	Enhanced Project Monitoring Plan	Supplement ongoing shoreline surveying plan with profiles at strategic locations; Perform detailed bathymetric surveys at inlets and other key locations; Analyze and formulate monitoring data for input to "living" sediment budget; Collect nearshore wave and current data; Incorporate data into wave/sediment transport models and to refine design parameters; Develop georeferenced database for monitoring data; Expand geophysical data sets, particular in inlets, to expand sediment sources for nourishment.	1	1
	Sediment Needs Vs. Sediment Availability	Pursue permits for authorized borrow sites to expand available sand to offset future sand deficits for renourishment, particularly offshore Cape May; Expand set of offshore and inlet-based sediment sources for future beach nourishment.	1	1
	Dredge Diversity Assessment	Pursue acquisition of a mobile dredging system to directly remove sand from inlets and nearshore areas and pumpout directly to the dry beach.	1	1
	Environmental Demonstration Studies	Implement environmental observation initiatives to quantify potential impacts associated with expanded inlet dredging; Pursue pilot projects for expanded inlet dredging and expand to full-scale based on environmental monitoring data; Perform expanded environmental monitoring surveys as basis for pilot installation of structures to maintain erosional hotspots and implement full-scale structures at hot-spots based on outcome of environmental surveys.	2	2
	Breach Contingency Plan	Develop breach contingency plans for the following four (4) areas: North Beach/Harvey Cedars on Long Beach Island; Island Beach State Park; Strathmere (Whale Beach); and Lower Cape May Meadows.	3	2

SITE SPECIFIC STRATEGIES

This chapter presents potential actions and strategies for optimizing the authorized shore protection projects along the Atlantic Ocean coastline of New Jersey. This includes project specific actions, as well as cross-cutting actions that apply to a number of authorized projects or adjacent projects (but are distinct from the broad regional strategies in Chapter 4). Potential actions and strategies are presented on an authorized project by authorized project basis. Each following section presents a specific authorized shore protection project, which includes:

1. A general description, including details on the components (e.g., beach nourishment, coastal structures, maintenance cycle, etc.), the design layout, the authorization, and other specific aspects of the authorized shore protection project.
2. A history of the authorized shore protection project that presents a summary of the features implemented and constructed, including initial construction and maintenance.
3. A summary of problems, concerns, or unexpected difficulties that have arisen during the contemporary history of the authorized shore protection project. For example, perhaps following the initial construction of a beach nourishment project, the nourishment had not performed as expected or specific hot spots of erosion developed along the shoreline resulting in more frequent re-nourishment requirements than anticipated.
4. A description and details of each strategy considered for potential design, construction and/or implementation for the authorized shore protection project. Strategies were developed jointly between the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. Specifics of each potential strategy are presented to adequately describe the proposed action in context of the overall, regional processes (Chapter 2), the existing authorization, and the history of projects and project performance at the site. Additionally, when feasible for each strategy, a first-order technical analysis is presented to evaluate the relative merit of each potential strategy/action as measured against following criteria:

- **Authorization Limitations** – Each strategy or potential action is evaluated in context of the current authorization for the shore protection project. There are two types of authorizations to consider in evaluating the various strategies for each project: (1) Study authorization; and (2) Construction authorization.

  The existing study authority for the New Jersey coast can be used to accomplish the strategies that are, in effect, studies of specific actions. In other words, a strategy that results in a significant change to the authorized project must first be studied under the study authority. The required decision documents, permits and other actions necessary to recommend a construction authorization must be completed, including the United States Army Corps of Engineers (USACE) quality control/quality assurance reviews. This effort will require a non-federal sponsor willing to cost-share the requisite studies and the necessary federal appropriations to conduct the activities. Strategies that change the project template, recommend modification to other structures, not part of the construction authorization, and/or result in a significant change to the authorized project will first have to be accomplished under the study authority. The result will be a determination of federal interest in the strategy in question, and a recommendation for federal participation in the implementation of that strategy (construction).

Conversely, the construction authorizations are generally specific to the individual project and are limiting in the type of adjustments that can be made to the project they authorize. In these cases, a decision document and permits required would have to be completed before a physical change can be made. However, these authorities can be indirectly broadened if a strategy is developed that reduces the federal government's long-term financial commitment to the project. Minor modifications (defined as those modifications that do not change the recommended plan's physical dimensions, do not require significant environmental studies, and result in significant savings to the federal government both short and long term), can generally be accomplished by considering them as variations in construction technique(s) or as value engineering options.

- **Constraints** – Each strategy or potential action is assessed relative to potential constraints that may limit the implementation of the strategy or action. These constraints may include logistics, public interest, political, cost concern, limited benefits, environmental, engineering, and federal authorization. For example, a potential inlet dredging expansion at an authorized navigation project may be constrained by environmental concerns with the expanded footprint of dredging, or a modified beach nourishment template may be constrained by the existing federal authorization, available sediment in permitted borrow areas, or public interest.
- **Potential Cost Savings** – The potential long- and short-term cost implications on the authorized project associated with each strategy or action is presented. If feasible, a preliminary value engineering assessment is also included for specific strategies. For example, the potential cost savings associated with informally synchronizing adjacent shore protection projects, such that the mobilization and demobilization cost of the dredge is reduced, is evaluated. The cost implications are evaluated over a 50-year time horizon and compared to the currently authorized project expected costs. Best available estimates of cost (e.g., cost/cubic yard) are presented based on existing and historic dredging records. The value engineering assessment should be considered a preliminary, rough estimate of cost implications for planning purposes.
- **Service Life** – If feasible for a particular action or strategy, the potential implications on the performance of the project (e.g., the service life of a coastal structure or nourishment project) is assessed. The results of this analysis are typically used in concert with the potential cost benefit criteria to complete the preliminary value engineering appraisal. For strategies that can be reasonably assessed, the service life analysis is primarily a technical evaluation of the performance gain expected by implementing the potential action or strategy. For example, a potential reduction in dredging of both the navigational inlet and offshore borrow sites may be realized by installation of a

bypassing program at an inlet that reduces the amount of sediment required for a downdrift authorized shore protection project.

- **Other Benefits** – Each potential action and strategy is evaluated from the perspective of other potential benefits that may be realized from implementation of the proposed action. This criterion covers areas less quantifiable than service life and cost criteria and focus on more qualitative items. These benefits may include, but are not limited to, environmental benefits, more stable regional shoreline or littoral cell, benefits to adjacent shorelines or adjacent authorized shore protection projects, expected reductions in dredging requirements, benefits to public usage or perception, net reduction in offshore borrow site reliance, and/or implementable solutions that can be transferred to multiple project locations.

5. Descriptions and results of each strategy assessment are presented relative to the criteria presented above, and will be used primarily to determine the following additional items:

- **Tier Level** – As discussed in Chapter 3, each possible action or strategy will be assigned a tier level based primarily on the alignment of the proposed strategy with the current authorization.

- **Prioritization** – Each proposed strategy or action is assigned a priority level to determine relative importance. The priority level is determined based on the criteria presented above, including tier level. For example, the priority level is established using factors such as ease of implementation, overall potential cost benefit, reduction of prior existing problems, and improved project longevity.

6. Finally, an overall summary of potential strategies and actions is presented for the authorized shore protection project. This incorporates and explains the prioritization and associated tier level of strategies, and also provides an analysis and comparison of the higher priority strategies over a 50-year time horizon.

LOWER CAPE MAY MEADOWS/CAPE MAY POINT

Project Description

The Lower Cape May Meadows (LCMM) and Cape May Point (CMP) Environmental Restoration Project was authorized for construction by the Water Resources Development Act of 1999. The project is located on the south coast of New Jersey, extending for approximately 1.9 miles from the 3rd Avenue terminal groin in Cape May City to the Central Avenue groin in Cape May Point. The authorized project includes dune and berm restoration using sand dredged from offshore borrow sites, restoration of freshwater wetlands through improved management of vegetation and hydrology, and enhancement of shorebird habitat. Periodic nourishment every 4 years is authorized to maintain the design template.

The design berm is 20 ft wide at an elevation of 6.7 ft NAVD88 (approximately 8.0 ft NGVD29). The dune is designed to an elevation of 16.7 ft NAVD88. The total length of fill is 10,050 linear ft, extending from the 3rd Avenue terminal groin in Cape May City to the Central Avenue groin in Cape May Point, which includes the Cape May Migratory Bird Refuge and Cape May Point State Park. The project authorizes an initial construction volume of 1,460,000 cy, with periodic nourishment of 650,000 cy every 4 years. Offshore borrow areas 4 and 5, and recently area K, are the authorized borrow sites for initial construction and periodic nourishment.

Wetland restoration design at LCMM includes elimination of 95 acres of *Phragmites australis*, planting 105 acres of emergent wetland vegetation, excavation of existing drainage ditches to restore freshwater flow, and installation of four (4) water control structures. The authorization also includes creation of three (3) ponds behind the dunes for enhanced Piping Plover habitat. Figure 67 shows the components of the authorized Environmental Restoration Project.

A Section 227 Demonstration Project was also authorized for Cape May Point by the Water Resources Development Act of 1996. This project is located in the existing groin field constructed at Cape May Point between the 1930s and 1950s, and builds on a State of New Jersey Pilot Reef Project initiated in 1994. The Demonstration Project authorizes construction of a Beachsaver Reef™ with a geotextile cloth base in groin cell 5, and an innovative Double-T sill structure in cell 6. The project includes monitoring to evaluate structural integrity and ability to retain periodic nourishment placed as part of the Environmental Restoration Project. Figure 68 shows the location of the Cape May Point Demonstration Project and photographs of the selected technologies.

Project History

Cape May Point has a long history of shoreline erosion due to the complex interaction of waves, currents, and tides between Delaware Bay and the Atlantic Ocean. Since the 1930s, local projects to control erosion at Cape May Point have included construction and rehabilitation of nine (9) groins, dune construction, seawall fortification, and beach nourishment.

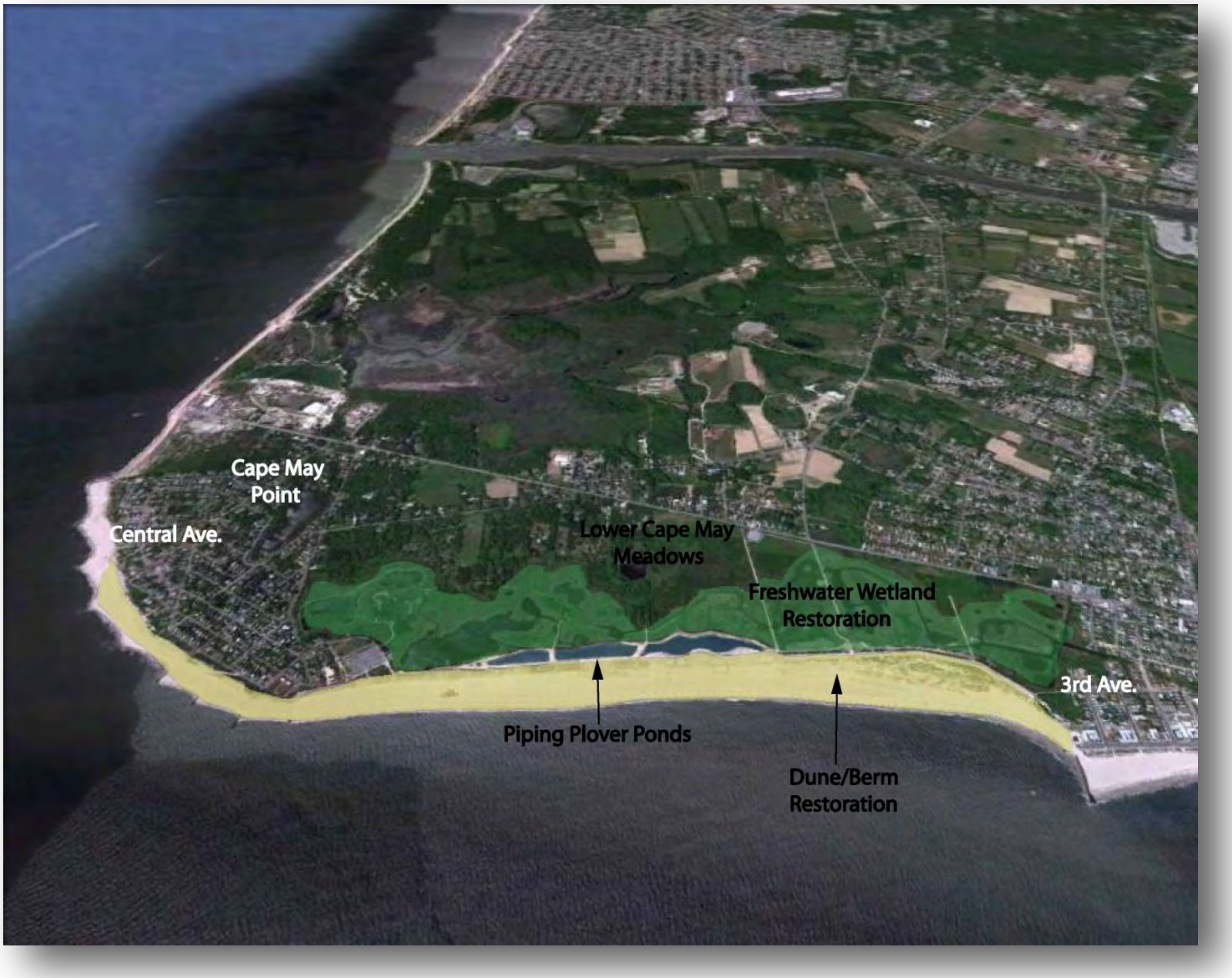


Figure 67. Lower Cape May Meadows – Cape May Point Authorized Environmental Restoration Project.

Beginning in the 1950s, The Meadows began to experience significant erosion and wetlands loss. Breaching and overtopping of the weakened dune system allowed inundation of the wetland, loss of freshwater wetland vegetation, and proliferation of *Phragmites australis*. The Lower Cape May Meadows – Cape May Point Environmental Restoration Project was authorized to mitigate the ongoing erosion and restore critical wetland areas. Initial nourishment was completed in 2005 with the placement of 1,406,000 cy of sand from borrow areas 4 and 5. Control of the invasive *Phragmites australis* was accomplished through herbicide applications beginning in the fall of 2005. Construction related to the internal hydrology, water control structures and Piping Plover habitat was completed in the spring of 2007. The 2nd periodic nourishment cycle was expected to be contracted in August to September 2012, approximately 7 years after initial construction. A total of 139,000 cy of sand is expected to be placed in Cape May State Park and the Borough of Cape May Point (102,000 cy) and Cell #4 (as discussed below) in Cape May Point (37,000 cy). This periodic nourishment cycle is expected to be completed by March 2013 and taken from offshore borrow area K.

Work on the Section 227 Demonstration Project at Cape May Point was initiated in 2002. A Beachsaver Reef™ (prefabricated reinforced concrete breakwater) was installed across the seaward end of groin cell 5. To prevent scour and settling experienced with the 1994 State of New Jersey Pilot Project, the structure was placed on a filter cloth base with a concrete-filled tube on the landward side. A unique Double-T sill structure, composed of prefabricated reinforced concrete parking garage decking, was installed across the seaward end of groin cell 6. The units were inverted so the legs of the structure faced upward to trap and hold sediment. Monitoring surveys to evaluate beach and nearshore topography, settlement, sediment characteristics, as well as waves and currents have been conducted since installation.

Figure 68. Cape May Point Section 227 Demonstration Project, and New Jersey State 1994 project.

Project Observations

Since initial construction of the Environmental Restoration Project and the Section 227 Demonstration Project, a number of observations have been made:

- Initial construction of the Environmental Restoration Project was extremely successful in restoring the beach and freshwater wetland areas. Low rates of erosion suggest the authorized 4 year cycle of periodic nourishment could be extended over a longer time period.
- The project improved habitat for Piping Plovers. The average fledge rate in 2005 was 1.6, up from an average of 0.83 in the pre-project period.
- Experimental structures installed at Cape May Point as part of the Section 227 Demonstration Project have a positive impact on the shoreline. Both structures worked well to maintain a perched beach in their respective groin compartments. Beach areas had to be closed to swimming since the beach advanced seaward from excess sediment and swimmers were in danger of striking the structures between the groins.
- Authorized offshore borrow areas 4 and 5 contain significant quantities of both fine-grained and cobble-sized material. Consequently, new potential sources of borrow material are needed for period nourishment.

Potential Strategies

This section presents the potential strategies for the Lower Cape May Meadows and Cape May Point Storm Damage Reduction Project intended to provide improved project performance, cost savings, or other benefits. These strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. In addition, some of the strategies include a first-order technical analysis to evaluate the relative merit of the proposed strategy. These analyses are not intended to be detailed assessments and include assumptions and simplifications. The analyses presented are geared towards providing a preliminary estimate of the potential benefits if the strategy is implemented. The analysis presented can be used as an initial screening tool to determine if a strategy warrants further consideration. More detailed analysis may be required if the strategy is more formally pursued.

A. Project Cycle Synchronization

The project cycle synchronization strategy represents informally synchronizing the construction of authorized shore protection projects in close proximity. The intent is to reduce mobilization and demobilization costs by combining re-nourishments. For this project, coordination of the LCMM/CMP nourishment project would be synchronized with the Cape May City nourishment project.

A first-order analysis of cost savings potentially realized by theoretically combining the periodic nourishment efforts at the Cape May City and LCCM/CMP authorized projects was conducted. The analysis follows a similar approach as presented in Gebert (2010). It is assumed the authorized two year periodic nourishment cycle at Cape May City could be extended to a four year cycle (which based on the analysis presented in Strategy B may be feasible), and nourished jointly with the Lower Cape May Meadows/Cape May Point authorized project.

Mobilization and demobilization costs constitute a significant portion of typical dredging contracts, and are not necessary reduced with increased contract size (e.g., larger dredging projects). A number of factors contribute to the variations in dredging contract costs, including market conditions at the time, proximity of the borrow area to the nourishment site, and the limited number of capable dredging contractors. There can be large uncertainties when forecasting beach nourishment dredging and placement costs. Recent dredging contracts (2002-2009) for nourishment efforts in New Jersey and Delaware (Gebert, 2010) can account for 10% to 60% of the total winning bid, and average mobilization and demobilization costs are approximately $2 million per nourishment effort (initial or periodic nourishment). The unit cost of sand over that same time period ranged from approximately $4 to $15/cy. Therefore, the preliminary analysis presented herein also assumes dredge mobilization and demobilization costs of $2 million, and a conservative unit price of $15/cy for sand.

Since many strategies involve integration of projects with different remaining authorized lifetimes, a 50-year time horizon is used for comparison purposes regardless of the remaining authorized project life. Use of a single standard time period allows direct comparison between various strategies across projects and for those involving initial construction costs and maintenance (O&M) costs.

Over a 50-year time horizon, the volume of sediment placed on the beach remains the same; however, there is a cost savings of $26 million based solely on the reduced number of nourishment events. Additional cost savings may be realized from reduced contracting and management requirements. A comparison to current operations and to other strategies is presented in the LCCM/CMP summary section.

Fewer periodic nourishment episodes will also have an environmental benefit since there will be less frequent disturbance (reduced by 2 times) of the offshore borrow site areas, reduced disturbance on the beaches, and reduced overall air and noise pollution.

Prior to implementing this strategy, evaluation of the storm damage protection impacts needs to be completed to ensure that protection of the Cape May City area is not compromised by extending the periodic nourishment interval from two to four years. However, this strategy also may have performance benefits due to a regional increase in the recurrent volume added to the system (presented in strategy B), perhaps resulting in potential improved project longevity and reduced periodic nourishment requirements. In addition, based on the profile monitoring (Stockton State College Annual Reports), the nourishment has performed reasonably well, indicating a reduced periodic nourishment cycle at Cape May City may be feasible.

This strategy can be implemented at any time since existing authorities do not preclude re-nourishment from being done as part of one contract as long as the funds for each are available and not comingled. Further, all requisite environmental clearances must be accomplished before award of such a contract. Implementation of this strategy has minimal constraints; limited to availability of dredging equipment and borrow site quantities, which are already constraints of current operations.

Table 20 presents a summary of the criteria evaluated for the improved project coordination strategy and ranks this strategy as a high priority and easily implementable (Tier 1 level). This strategy should be pursued since the pathway to implementation is straightforward and there are no significant constraints.

Table 20. Project Cycle Synchronization Strategy Summary.

Criteria	Summary
1. Authorization	No existing authorization limitations
2. Constraints	No constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$26 million over 50-year time horizon
4. Service Life	Potential increase in project longevity and service life
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale
6. Priority	High Priority
7. Tier Level	Tier 1
8. Next Steps	Evaluate potential storm damage impacts, coordinate dredging, and implement

B. Feeder Beach Nourishment Effects

As originally presented in the 1980 and 1983 General Design Memorandums (GDM), the Lower Cape May Meadows/Cape May Point (LCMM/CMP) and Cape May City (CMC) projects span the entire length of shoreline from the Cape May Inlet to the Central Avenue groin at Cape May Point and a single nourishment project could replenish the contiguous stretch (with varying berm width) of shoreline in this region. Consideration was initially given to a strategy geared towards formally aligning the federal authorizations of Lower Cape May Meadows/Cape May Point (LCMM/CMP) and Cape May City (CMC) projects, such that periodic nourishment of these projects always occurs at the same time. This would involve a more formal synchronization of projects that would combine the nourishment volumes, and align periodic nourishment efforts to create a single authorized project. The goal of this strategy is to reduce mobilization and demobilization costs, and provide better project performance.

However, the complex nature of this stretch of shoreline, including the change in shoreline orientation from CMC to CMP and the interaction of Cape May Point with the ebb and flood tidal currents of Delaware Bay, affects the behavior of the beach nourishment efforts. In addition, actual implementation of the authorized projects consisted of nourishment for only a portion of the Cape May City authorized length due to accelerated erosion at the U.S. Coast Guard Training Facility (no periodic nourishment sediment has been placed southwest of Wilmington Avenue since 1999). Therefore, the periodic nourishment efforts at LCMM/CMP and CMC are not completed as originally authorized and have a significant spatial gap between actual placement locations. These factors likely make traditional assessment of the nourishment performance inapplicable for this stretch of shoreline. To assess the influence the two nourishment projects have on one another, two approaches were implemented. The first approach evaluated nourishment interaction if the projects were nourished jointly, as authorized to provide a preliminary assessment of the beach performance. The second approach evaluated the nourishment interaction based on the recent (last 20 years), actual periodic nourishment efforts. Both approaches are idealized, and offer simplified estimates of the performance and interaction of the LCMM/CMP and CMC periodic nourishment efforts.

Both assessment approaches use an analysis that combines the conservation of sediment equation with the linearized transport equation. This formulation, called the Pelnard-Considére (1956) equation (Equation 1), is used to obtain theoretical results to establish design and performance standards for the nourishments. A more detailed description of the derivation of the equations and applications can be found in Dean (2002).

Equation 1:

$$M(t) = \frac{2\sqrt{Gt}}{l\sqrt{\pi}}\left(e^{-\left(\frac{l}{2\sqrt{Gt}}\right)^{2}-1}\right) + erf\left(\frac{l}{2\sqrt{Gt}}\right) \tag{11-1}$$

where M(t) is the proportion of sand remaining in the placed location, G is the alongshore diffusivity parameter, t is time, and l is the project (nourishment) length. The alongshore diffusivity (Equation 2) is presented by Pelnard-Considére (1956).

Equation 2:

$$G = \frac{KH_b^{5/2}\sqrt{g/\kappa}}{8(s-1)(1-p)(h_* + B)}$$

where K is the sediment transport coefficient, which is a function of sediment size, B is the berm elevation, Hb is the breaking wave height, h* is the depth of closure, p is the in-situ sediment porosity (approximately 0.35 to 0.40), s is the sediment specific gravity (approximately 2.65), and κ is the ratio of wave height to water depth within the surf zone (approximately 0.78).

The Pelnard-Considére equation can be applied to determine the performance of a beach nourishment project. For example, Figure 69 presents spreading of an idealized, rectangular nourishment. Although simplified, this example illustrates the planform view of nourishment dispersion. Figure 69 contains a series of lines depicting the temporal planform evolution of this example rectangular nourishment. The resulting planform is symmetrical about the centerline of the nourishment. Only one-half of the resulting planform is shown in Figure 69. The solid black line indicates the initial fill template, and subsequent lines indicate the temporal dispersion of the nourishment. The vertical axis indicates nourishment width (or distance seaward from the original shoreline), while the horizontal axis indicates alongshore distance from the center of the nourishment. Within 1-year of nourishment placement, the shoreline excursion at the center of the project has retreated over 100 ft (in this simple example starting nourishment was 350 ft), as sand has been transported in both directions due to the perturbation created on the shoreline. As shown by the lines corresponding to temporal changes in fill, the material diffuses onto the adjacent shorelines and is not lost from the local system.

The Wave Information Study (WIS) time series of wave and wind data, developed by the United States Army Corps of Engineers, were used to describe the wave climate offshore of New Jersey. WIS, performed by the USACE, has met a critical need for wave information in coastal engineering studies since the 1980s, and is accepted for design purposes for United States shorelines (http://wis.usace.army.mil/). WIS contains time series information of spectrally-based, significant wave height, peak period, peak direction, and wind speed and direction produced from a computer hindcast (prediction) model. The hindcast wave model, WISWAVE (Resio and Tracy, 1983) is simulated using wind information (speed and direction) at selected coastal locations around the United States. Wave measurements made by NOAA during the 1980s made verification of the WIS results possible by comparing statistics and distributions of wave heights and periods from different time periods (Hubertz et al., 1993). The availability of long-term records makes WIS data attractive when considering average or seasonal wave conditions. Twenty years of wave hindcast data from WIS station 63152 were used for analysis of the Cape May City and Lower Cape May Meadows nourishment.

Since the offshore wave environment can be complex, calculation of alongshore diffusivity was based on wave energy distribution for average annual directional approach bins. Data were segregated by direction of approach, and energy distribution (as a function of frequency) was generated from the waves in each directional bin. The energy associated with each frequency was summed to create an energy distribution for each approach direction. A representative two-dimensional spectrum was generated for each approach direction bin based on the sum of the waves approaching from that mean direction. This was combined with the percentage of occurrence to create a 20 year evaluation of wave impacts at the shoreline. This energetic directional bin approach has been successfully utilized in transformation modeling (Byrnes et al., 2000) and identifies potential approach directions, including those that occur only a small percentage of time during a typical year, but potentially have significant impact on sediment transport. Values of alongshore diffusivity were computed for each directional bin and used for modeling beach nourishment performance.

Since the material spreads over time, it is possible to evaluate the longevity of the nourishment by looking at the amount of material left in the project area. Subsequently, nourishment alternatives can be compared to one another based on longevity. The service life of the beach nourishment can be based upon the percent of initial beach nourishment left within the boundary of the initial fill. The percentage remaining will decrease with time, but material is not necessarily lost from the system; it has just spread to regions outside of the original nourishment template. Sediment may have been transported offshore or along the beach. Although the sediment no longer falls within the initial nourishment template, it has not disappeared from the system.

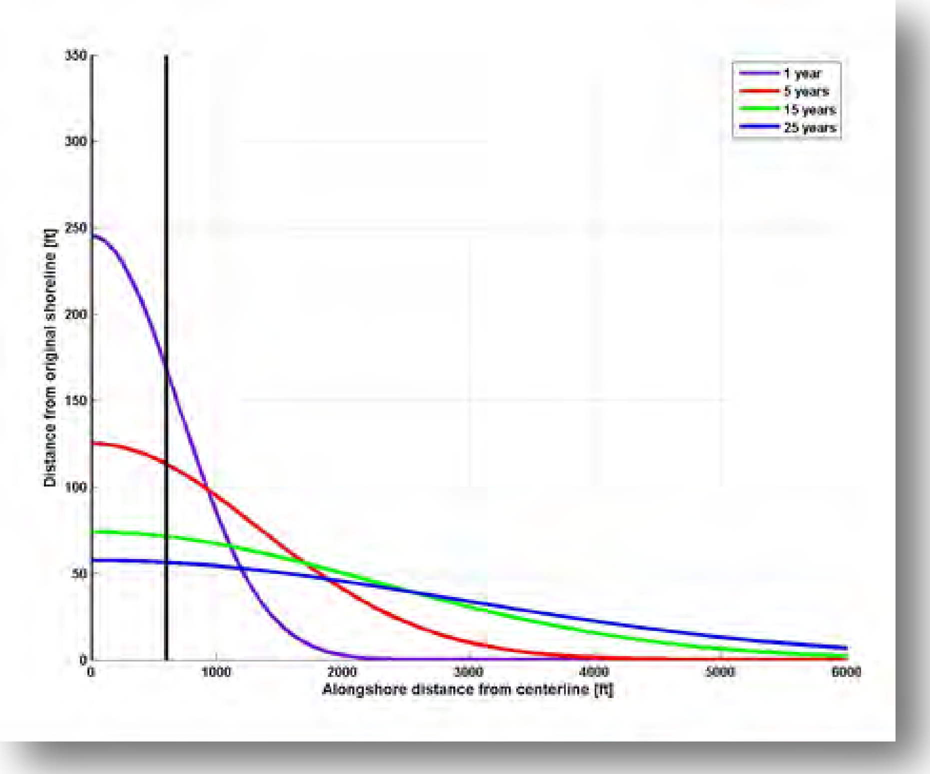


Figure 69. Temporal evolution of an example, idealized, rectangular beach nourishment project. Since the nourishment spreading is symmetrical in this simple case, only half the fill distance is presented.

Using the first idealized approach (assuming the projects were renourished at the authorized volumes, intervals, and distances to represent a contiguous nourishment), Figure 70 presents the performance of the authorized projects for Cape May City, Lower Cape May Meadows, and a combined nourishment scenario that would nourish both projects simultaneously. The performance is expressed in terms of amount of material remaining in the initial template region, as a function of time, for project lengths corresponding to the Cape May City (black line), Lower Cape May Meadows and Cape May Point (green line), and a combined nourishment (blue line). Results were adjusted to include a background erosion rate corresponding to the historical performance of the nourishments at Cape May City. In addition to dispersion, an additional amount is eroded due to natural erosion of the beach. The percent of initial material remaining is presented along the left hand axis, while the time in years is presented along the bottom axis. For example, after 2 years, approximately 74% and 64% of the initial fill volume is remaining for Cape May City and Lower Cape May Meadows, respectively. For an idealized combined nourishment (blue line), approximately 85% of the initial fill volume remains if the projects were constructed together. This represents a potential significant improvement in project performance. The increases in the percent remaining after 2 years (CMC) and 4 years (LCMM/CMP) represent the authorized periodic nourishments.

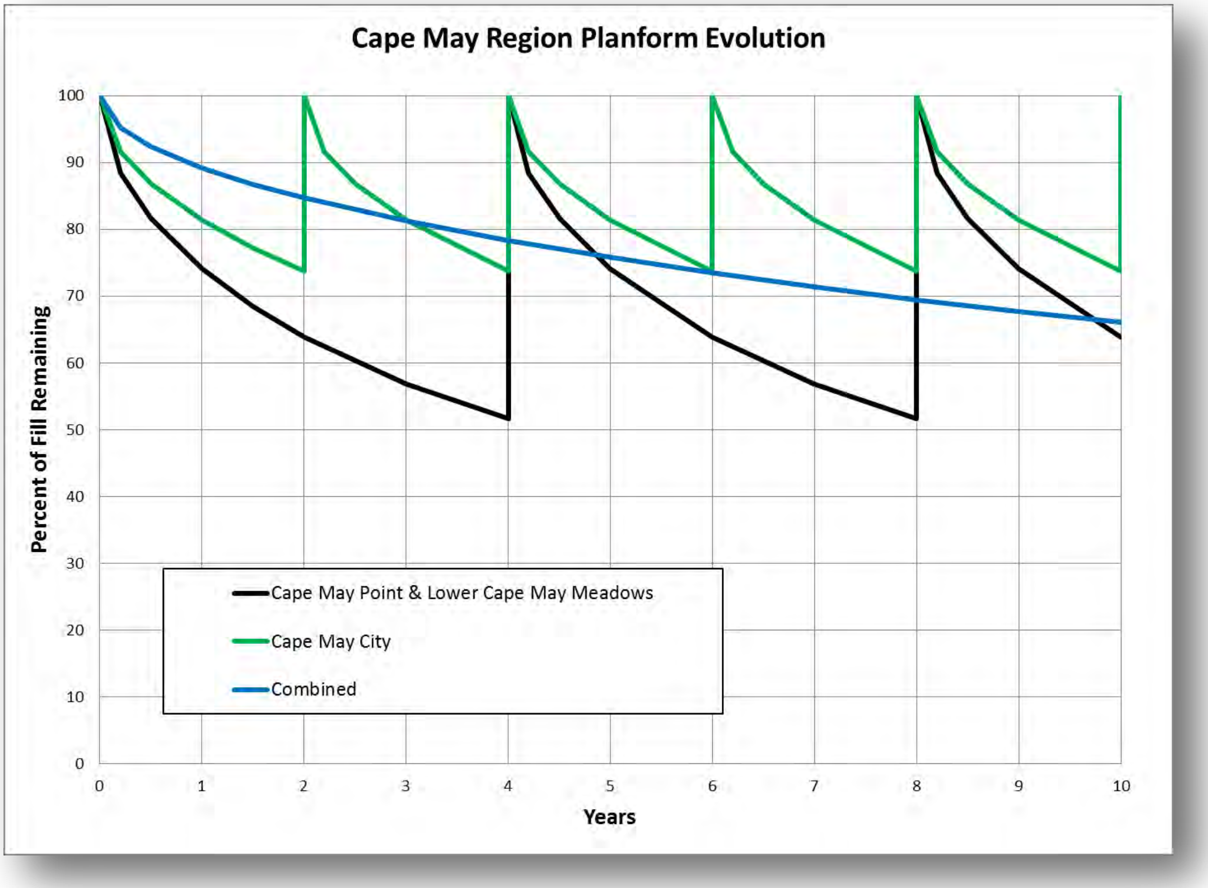


Figure 70. Estimated beach nourishment performance for the authorized projects at Cape May City and Cape May Point/Lower Cape May Meadows, as well as for combination of the two projects. This analysis assumes the projects were constructed as authorized.

Currently, the Lower Cape May Meadows project has a 4 year periodic nourishment cycle, while the Cape May City project has a 2 year periodic nourishment cycle. One or both of the nourishment cycles would need to be re-adjusted to result in a combined project. Analysis indicates that through combining the projects, the Cape May City periodic nourishment cycle should be able to be extended to four years, and possibly even 6 years. For example, after four years, the combined project indicates that approximately 78% of the material would still remain in the template area. This is more remaining than at two years (approximately 74%) for the Cape May City alone nourishment. Theoretically, the larger combined nourishment would make it feasible to increase the periodic nourishment interval.

However, the actual periodic nourishment efforts for the Cape May City (CMC) project have not followed the originally authorized layout. Actual implementation of the authorized CMC project consisted of nourishment for only a portion of the authorized length. Due to accelerated erosion at the U.S. Coast Guard Training Facility, no periodic nourishment sediment has been placed southwest of Wilmington Avenue since 1999. While the periodic nourishment has been required for a portion of the CMC area, the borough of Cape May

City and area southwest of Wilmington Avenue has not needed to be nourished as expected. Figure 71 shows the cumulative volume of periodic nourishment that has been added to CMC since 1993 (blue line) and the authorized cumulative volume of periodic nourishment (green line) over the same time period. Since approximately 2002, the actual nourishment placed has decreased and the periodic volumes are less than the authorized amount. For example, the expected nourishment in 2013 is only 139,000 cy, significantly less than the authorized 360,000 cubic yard amount. Coupled with the fact that all of the nourishment efforts since 1999 have been in the Coast Guard Training area directly adjacent to Cape May Inlet, the periodic nourishments may be acting as a feeder beach by delivering sediment to the downdrift shorelines. The successive periodic nourishment efforts may be successfully stabilizing the downdrift beaches by providing sediment to the remaining CMC authorized area and the LCMM/CMP authorized area.

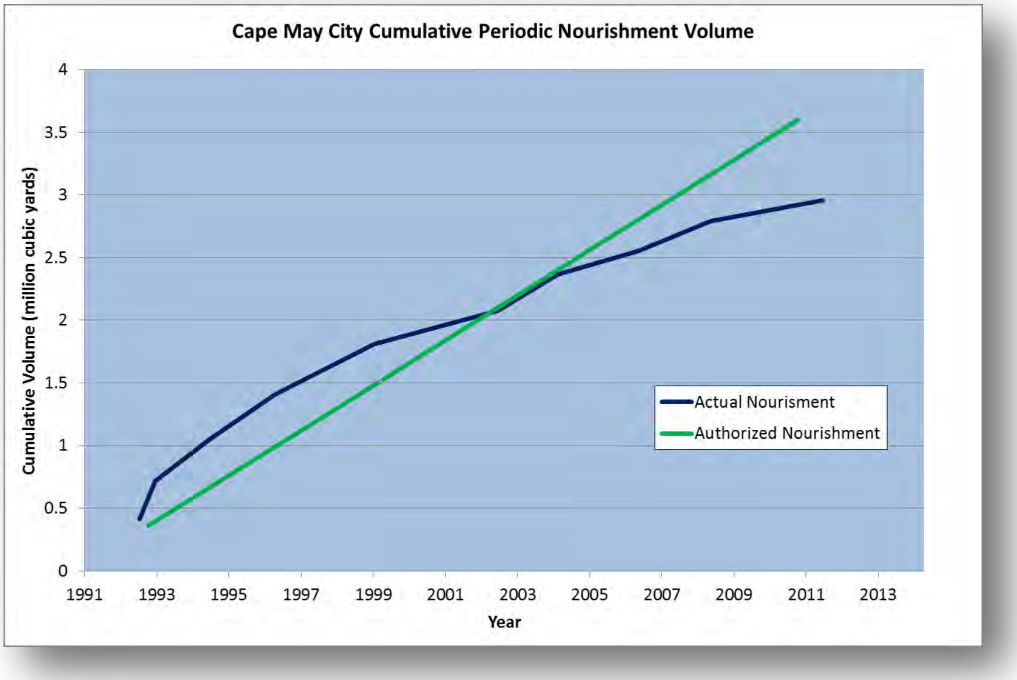


Figure 71. Actual and authorized cumulative volume of periodic nourishment added to Cape May City area.

Therefore, the second approach to evaluating the interaction between the CMC and LCMM/CMP projects assessed cumulative effect of the CMC periodic nourishments and the ability of the CMC nourishment to reduce the periodic nourishment needs at LCMM/CMP. Figure 72 shows an idealized planform representing the shoreline from Cape May Inlet (zero on the horizontal axis) to the Central Ave. groin at CMP. The vertical axis shows beach berm width in ft. The blue line represents the approximate berm width increase after the placement of periodic nourishment at both CMC and LCMM/CMP. The periodic nourishment is assumed to be placed at the U.S. Coast Guard Training Facility (using it as a feeder beach) and Lower Cape May Meadows and Cape May Point, and placing no additional sand at Cape May City. This represents the placement approach for renourishment material since approximately

1999. Subsequent lines indicate the expected dispersion of the berm width as a function of time (years following the periodic nourishment). Figure 72 shows the evolution of one periodic nourishment, and does not show any subsequent periodic nourishments to more easily assess dispersion of the material throughout the domain.

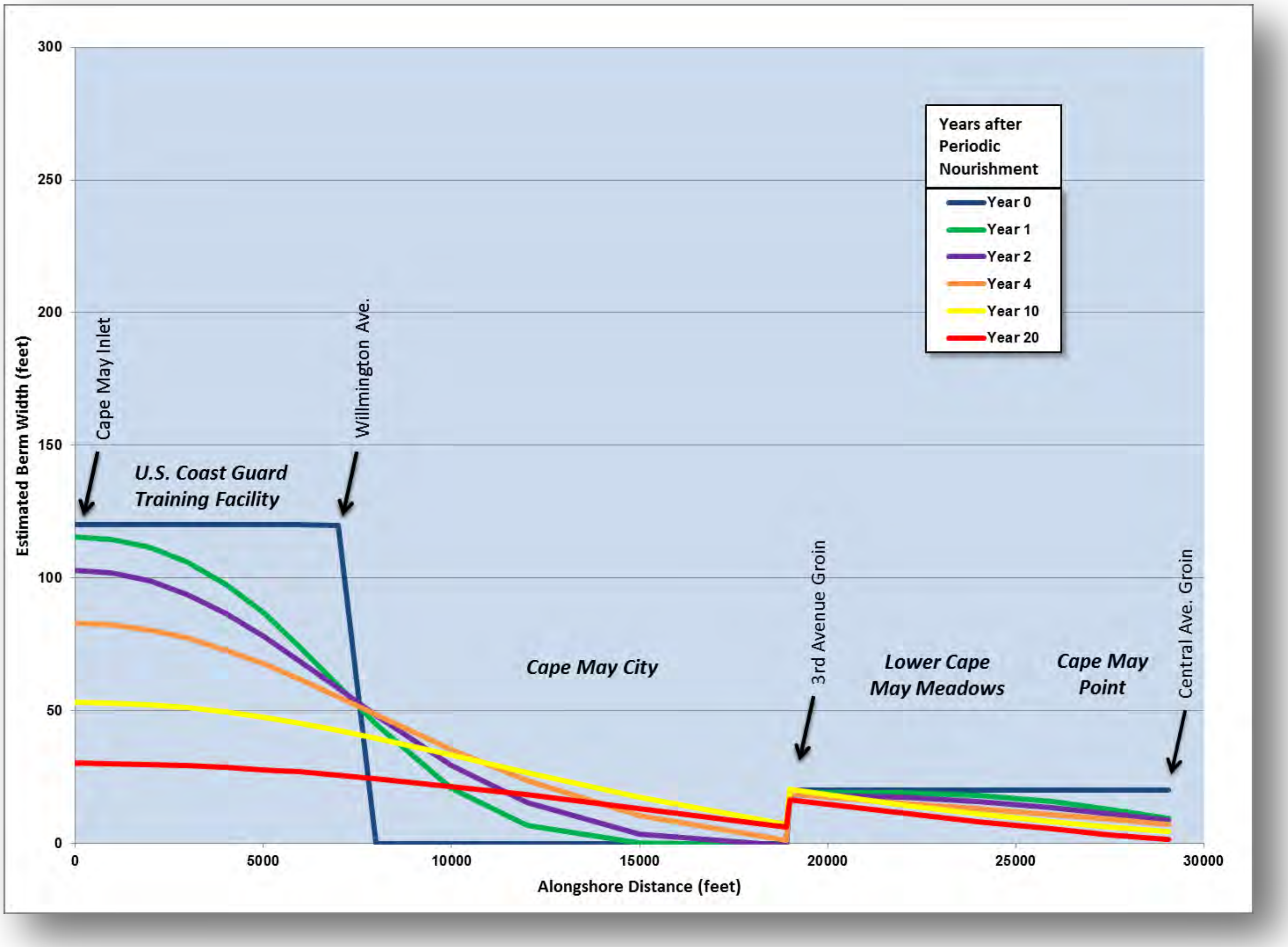


Figure 72. Spreading of a single periodic nourishment at Cape May City and Lower Cape May Meadows.

Under this scenario, the Cape May City region receives dispersed sediment from the U.S. Coast Guard Training Facility Area and increases in width between 15 to 50 ft. After approximately 4 years, sediment from the U.S. Coast Guard Training Facility area also begins to disperse into the Lower Cape May Meadows area. This additional sediment slows the rate of erosion in this area, and reduces periodic nourishment requirements for LCMM. The first periodic nourishment for the LCMM/CMP of only 139,000 cy (much less than the authorized amount of 650,000 cy) is scheduled to occur by March 2013 in selected areas of concern. Since the actual amount is less than expected, there appears to be influx of material from the ongoing nourishment efforts at Cape May City (2.9 million cy since 1993).

Figure 73 presents a similar analysis showing the same planform view and beach nourishment dispersion; however, Figure 73 also includes subsequent periodic nourishments at both CMC (every 2 years) and LCMM/CMP (every 4 years). Dashed lines show berm width before a periodic nourishment, while solid lines show after a periodic nourishment. Although not an exact representation of the periodic nourishment placements, which are likely varied based on need, this idealized case shows the general trend of the dispersion throughout the region and demonstrates the effectiveness of the feeder beach concept for both Cape May City and Lower Cape May Meadows. Results indicate after approximately 2 periodic nourishment events (4 years) at CMC, the required periodic nourishment for LCMM/CMP would be reduced, and after approximately 24 years no periodic nourishment would be required as long as CMC continues to be nourished and serve as a feeder beach.

Although this one-line modeling approach is a simplified analysis of beach nourishment performance, and its application is not directly applicable to the complex nature of the LCMM/CMP region, which features a curved shoreline, groins, and the influence of tidal currents in and out of Delaware Bay, etc., the analysis provides a preliminary assessment of the relative impacts of potential combined nourishments, cumulative effects, and feeder beach impacts. To ensure the results of the preliminary analysis were reasonable, the volume of material predicted to be lost was compared to the periodic nourishment volume added over the last 20 years. For example, since 1993, the Cape May City project has lost approximately 20-25% of the total volume every 2 years based on periodic nourishment cycles. Assuming each periodic nourishment attempts to return the beach to the approximate original construction template, the modeled performance can be compared to this observed volumetric loss. Figure 70 indicates the Cape May City nourishment loses approximately 25% in the first two years after returning the template to 100%, and corresponds well to observed performance. As such, the presented analysis represents a reasonable preliminary estimate of how the nourishment longevity may improve through various nourishment effects and approaches.

Using the same cost assumptions as presented in strategy A (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), the feeder beach effects would result in a cost savings of approximately $78 million over a 50-year time horizon due to reduced periodic renourishment with reduced volume. This continues the practice of periodic nourishment every 2 years of approximately 360,000 cy to return the nourishment to the original construction template at Cape May City, and reduced periodic nourishment through time for Lower Cape May Meadows. The analysis also assumes some material (approximately 40,000 cy) would be required every 4 years at Cape May Point due to the change in shoreline orientation and expected sediment loss due to tidal currents. Storm response repairs may be required as well. Cost benefits of this strategy are compared to current operations and other strategies in the summary section. Additional cost savings may be realized from reduced contracting and management requirements.

The reduced number of periodic nourishment episodes at LCMM/CMP and associated reduced long-term volume requirements will also have an environmental benefit since there will be less frequent disturbance of the offshore borrow site areas, reduced disturbance on the beaches of LCMM, reduced overall sediment needs (approximately 5 million cy less over 50 years) and reduced overall pollution (e.g., noise, air, etc.).

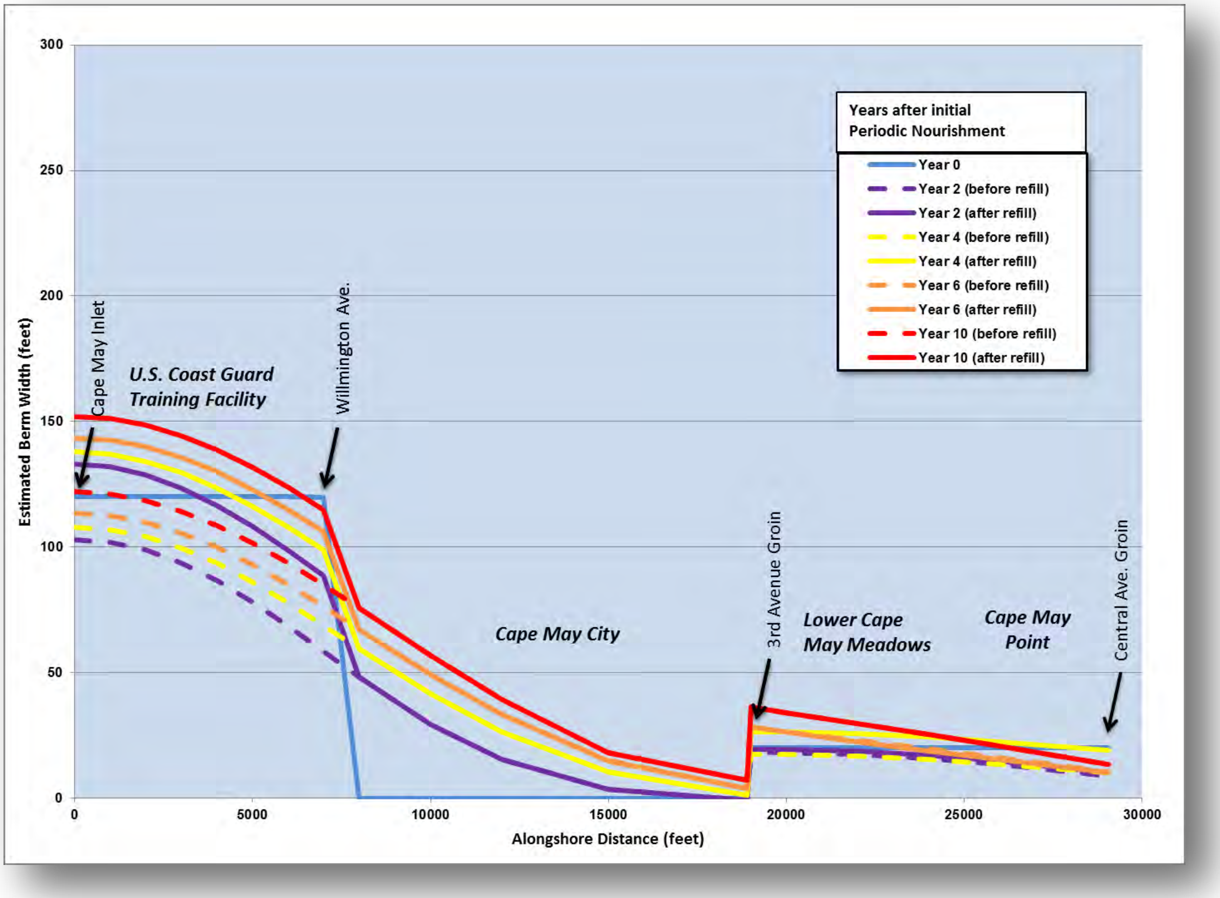


Figure 73. Spreading of periodic nourishments at Cape May City and Lower Cape May Meadows.

Based on the periodic nourishment history, this strategy is currently being conducted at a certain level by the Corps. Therefore, no new or modified authorization would be required to continue the current practices (feeder beach approach) for nourishment conducted under the authorization. If the projects were formally combined, new construction authorization would be required since the combined projects may be different in scale than the individual projects. A new feasibility study would have to be performed to determine the extent of federal interest in a new plan and to address the environmental requirements of a new plan. There is potential that the cost sharing may change as a result of the new plan as well as the timing and amount of non-federal funds required. Borrow areas would have to be revisited and sufficient borrow sites identified and evaluated as part of the reanalysis. The study itself could be accomplished under the existing New Jersey shore study authority, and would likely require a feasibility study cost sharing arrangement. Finally, if a project is recommended and authorized for construction, a new Project Cooperation Agreement (PCA) would have to be executed. If however, the project templates remain the same scale as the currently authorized projects, it may be more reasonable to implement this approach in an informal synchronization (Strategy A) and achieve the same benefits.

Implementation of this strategy has minimal additional constraints, limited to availability of dredging equipment and borrow site quantities, which are constraints of the current operations as well.

Table 21 presents a summary of the criteria evaluated for the feeder beach strategy and ranks this strategy as a high priority with a Tier level of 1.

Table 21. Feeder Beach Strategy Summary.

Criteria	Summary
1. Authorization	For continued implementation of the feeder beach approach, no authorization change is required. If a formal combination is considered, depending on the exact nature of the combination or modification to the project scale, it is likely that a new construction authorization will be required.
2. Constraints	No additional non-authorization requirement constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$78 million over 50-year time horizon for feeder beach approach
4. Service Life	Relatively significant increase in project longevity and service life with reduced nourishment of downdrift beaches
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale and reduced overall volumetric sand requirements in long-term
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	If formal combination is sought, site-specific, detailed analysis of LCMM/CMP and CMC areas, including detailed beach nourishment dispersion analysis

C. *Beneficial Re-use of Cape May Inlet Dredge Material*

This strategy intends to beneficially use sediment dredged from the Cape May Inlet (Cold Springs) authorized navigational project for the LCMM/CMP authorized shore protection project, and is in direct concurrence with the Regional Sediment Management Initiative.

Cape May Inlet, one of five federally authorized navigational projects along the NJ coastline, was stabilized in 1911 with two parallel rubblemound jetties approximately 4,500 ft long. Maintenance dredging of the inlet started in approximately 1919 and annual USACE reports provide information on the quantity dredged each fiscal year. Up until 1988, sediment dredged from the inlet was removed from the littoral system and deposited offshore. Since 1988, the USACE has been maintaining the channel using the sidecasting dredges the Merritt, Schweitzer, and Fry. Most of the work is conducted at a shoal that forms near the entrance to the inlet just inside the end of the southwest jetty. Typical sidecasting dredge quantities have been approximately 95,000 cy per year. In 1986-1988 and more recently (2005 and 2009), the USACE hopper dredge Currituck has maintained the channel, and has placed sand west of the inlet in the nearshore zone (bar) of Cape May City.

To determine the average annual amount of material dredged from Cape May Inlet, the USACE annual reports were used to calculate the cumulative maintenance dredging completed prior to sidecasting practices, independent of location or sediment type. Sidecasting volumes were not included in the analysis, since this dredging approach does not remove sediment from the inlet. Figure 74 presents the cumulative sediment volume dredged in Cape May Inlet from 1918 to 1988. Each black dot in the figure represented a dredging event, and shows the cumulative volume dredged as a function of time. The blue line in the figure represents a linear fit to the data and provides an average dredge quantity of approximately 60,000 cy per year, consistent with earlier USACE studies of Cape May Inlet dredging (USACE EM 1110-2-1616, 1991). Historically, non-sidecasting dredge frequency has been every 2.2 years.

The more recent dredging in Cape May Inlet, primarily completed by sidecasting, consists of a greater volume (approximately 95,000 cy/yr) and increased frequency (approximately twice a year) than historic dredging. This is likely due to the side casting methodology, which does not remove the sediment from the inlet. Tidal currents redistribute the material relatively quickly and may return it to the navigational channel. At the same time, the limited, recent hopper dredging events (in 2005 and 2009) only dredged an average of 26,000 cy, probably due to the much more frequent sidecast dredging distributing shoaled sediment throughout the inlet.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this strategy would result in a cost savings of approximately $45 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments

This analysis assumes that:

- the historic rate of 60,000 cy/yr and frequency (every 2 years) of dredging at Cape May Inlet continues;
- the dredged material is beach compatible;
- the dredged material can be placed in the littoral zone or directly on the beach, such that adequate storm damage protection can be provided; and
- the incremental cost of placing the material on the beach is relatively insignificant, since periodic nourishment would also be required concurrently with the inlet dredging to supplement the needed quantity of material.

Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

This strategy reduces the overall offshore borrow site sediment needs (approximately 3 million cy less over 50 years) and provides interagency team building while supporting the overall RSM initiative.

There are two pathways to implement this strategy assuming the dredged material is suitable for direct placement on the beach. The first would involve developing a beneficial re-use project using the Cape May City authorities for implementation. However, the authority to construct the project does not include a provision for this type of beneficial reuse. As such, it would likely have to be modified to include this, and the project cost sharing adjusted to reflect a new purpose. The attendant documentation would have to be developed to accomplish this, as well as a new PCA reflecting today’s model agreement would have to be negotiated and signed. The second way to implement this is to use the existing Cape May Inlet navigation project authorities. Under the existing authorities, if the material is suitable, the federal government could request the material be placed directly on the beach. Permits are required to do so, but they can be obtained under the authorized navigation project. If there is a cost differential to the navigation project, the State would likely have to pay the difference.

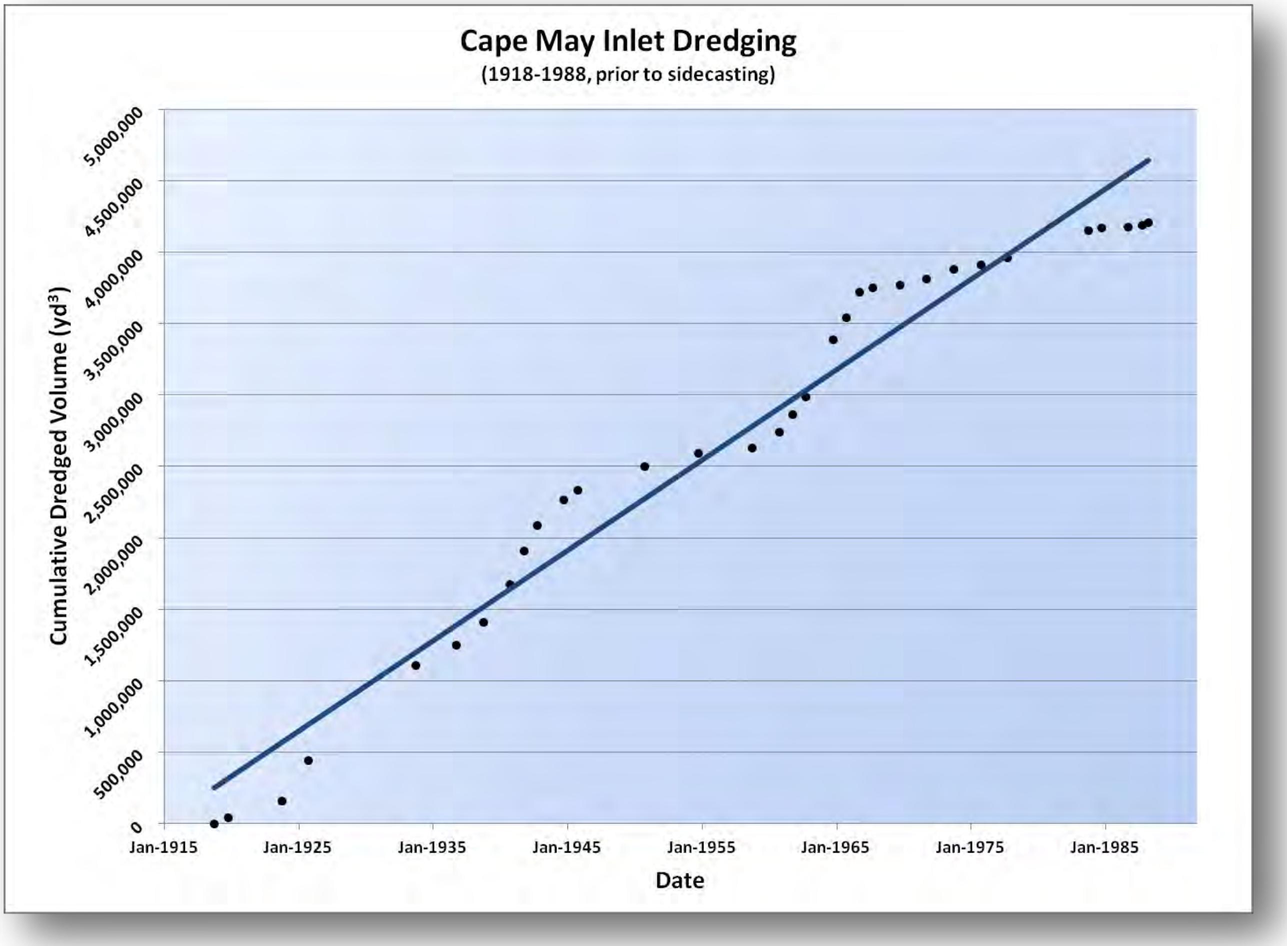


Figure 74. Cumulative dredge volume extracted from Cape May Inlet from 1919 to 1988.

Implementation of this strategy has limited additional constraints; however, sediment compatibility of the Cape May Inlet dredge material has to be determined. Previous investigations revealed that overdredging areas may not be feasible due to poor sediment quality at depth, although regular shoaled material should be of good quality. This may also be complicated by the fact that dredged material may be of varying compatibility levels. For example, the shoal near the inlet entrance may be compatible, while the material closer to the Harbor region may be of more mixed compatibility with both sand and finer grain sediment. Incremental dredge cost increases would also need to be determined.

Table 22 presents a summary of the criteria evaluated for the beneficial re-use of Cape May Inlet strategy and ranks this strategy as a high priority with a Tier level of 2. As long as the sediment dredged is compatible for beach nourishment or nearshore placement and the quantity of dredging remains approximately the same as historic levels, this strategy should be further pursued since it is directly in line with RSM strategies and initiatives. Additionally, every effort should be made to coordinate inlet dredging (navigation project) with the periodic nourishment (shore protection project) to minimize dredge mobilization costs.

Table 22. Beneficial Re-use Strategy Summary.

Criteria	Summary
1. Authorization	Implement under federally-authorized navigational project.
2. Constraints	Questionable sediment compatibility in some areas, incremental cost increases for dredge material placement
3. Cost Savings	$45 million over 50-year time horizon
4. Service Life	No change to existing service life of shore protection project or navigational dredging
5. Other Benefits	Reduced offshore sediment source requirements. Interagency and state team building, RSM initiative.
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Evaluate sediment compatibility obtain permits for placement of dredged material on beaches.

D. Offshore Borrow Area Expansion or Establishment

Sediment sources for initial construction of the LCMM/CMP project have been offshore borrow sites. Currently, the permitted offshore borrow sites are nearly depleted and the most recent periodic nourishment material source was upland. Unless sediment needs of the shore protection project can be reduced (e.g., beach nourishment performance is enhanced), or alternative sediment sources are utilized (e.g., bypassing, inlet dredge sediment, etc.), additional offshore borrow location will be required.

This strategy is not specifically geared towards providing a cost savings, but rather at maintaining current operations costs since upland and distant offshore sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., track traffic, road repairs, time of construction, etc.).

Over a 50 year time horizon, the remaining periodic nourishment sediment needs at Cape May City are approximately 9,000,000 cy, and at nearby Lower Cape May Meadows and Cape May Point are 8,125,000 cy. These two projects have shared offshore borrow sites in the past, and would likely be able to share new borrow sites in the future. Overall, the LCMM/CMP and CMC projects require approximately 17,125,000 cy over a 50-year time horizon.

Borrow locations 4 and 5 used for the Lower Cape May Meadows and Cape May Point nourishments have limited material remaining (approximately 400,000 cy). Recently permitted borrow area K contains approximately 10.7 million cy (if dredged 15 ft in depth). As such, there is a deficit of approximately 6 million cy for the combined CMC and LCMM/CMP projects. If the Cape May Inlet is used as an additional sediment source (approximately 3 million cy over 50 years), there remains a deficit of approximately 3 million cy for the reach.

Continued expansion of existing sites or searches for new borrow sites is needed for this region. For example, the Area K extension area should be considered (as additional 7.5 million cy with a dredge cut of 15 ft). Potential searches in Federal waters may be warranted through cooperation with the Bureau of Ocean Energy Management (BOEM).

This strategy can be accomplished under the existing project authorities. The provision of borrow areas for the life of the project is part of the authorization. It would require cost sharing likely at the same level as the project. Appropriate studies and environmental clearances would be needed.

The primary constraints with expansion or establishment of offshore borrow sites are environmental. Establishing offshore borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave and sediment transport processes also are needed. The physical and environmental delineation would add cost; however, once permitted, the construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 23 presents a summary of the criteria evaluated for the offshore borrow area expansion and establishment strategy and ranks this strategy as a high priority with a Tier level of 1. It is recommended that this strategy is pursued in advance of potential need, such that the borrow areas are established for future use. Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted offshore sites available if needed for storm events or unforeseen circumstances is good planning. Next steps for this strategy would be to initialize studies and surveys needed to expand or establish new borrow sites for this region, which has a known deficit and coordinate with BOEM for potential federal waters borrow sites.

E. Refine Beach Nourishment Template

This strategy involves applying adjustments to the authorized beach nourishment template at LCMM/CMP to determine if modifications to the template may result in increased performance or improved storm damage protection. A successful beach nourishment project consists of more than simply placing sediment on a beach. Beach nourishment projects are engineered. A beach nourishment template, which consists of numerous design parameters, is based on the characteristics of the site and the needs of a project. Every beach nourishment design is unique, since different beaches and areas have unique physical, geologic, environmental, and economic characteristics, as well as different levels of required protection. The design must consider climatology, the shape of the beach, type of native sand, volume and rates of sediment transport, erosion patterns and causes, waves and water levels, historical data and previous storms, probability of certain beach behaviors at the site, existing structures and infrastructure, and past engineering activities in the area.

Table 23. Offshore Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Initiate studies and surveys. Coordinate with BOEM

The structure of a nourishment template is designed to yield a protective barrier that also provides material to the beach. A higher and wider beach berm is designed to absorb wave energy. Dunes may be constructed or existing dunes improved to reduce storm damage, including potential upland flooding. Figure 75 depicts a beach berm and dune on a typical beach profile. Nourishment length, berm height and width, dune height, and offshore slope are critical elements of a beach nourishment design. Periodic nourishment intervals are also usually a part of the nourishment design. The renourishment interval will vary based on the initial design, wave climate, sand used, frequency of storms, and project age.

In addition, beach nourishment is not an exact science; variables and uncertainties exist. Actual periodic nourishment intervals differ from planned intervals based on conditions at the nourished beach and the frequency and intensity of storms.

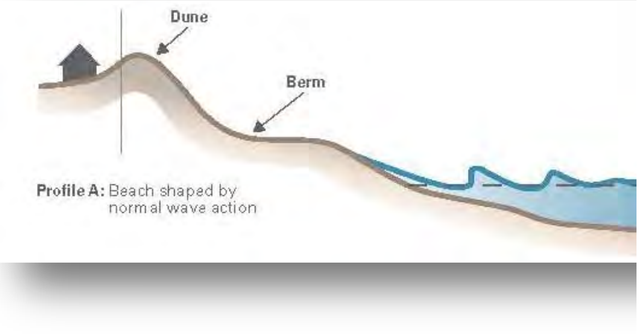


Figure 75. Typical beach profile and features (from Coastal Engineering Manual, 2003).

This proposed strategy evaluates potential improvements to project performance, storm damage protection, and subsequent cost savings that can be realized by modifications to the currently authorized beach nourishment template.

The feasibility studies for the authorized projects typically evaluate a range of proposed beach nourishment template designs using alongshore and cross-shore analysis and/or modeling efforts to assess performance and storm damage protection afforded. However, the USACE policy has been to not consider increases to the natural berm elevation for the design template or to see if changes to the natural berm height result in performance gains or improved storm damage protection. Additionally, the currently authorized design template has not been re-evaluated following monitoring of the performance of the system. Monitoring data reveal potential insight leading to modifications to the template. Therefore, this strategy involves assessing changes to the beach nourishment template that may yield cost savings over the long-term. An example of this type of analysis is presented herein by evaluating change in berm height and width on the performance of the LCMM/CMP project as a preliminary analysis of potential template modification.

Similar analyses could be completed for a number of parameters for beach nourishment design; including:

- Nourishment length – expanding the nourishment length, specifically through combining or syncing projects could be evaluated.
- Berm Width – The width of the berm could be modified to see if there is a cost benefit that could be attained. This also may involve a spatially variable berm width modification (e.g., overfilling the Coast Guard Training Area).
- Berm Height – The height of the berm could be modified to determine impact on storm damage protection.
- Offshore slope – The offshore slope of the nourishment can be changed.
- Grain size – The grain size of the source material for the nourishment may affect the performance of the projects. For example, coarser nourishment material may result in improved project performance (lower erodibility and hence more protection.

To assess potential changes in berm width and height at LCMM/CMP, the computer model SBEACH (Larson and Kraus 1989) was used to assess cross-shore evolution. SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and further developed and verified based on field measurements (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990). The model predicts the time-dependent evolution of existing or design beach and dune profiles for specified water levels and wave conditions. In addition to the proposed nourishment template, the model requires a time series of wave heights, wave periods and water levels as forcing inputs. The specific storm information required by SBEACH is a time history of total water level (tide plus surge) and wind wave height and period. The WIS hindcast information, FEMA FIS still water storm surge elevation, and extremal analysis were used to develop a simulated 10-year storm for this analysis.

Figure 76 presents results of varying the berm height (blue line) and width (green line) of the LCMM/CMP authorized beach nourishment template. The horizontal axis shows the percent of material eroded from the nourishment template area caused by a 10-year, 24-hour storm for various berm heights and widths. The left hand vertical axis shows berm height (NAVD88, feet), while the right hand vertical axis shows berm width (feet). The variable width scenarios use a constant 6.7 ft NAVD88 berm height, while the variable height scenarios use a constant 20 ft berm width. The currently authorized template consists of a berm height of approximately 6.7 ft NAVD88 and a berm width of 20 ft. Figure 76 shows the changes in expected sediment eroded from the template for increased berm height and width. For example, the currently authorized project template loses approximately 22% of the periodic nourishment (650,000 cy) during the 10-year, 24-hour storm. Increasing the berm height by a ft to 7.7 ft NAVD88 reduces the percentage of material lost to approximately 14%. Increasing the berm height further results in decreased losses, but also requires additional nourishment volumes, and additional sediment sources and finances. There is a point of diminishing returns on the amount of required sand needed to extend the berm height or width and the increased performance gained. For example, Figure 76 shows that increasing the berm width beyond 60 ft at LCMM/CMP does not result in improved performance. This type of analysis helps evaluate the sensitivity of various parameters in the beach nourishment design, their potential impacts on overall cost of the project, and identify the most cost-effective design template.

The 7.7 ft NAVD88 berm height modified design requires approximately 288,000 cy of additional sediment to gain the required berm height during the initial increased periodic nourishment; however, the performance is improved over each 4 year cycle, such that the amount of sediment required for each periodic nourishment is reduced.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this example approach to template modification results in a cost savings of approximately $28 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments, or increased renourishment intervals. The required periodic nourishments could be reduced to every 8 years if the performance gains respond as estimated. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

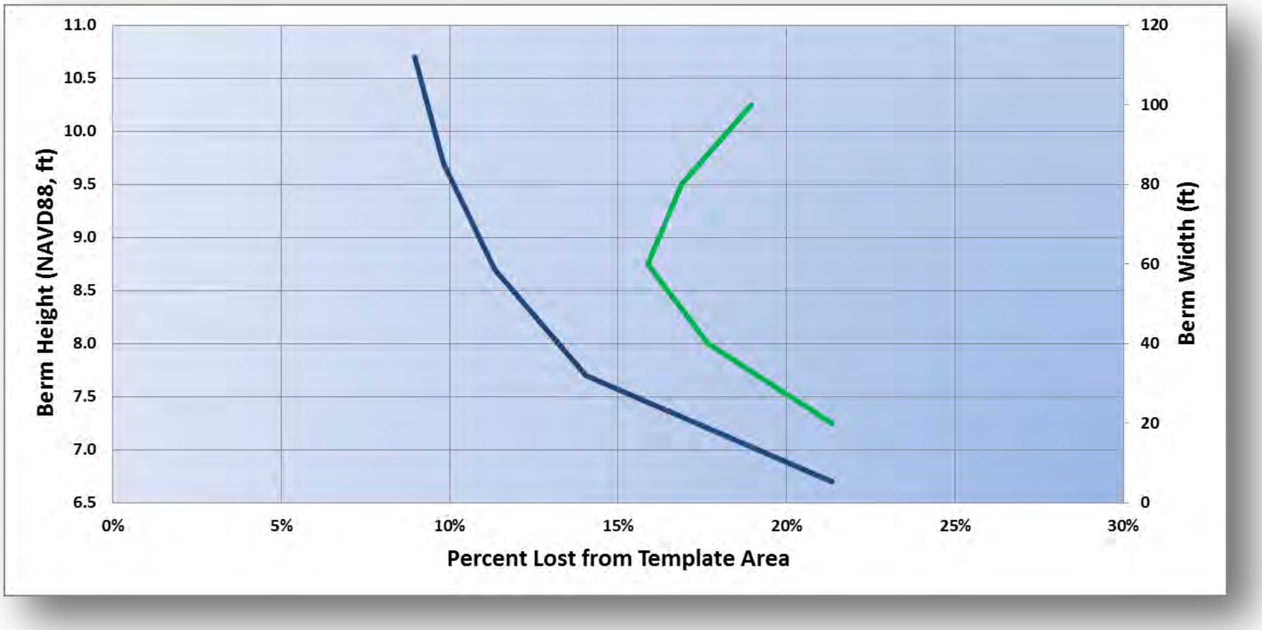


Figure 76. Eroded beach volume as a function of template berm height (blue line) and width (green line) for the Lower Cape May Meadows/Cape May Point nourishment project in response to a 24-hour, 10-year return period storm event.

In addition to the cost savings estimated from the reduced sediment volume requirements for periodic nourishments, modification of the beach nourishment template may have other benefits. For example, the modified template may result in improved storm damage protection and reduced potential upland damage costs. Examples of other potential benefits included habitat enhancement, reduced ponding or upland flooding, and reduced environmental impacts offshore due to reduced offshore sediment needs.

Relative to the current authorization, the existing template defines the authorized project and the NED plan. Changing the template implies that the authorized plan was no longer the NED plan and the project would have to be reanalyzed. To do so would require the use of the existing New Jersey shore study authority to determine the degree of federal interest, secure requisite environmental clearances, and recommend a change in the authorized plan. This would require the existing project authority to be modified by Congress. It would also likely require a new study cost sharing agreement to be signed, as well as a non-federal sponsor willing to contribute 50% of the study costs and agree to any changes in the construction and long-term cost sharing. A new PCS conforming to the model agreement would have to be signed.

Potential constraints associated with modification of the beach nourishment template include environmental concerns (e.g., occupying a larger offshore footprint), political and local community concerns that would limit the ability to change the template (e.g., communities wouldn't want an increase berm height), and logistical concerns associated with modification of the authority to construct the project.

Table 24 presents a summary of the criteria evaluated for the refined beach nourishment template strategy and ranks this strategy as a low to intermediate priority with a Tier level of 2. Next steps for this strategy would be to conduct more detailed studies to assess if template modifications are warranted. The studies would focus on the cost benefit aspects of template modification.

Table 24. Refined Beach Nourishment Template Strategy Summary.

Criteria	Summary
1. Authorization	Requires a change to the authorized plan and would include new study, permits, and cost-sharing agreements.
2. Constraints	Logistic, political, local community, and environmental concerns.
3. Cost Savings	Depends on template modification, $28 million for the example provided.
4. Service Life	Increase service life of beach nourishment expected
5. Other Benefits	Improved storm damage protection, habitat enhancement, reduced offshore environmental impacts
6. Priority	Low to Intermediate
7. Tier Level	Tier 2
8. Next Steps	USACE Philadelphia district decide if the strategy is warrants further study.

F. Modification of CMP Groin Field

The Section 227 Demonstration Project (Figure 68), consisting of construction of a Beachsaver Reef™ with a geotextile cloth base in groin cell 5, and an innovative Double-T sill structure in cell 6, has been monitored and evaluated by Stauble et al. (2005, 2006). Stauble et al. (2005, 2006) evaluated performance by assessing the ability of structures to retain sediment within the groin cell, remain structurally stable, and reduce the required sediment needs for maintaining the beach. To complete this evaluation, monitoring data were collected of beach profiles, waves, currents, and water levels in all the cells along CMP.

Shoreline and volumetric changes were determined from the monitoring data and the nourishment material placed in the structured groin cells was retained better than the unstructured groin cells (Stauble et al., 2006). This strategy considered installation of similar shore parallel structures along the currently unstructured groin cells. The cumulative volume change data determined by Stauble et al. (2005) within each cell were used to assess the potential improvement of sediment retention along CMP groin field.

Based on the monitoring data, the structured groin cells retained approximately 1,560 cy per year (2.6 cy per year per linear foot of beach) more than the unstructured cells between July 2000 and October 2003. Installation of Beachsaver Reef™ or similar type structures at Cells 4, 7, and 8, which are currently unstructured, would retain approximately 5,750 cy/yr of sediment.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), adding the structures to the CMP groin cells 4, 7, and 8 would result in a cost savings of approximately $2 million over a 50-year time horizon due to reduced volume requirements. This cost analysis assumes:

- Beachsaver Reef™ construction costs of $1000 per linear foot based on previous construction costs
- periodic nourishment conducted as currently authorized (every 4 years for LCMM/CMP)
- the structures maintain the same rate of effectiveness over the 50-year service life

Changing the existing structures, presumed in place when the authorized project was developed, would require a reanalysis of the existing project's design and determination as to whether it is still the NED plan. If proved to be sound engineering and more cost effective than the current situation; environmental documentation and permits would be required. The study could be accomplished under existing authorities with appropriate sponsorship and cost sharing. Resulting changes to the project would likely lead to a reauthorization and the documentation associated with it.

Constraints for this strategy include potential environmental impacts that need to be assessed and coastal processes evaluations that evaluate the impact of proposed structural modifications.

Table 25 presents a summary of the criteria evaluated for the structural modification strategy and ranks this strategy as a low priority with a Tier level of 3. Next steps for this strategy would be to continue monitoring and evaluation of the existing Section 227 project components to determine their functionality over a longer time span. More detailed studies of these structural modifications from a physical and environmental impact basis may also be required. The studies should also focus on the cost benefit aspects of the structural modification.

G. *Adjustment of 3rd Avenue Groin*

This strategy proposes to adjust the coastal engineering structure at the seaward end of 3rd Avenue within the Cape May City region to provide potential cost savings and improved beach nourishment performance for the LCMM region. This strategy evaluates notching or lowering of a portion of the 3rd Avenue groin to allow more sediment transport into the Lower Cape May Meadows region. Figure 77 presents the conceptual design for this structural modification.

Table 25. Modification of CMP Groin Field Strategy Summary.

Criteria	Summary
1. Authorization	Requires a reanalysis and environmental permitting
2. Constraints	Environmental impacts need to be evaluated, coastal processes assessment to evaluate impact of structural modification
3. Cost Savings	$2 million
4. Service Life	Potential beach nourishment performance enhancement, structural service life may need further evaluation
5. Other Benefits	Reduced environmental impacts to offshore resources
6. Priority	Low
7. Tier Level	Tier 3
8. Next Steps	Continued monitoring and evaluation of existing Section 227 project components

To provide a preliminary evaluation of the potential modification of the groin at 3rd Avenue, the cross-shore distribution of the longshore transport was evaluated using relationships proposed by Longuet-Higgins (1970, 1970a). Using the cross-shore distribution, the effect of a shore-perpendicular structure on reducing or increasing the longshore sediment transport can be estimated.

Figure 77. Conceptual design of the groin at 3rd Avenue, impacts evaluated in the Lower Cape May Meadows project strategy section.

The cross-shore distribution of longshore transport can be determined using a theoretical radiation stress approach (Longuet-Higgins and Stewart, 1962). This momentum based theory describes the energy imparted on the bottom of a nearshore breaking zone by shallow water waves.

When shallow water waves break at an oblique angle to the coastline, the result is a net force that pushes a parcel of alongshore. In the case of a series of multiple waves breaking at a similar angle; a net current results that continually forces water along the shore (or alongshore). The total volume flow rate, Q, is given as a function of velocity, v_o, as

Equation 3:

$$Q = \frac{1}{3s} h_B{}^2 v_0 = \frac{1}{3} h_B |x_B| v_0$$

where h_B is the depth of water at the breaker line, s is the slope of bottom, and x_B is the normalized distance to the breaker line.

Horizontal mixing is the result of waves breaking at different locations and wave-induced eddies varying the profile of the cross-shore velocity distribution. To account for this variability due to mixing, a quadratic equation is used to create a typical cross-shore flow profile. The shape of this new function is dependent on the known variability of the wave conditions and a horizontal eddy parameter. Figure 78 is a schematic representation of the long-shore velocity profile as a function the normalized offshore distance to the breaker line. The broken line represents the values without mixing. After applying a quadratic equation and its mixing coefficients, the longshore velocity profile looks like the solid line. The area under both lines equals to the volume flow rate, *Q*.

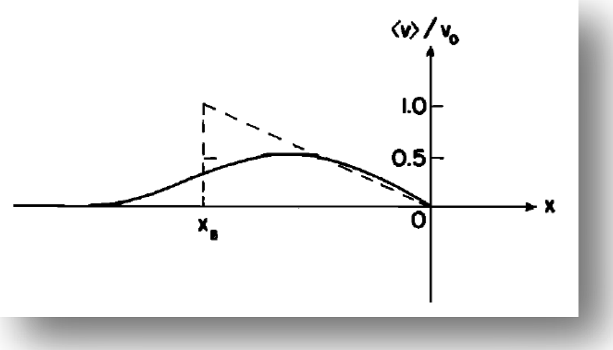


Figure 78. Example cross-shore distribution of alongshore velocities.

This distribution is calculated based on site-specific physical processes data (e.g., WIS hindcast information) for the Lower Cape May Meadows region, and is presented in Figure 79. The distribution can then be applied to assess different lengths (cross-shore direction) of structure by determining the amount of littoral transport that may be intercepted by the structures.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), notching the 3rd avenue groin for a section of 150 ft from the current Mean High Water (MHW) line landward would result in a cost savings of approximately $8 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments for LCMM. This cost analysis assumes:

- Groin modification construction costs of $1.0 million based on previous structural cost bids
- a net southward littoral drift rate of 137,000 cy/yr (USACE, 2006)
- periodic nourishment conducted as currently authorized (every 2 years for Cape May City and every 4 years at LCMM)
- the structure maintains its same rate of effectiveness over the 50-year service life
- increased sediment flow towards LCMM/CMP does not significantly impact the stability of the CMC shoreline. Given the historic seaward growth of the shoreline during the nourishment activities (shoreline change rates), this appears to be a reasonable assumption.

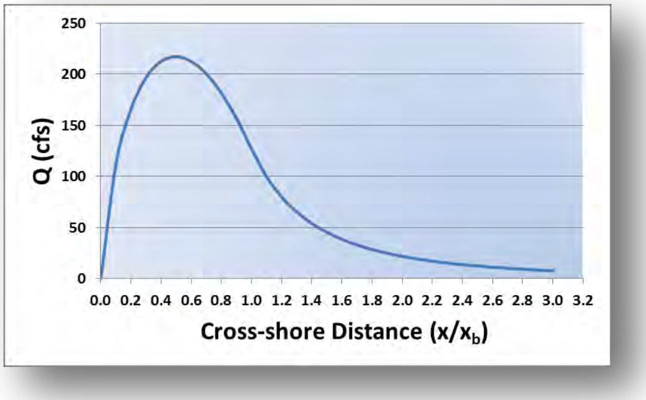


Figure 79. Cross-shore distribution of alongshore flux for LCMM/CMP area.

Notching or lowering of other extends can also be evaluated. However, the structure should not be lowered or notched to the extent that it would negatively impact the Cape May City shoreline by allowing too much sediment to drift out of the region. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Structural modifications could be evaluated under the existing New Jersey Shore authority. However, it would require study cost sharing, a non-federal sponsor, and (if it meets the criteria for implementing) a new construction authorization.

Constraints for this strategy include potential environmental impacts that need to be assessed, and coastal processes evaluations that should evaluate the impact of proposed structural modifications.

Table 26 presents a summary of the criteria evaluated for the structural modification strategy and ranks this strategy as a low to intermediate priority with a Tier level of 3. Next steps for this strategy would be to initialize more detailed studies to assess the impact of proposed structural modifications from a physical and environmental impact basis. The studies would also focus on the cost benefit aspects of the structural modification proposal(s).

Table 26. Adjustment of 3rd Avenue Groin Strategy Summary.

Criteria	Summary
1. Authorization	Requires study of cost sharing and a non-federal sponsor to implement construction authorization
2. Constraints	Environmental impacts need to be evaluated, coastal processes assessment to evaluate impact of structural modification
3. Cost Savings	$8 million for structural modification presented herein
4. Service Life	Potential beach nourishment performance enhancement, structural service life expected to be 50 years
5. Other Benefits	Reduced environmental impacts to offshore resources
6. Priority	Low to Intermediate
7. Tier Level	Tier 3
8. Next Steps	Coastal processes and environmental studies to determine relative cost benefit of structural modifications

H. Bio-Engineering for LCMM Dunes

This strategy involves enhancing the dune portion of the authorized shore protection project at LCMM using bio-degradable solutions to create a dune core. For example, the use of coir fiber rolls, or envelopes could be placed in the core or outer face of a dune during a reconstruction project. Although not intended to be a viable long-term solution, the coir fiber rolls would provide added scour protection during a winter storm event, and have performed well over a limited time frame in the coastal zone (Woods Hole Group, 2011). The intent of the bio-engineering would be to allow time for the dune to become fully established with vegetation and become more stable.

Coir fiber rolls are commercially made erosion control products. They consist of tightly bound cylinders of coconut fiber (coir fiber) held together by wire mesh or coir fiber netting. They are generally available in 10 to 20 ft lengths and are 10 to 20 inches in diameter. Coir fiber rolls provide a natural, unobtrusive appearance and decompose over a three to six-year period. They are relatively lightweight (10' length weighs 75 lbs.) and can be installed with a minimum of site disturbance. Figure 80 shows an example section of a fiber roll. They can be wrapped in wire mesh, as shown in Figure 80, or wrapped in coir fiber netting for a completely biodegradable alternative.

The fiber rolls would be non-visible, placed within the dune (in either a single roll or pyramid configuration), anchored into place, and covered with sediment. They would only be exposed during a storm event. The cost for coir fiber rolls is approximately $20 per linear foot and additional cost for anchoring. If current sediment placement is supplemented with coir fiber rolls, additional design guidance and recommended placement methodology (e.g., staking, anchoring, etc.) would be required.

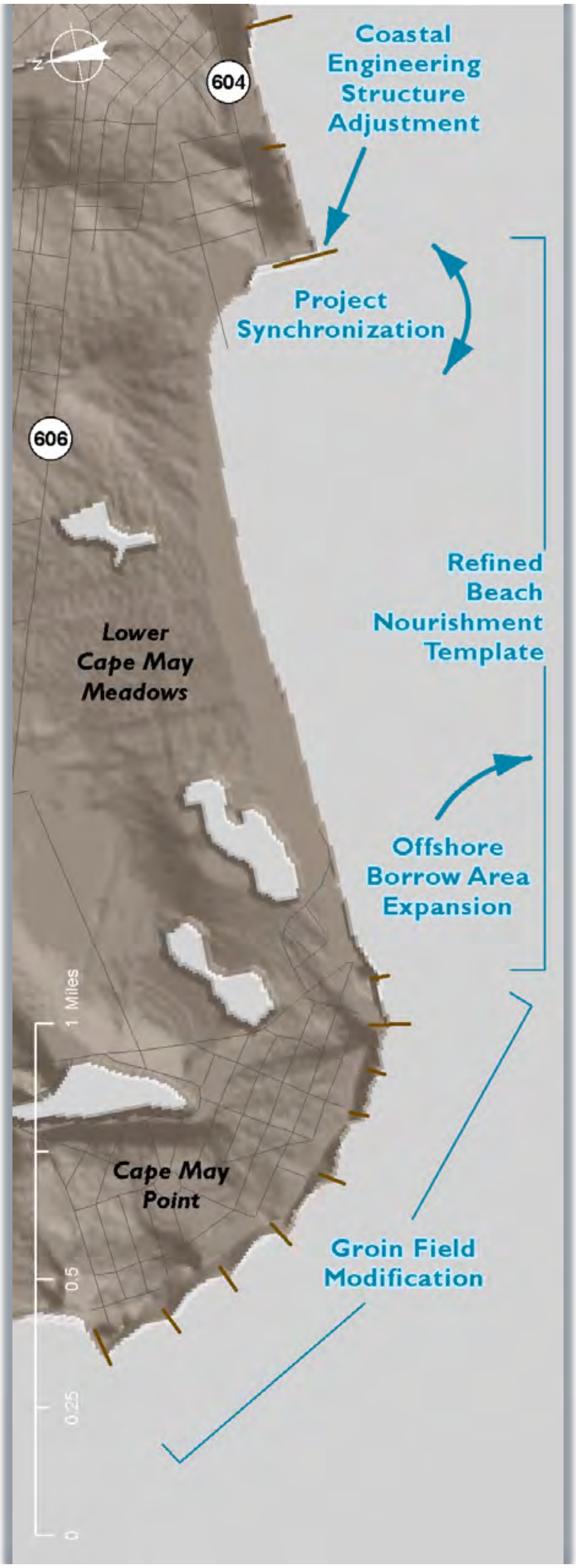
Figure 80. Example of coir fiber roll wrapped in a wire mesh.

The development of new alternatives would likely require a new determination of the extent of federal interest, non federal sponsorship of the studies with the requisite cost sharing and a likely reauthorization of the project. There are minimal additional constraints for this strategy, as the solution is fully bio-degradable, and is expected to have minimal environmental impact.

Table 27 presents a summary of the criteria evaluated for the bio-engineered solution for LCMM dunes. This strategy ranks as a low to intermediate priority with a Tier level of 3. Next steps for this strategy would be to initialize more detailed studies to assess the impact of proposed structural modifications from a physical and environmental impact basis. The studies would also focus on the cost benefit aspects of the structural modification proposal(s).

Table 27. Bio-engineering solution for LCMM Dunes Strategy Summary.

Criteria	Summary
1. Authorization	Requires a new determination of the extent of federal interest, non-federal sponsorship of the studies with the requisite cost sharing and reauthorization of the project.
2. Constraints	Minimal additional constraints
3. Cost Savings	Reduced dune replenishment expected.
4. Service Life	Coir logs expected to have approximately a 5 year service life.
5. Other Benefits	Improved storm damage protection and dune enhancement
6. Priority	Low
7. Tier Level	Tier 3
8. Next Steps	Determination if strategy warrants further consideration



Summary

This section presents a brief summary of the strategies presented for LCMM/CMP. The focus is on the potential cost savings and priority levels associated with the strategies to assist the identification and selection of strategies that could be implemented immediately and/or further pursued to more cost effectively manage sediment within the LCMM/CMP project.

Figure 81 provides a summary of the estimated total cost savings (compared to current operations) over a 50-year time horizon for a number of potential strategies (those that indicated a cost saving could be realized) for comparison purposes. Similarly, Figure 82 presents the cumulative cost savings for the same project strategies over that 50-year time horizon. Additional analysis could be completed to evaluate the potential cost savings associated with combining various strategies as well.

Table 28 presents an overarching summary of strategies focused on the prioritization and Tier level. The strategies presented in Table 28 are listed in order of priority and estimated ease of implementation.

Table 28. LCMM/CMP Strategy Summary.

Strategy	Prioritization	Tier
A. Project Cycle Synchronization	High	1
B. Feeder Beach	High	1
C. Beneficial Re-use	High	2
D. Offshore Borrow Site Expansion	High	1
E. Refined Beach Nourishment Template	Low to Intermediate	2
G. Adjustment of 3rd Avenue Groin	Low to Intermediate	3
F. Modification of CMP Groin Field	Low	3
H. Bio-engineering for LCMM Dunes	Low	3

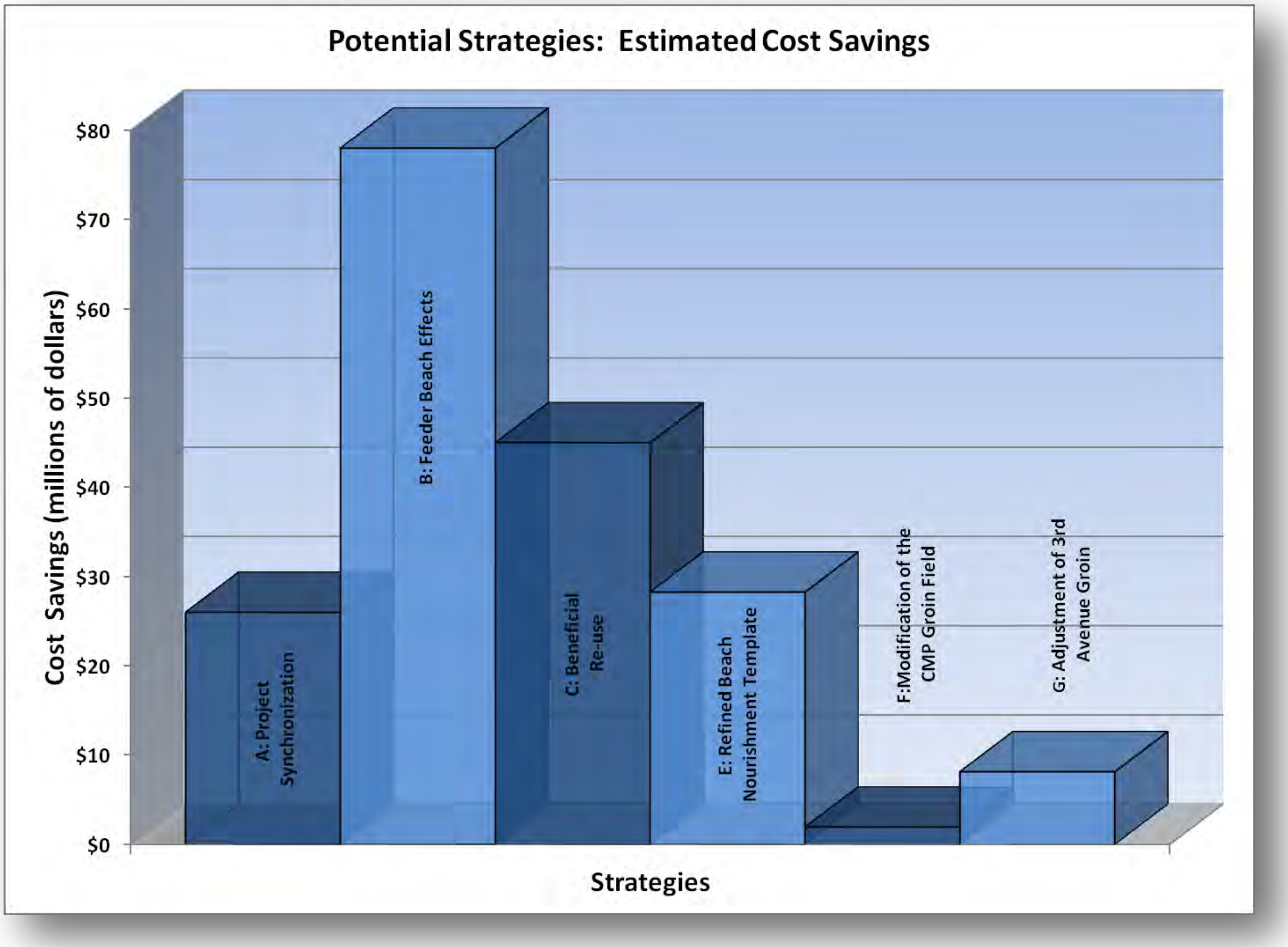


Figure 81. Estimated cost savings (compared to current operations) over a 50-year time horizon for select LCMM/CMP strategies.

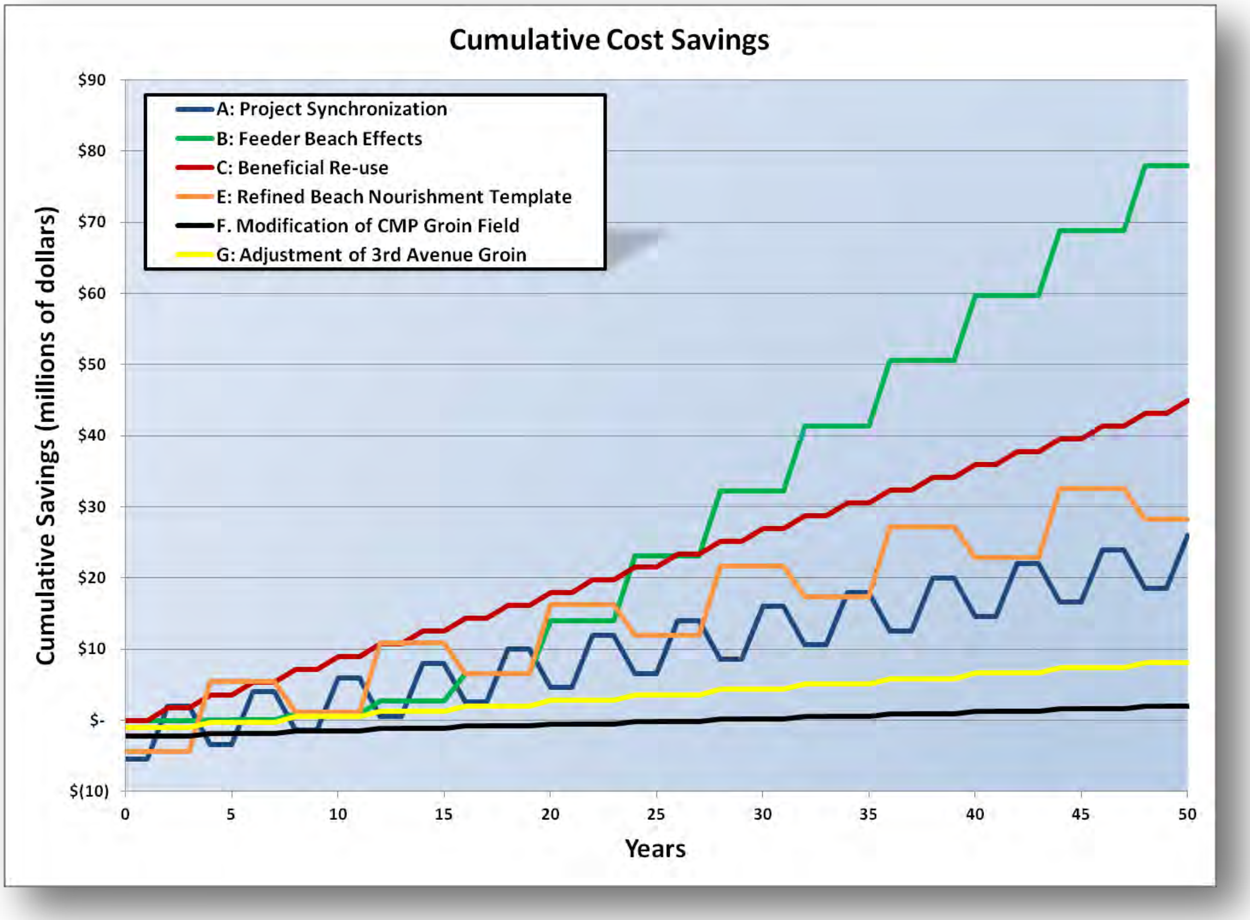


Figure 82. Cumulative cost savings (compared to current operations) over a 50-year time horizon for select LCMM/CMP strategies.

CAPE MAY CITY

Project Description

The Cape May Inlet to Lower Township Storm Damage Reduction Project was authorized by the Water Resources Development Act of 1986. The project is located on the south coast of New Jersey, extending from the southwest jetty at Cape May Inlet to 3rd Ave. in Cape May City. The project area includes the City of Cape May, as well as the US Coast Guard Training Center. The authorized project includes berm construction using sand dredged from offshore borrow sites or from Cape May Inlet, extension of 17 storm water outfalls, reconstruction/maintenance of seven (7) groins (Philadelphia Avenue, Queen Avenue, Stockton Place, Jackson Street, Windsor Avenue, Patterson Avenue, and Third Avenue), and construction of two (2) new groins (Baltimore and Trenton Avenues). Periodic nourishment every 2 years is authorized to maintain the design template and a shoreline monitoring program is included to track performance of the project. Construction of a 2,560 ft long rubble mound weir-breakwater east of the Cape May Inlet eastern jetty is deferred (at least ten years from approximately 1986) pending demonstration of need.

The berm design varies from 25 ft wide in Cape May City to 180 ft wide at the US Coast Guard Training Center, with an elevation of 8.0 ft NGVD88 (approximately 6.7 ft NGVD29). The berm length is 14,000 ft from the southwest jetty of Cape May Inlet to the 3rd Ave. groin in Cape May City. The project includes an initial construction volume of 1,365,000 cy, with periodic nourishment of 360,000 cy every two (2) years. Offshore areas M1, and recently area K, are the authorized borrow sites for initial construction and periodic nourishment. The authorization also allows for nourishment with dredged sediment from Cape May Inlet and for periodic nourishment from a deposition basin to be located east of Cape May Inlet's eastern jetty (just offshore of the southwestern end of Five Mile Island). Figure 83 provides an oblique aerial photo of the authorized project.

Project History

The history of shore protection measures at Cape May City started following construction of the Cape May Inlet (also referred to as Cold Springs Inlet) jetties in 1911. Cape May City suffered chronic erosion since stabilization of the inlet when the jetties began to interrupt a significant amount of sediment previously naturally bypassing the inlet and feeding Cape May City beaches. The Federal government accepted responsibility for the extensive shoreline retreat and commenced funding restoration of Cape May City beaches in 1989. The project also includes United States Coast Guard participation, since their Training Center lies just south of Cape May Inlet. The initial nourishment was completed in 1991 with the placement of 1,365,000 cubic yards (cy) in the authorized template. Periodic nourishments have been conducted on approximately a 2 year time scale, as detailed in Table 29. Sediment for these nourishments has come primarily from offshore borrow sites (areas M1, 4, and 5), with the most recent coming from an upland quarry due to depletion of authorized and permitted offshore borrow site sediment. Sediment placed during the periodic nourishment cycles has been primarily in the northeastern portion of the authorized nourishment area with approximately 75% of the periodic nourishment volume placed in the Coast Guard Training area. No periodic nourishment sediment has been placed southwest of Wilmington Avenue since 1999. Another periodic nourishment effort is expected by March 2013 with a total amount of 163,000 cy.

Construction of the Cape May Inlet jetties in 1911 also caused the subsequent installation of a number of coastal engineering structures along the Cape May City shoreline (detailed in Chapter 2). In addition to the beach nourishment component, the authorized project included extension of 17 storm water outfalls, reconstruction of 7 groins, and construction of two new groins. The project authorization also included construction of a 2,560 ft rubble mound weir breakwater pending demonstration of need. In 1990, 2 groins were extended at Trenton Ave. and Baltimore Ave. and 16 storm water outfalls were extended. These two extended groins are currently buried under sand from the ongoing periodic nourishments at the northeast end of the project area.

Figure 83. Cape May City Authorized Shore Protection Project.

Table 29. Cape May City Nourishment History.

Date	Volume (cy)	Source
Aug. 1989	465,000	Borrow Site M1
Jul. 1991	900,000	Borrow Site M1
Apr. 1993	415,000	Borrow Site M1
Sep. 1993	300,000	Borrow Site M1
Mar. 1995	330,000	Borrow Site M1
Jan. 1997	366,000	Borrow Site M1
Oct. 1999	400,000	Borrow Site M1
Mar. 2003	267,000	Borrow Sites 4 and 5
Nov. 2004	290,145	Borrow Site M1
Feb. 2007	190,000	Cape May Inlet
Feb. 2009	233,650	Upland Quarry

Project Observations

Since initial construction of the project a number of developments have been observed:

- There continues to be a high rate of erosion in the Coast Guard Training area portion of the beach. Although it has served as a feeder beach to the Cape May City region, this area requires continued nourishment on the 2 year authorized cycle.
- The beach fronting Cape May City has accreted substantially since initial project construction. The beach is well seaward of the design template and may become an issue for storm water outfalls. Since 1991, the Cape May City beach has grown approximately 100 cubic yards/foot.
- Sediment grain size of the recreational beaches in Cape May City has become coarser due to the composition of the offshore borrow site material.
- Due to the required 2 year periodic nourishment cycle, permitted offshore borrow sources are diminishing, and is becoming more costly. The most recent periodic nourishment source was an upland quarry (Table 1).
- Although there is likely a significant amount of sediment available offshore of the Cape May City area, these regions require environmental studies prior to establishment of suitable borrow areas.
- There is sediment available on the north side of Cape May Inlet; however, potential sediment compatibility concerns exist.

Potential Strategies

This section presents potential strategies for the Cape May City to Lower Township Storm Damage Reduction Project intended to improve project performance, cost savings, or provide other benefits. Strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. Some of the strategies include a first-order technical analysis to evaluate the relative merit of the proposed strategy. The analyses are not intended to be detailed assessments and include assumptions and simplifications. The analyses are geared towards providing a preliminary estimate of potential benefits that may be realized if the strategy is implemented. The analysis presented can be used as an initial screening tool to determine if a strategy warrants further consideration. For some strategies, a more detailed analysis may be required if the strategy is more formally pursued.

A. Project Cycle Synchronization

The project cycle synchronization strategy represents informally synchronizing construction of authorized shore protection projects in close proximity. The intent is to reduce mobilization and demobilization costs by combining re-nourishments. For this project, coordination of the Cape May City nourishment project would be synchronized with the Lower Cape May Meadows and Cape May Point nourishment project.

A first-order analysis of cost savings potentially realized by combining the periodic nourishment efforts at the Cape May City and Lower Cape May Meadows authorized projects was conducted. The analysis follows a similar approach as presented in Gebert (2010). In this particular case, it is assumed the authorized two year periodic nourishment cycle at Cape May City could be extended to a four year cycle (which based on the analysis presented in Strategy B may be feasible), and nourished jointly with the Lower Cape May Meadows/Cape May Point authorized project.

Mobilization and demobilization costs constitute a significant portion of typical dredging contracts, and these costs are not always reduced with increased contract size (e.g., larger dredging projects). A number of factors contribute to the variations in dredging contract costs, including market conditions at the time, proximity of the borrow area to the nourishment site, and the limited number of capable dredging contractors. There can be large uncertainties when forecasting beach nourishment dredging and placement costs. Recent dredging contracts (2002-2009) for nourishment efforts in New Jersey and Delaware (Gebert, 2010) can account for 10% to 60% of the total winning bid, and average mobilization and demobilization costs are approximately $2 million per nourishment effort, regardless if it is an initial or periodic nourishment effort. The unit cost of sand over that same time period ranged from approximately $4 to $15/cy. Therefore, the preliminary analysis presented assumes dredge mobilization and demobilization costs of $2 million, and a conservative unit price of $15/cy for sand.

Since many strategies involve integration of projects with different remain authorized lifetimes, a 50-year time horizon is used for comparison purposes regardless of the remaining authorized project life. Use of a single standard time period allows direct comparison between various strategies across projects and for those involving initial construction costs and maintenance (O&M) costs.

Over a 50-year time horizon, the volume of sediment placed on the beach remains the same; however, there is a cost savings of $26 million based solely on the reduced number of nourishment events and mobilization costs. Additional cost savings may be realized from reduced contracting and management requirements.

Fewer periodic nourishment episodes will also have an environmental benefit since there will be less frequent disturbance (reduced by 2 times) of the offshore borrow site areas, reduced disturbance on the beaches, and reduced overall air and noise pollution.

Prior to implementing this strategy, evaluation of the storm damage protection impacts needs to be completed to ensure protection of the Cape May City area is not compromised by extending the periodic nourishment interval from two to four years. This strategy also may have some performance benefits due to a regional increase in the recurrent volume added to the system (presented in strategy B), perhaps resulting in potential improved project longevity and reduced periodic nourishment. In addition, based on the profile monitoring (Stockton State College Annual Reports), the nourishment has performed reasonably well, indicating a reduced periodic nourishment cycle may be feasible.

This strategy can be implemented at any time since existing authorities do not preclude re-nourishment from being done as part of one contract as long as the funds for each are available and not comingled. Further, requisite environmental clearances must be secured before award of a contract. Implementation of this strategy has minimal constraints; limited to availability of dredging equipment and borrow site quantities, which are already constraints of current operations.

Table 30 presents a summary of the criteria evaluated for the improved project coordination strategy and ranks this strategy as a high priority and easily implementable (Tier 1 level). This strategy should be pursued since the pathway to implementation is straightforward and there are no significant constraints.

Table 30. Cycle Synchronization Strategy Summary.

Criteria	Summary
1. Authorization	No existing authorization limitations
2. Constraints	No constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$26 million over 50-year time horizon
4. Service Life	Potential increase in project longevity and service life
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Evaluate potential storm damage impacts, coordinate dredging, and implement

B. *Feeder Beach Nourishment Effects*

As originally presented in the 1980 and 1983 General Design Memorandums (GDM), the Lower Cape May Meadows/Cape May Point (LCMM/CMP) and Cape May City (CMC) projects span the entire length of shoreline from Cape May Inlet to the Central Avenue groin at Cape May Point, and a single nourishment project could replenish the contiguous stretch (with varying berm width) of shoreline in this region. As such, consideration was initially given to a strategy geared towards formally aligning the federal authorizations of Lower Cape May Meadows/Cape May Point (LCMM/CMP) and Cape May City (CMC) projects, such that periodic nourishment of these projects always occurs at the same time. This would involve a more formal synchronization of projects that would combine the nourishment volumes, and align periodic nourishment efforts to create a single authorized project. The goal of this strategy is to reduce mobilization and demobilization costs, and provide better project performance.

The complex nature of this stretch of shoreline, including the change in shoreline orientation from CMC to CMP and the interaction of Cape May Point with the ebb and flood tidal currents of Delaware Bay, affects the behavior of the beach nourishment efforts. In addition, actual implementation of the authorized projects consisted of nourishment for only a portion of the Cape May City authorized length due to accelerated erosion at the U.S. Coast Guard Training Facility (no periodic nourishment sediment has been placed southwest of Wilmington Avenue since 1999). The periodic nourishment efforts at LCMM/CMP and CMC are not completed as originally authorized and have a significant spatial gap between actual placement locations. These factors likely make traditional assessment of the nourishment performance inapplicable for this stretch of shoreline. To assess the influence that the two nourishment projects may have on one another, two approaches were implemented. The first approach evaluated the nourishment interaction if the projects were nourished jointly (as authorized) to provide a preliminary assessment of the beach performance. The second approach evaluated the nourishment interaction based on the recent (last 20 years), actual periodic nourishment efforts. Both approaches are idealized and represent simplified estimates of the performance and interaction of the LCMM/CMP and CMC periodic nourishment efforts.

Both assessment approaches use an analysis that combines the conservation of sediment equation with the linearized transport equation. This formulation, called the Pelnard-Considére (1956) equation (Equation 4), is used to obtain theoretical results to establish design and performance standards for the nourishments. A more detailed description of the derivation of the equations and their applications can be found in Dean (2002).

Equation 4:

$$M(t) = \frac{2\sqrt{Gt}}{l\sqrt{\pi}}\left(e^{-\left(\frac{l}{2\sqrt{Gt}}\right)^2} - 1\right) + erf\left(\frac{l}{2\sqrt{Gt}}\right)$$

where *M(t)* is the proportion of sand remaining in the placed location, G is the alongshore diffusivity parameter, t is time, and l is the project (nourishment) length. The alongshore diffusivity (Equation 5) is presented by *Pelnard-Considére* (1956).

Equation 5:

$$G = \frac{KH_b^{5/2}\sqrt{g/\kappa}}{8(s-1)(1-p)(h_* + B)}$$

where K is the sediment transport coefficient, which is a function of sediment size, B is the berm elevation, H_b is the breaking wave height, h_* is the depth of closure, p is the *in-situ* sediment porosity (approximately 0.35 to 0.40), s is the sediment specific gravity (approximately 2.65), and κ is the ratio of wave height to water depth within the surf zone (approximately 0.78).

The *Pelnard-Considére* equation can be applied to determine the performance of a beach nourishment project. For example, Figure 84 presents the spreading of an idealized, rectangular nourishment. Although simplified, this example illustrates the planform view of nourishment dispersion. Figure 84 contains a series of lines depicting the temporal planform evolution of this example rectangular nourishment. The resulting planform is symmetrical about the centerline of the nourishment. Therefore, only one-half of the resulting planform is shown in Figure 84. The solid black line indicates the initial fill template, and subsequent lines indicate the temporal dispersion of the nourishment. The vertical axis indicates the nourishment width (or distance seaward from the original shoreline), while the horizontal axis indicates the alongshore distance from the center of the nourishment. Within 1-year of nourishment placement, the shoreline excursion at the center of the project has already retreated over 100 ft (in this simple example, the starting nourishment was 350 ft), as sand has been transported in both directions due to the perturbation created on the shoreline. As shown by the lines corresponding to temporal changes in fill, the material diffuses onto the adjacent shorelines and is not lost from the local system.

(1.1-1)

For this analysis, the Wave Information Study (WIS) time series of wave and wind data, developed by the United States Army Corps of Engineers, were used to describe the wave climate offshore of New Jersey. The WIS, performed by the USACE, has met a critical need for wave information in coastal engineering studies since the 1980s, and is widely accepted for design purposes for United States shorelines by coastal engineers and scientists (http://wis.usace.army.mil/). WIS contains time series information of spectrally-based, significant wave height, peak period, peak direction, and wind speed and direction produced from a computer hindcast (prediction) model. The hindcast wave model, WISWAVE (Resio and Tracy, 1983) is simulated using wind information (speed and direction) at selected coastal locations around the United States. Wave measurements made by NOAA during the 1980s made verification of the WIS results possible by comparing the statistics and the distributions of modeled and measured wave heights and periods from different time periods (Hubertz et al., 1993). The availability of long-term records makes WIS data attractive when considering average or seasonal wave conditions. Twenty years of wave hindcast data from WIS station 63152 were used for analysis of the Cape May City and Lower Cape May Meadows nourishment.

Since the offshore wave environment can be complex, calculation of the alongshore diffusivity was based on the wave energy distribution for average annual directional approach bins. Data were segregated by direction of approach and an energy distribution, as a function of frequency, was generated from the waves in each directional bin. The energy associated with each frequency was then summed to create an energy distribution for each approach direction. A representative two-dimensional spectrum was generated for each approach direction bin based on the sum of the waves approaching from that mean direction. This was combined with the percentage of occurrence to create a 20 year evaluation of wave impacts at the shoreline. This energetic directional bin approach has been successfully utilized in transformation modeling (Byrnes et al., 2000) and identifies a range of potential approach directions, including those that occur only a small percentage of time during a typical year, but potentially impact sediment transport. Values of alongshore diffusivity were computed for each directional bin and used for modeling beach nourishment performance.

Since the material spreads over time, it is possible to evaluate the longevity of the nourishment by looking at the amount of material left in the project area. Subsequently, nourishment alternatives can be compared based on longevity. The service life of the beach nourishment can be based upon the percent of initial beach nourishment left within the boundary of the initial fill. The percentage remaining will decrease with time, but material is not lost from the system; it has spread to regions outside of the original nourishment template. Although the sediment no longer falls within the initial nourishment template, it has not disappeared from the littoral system.

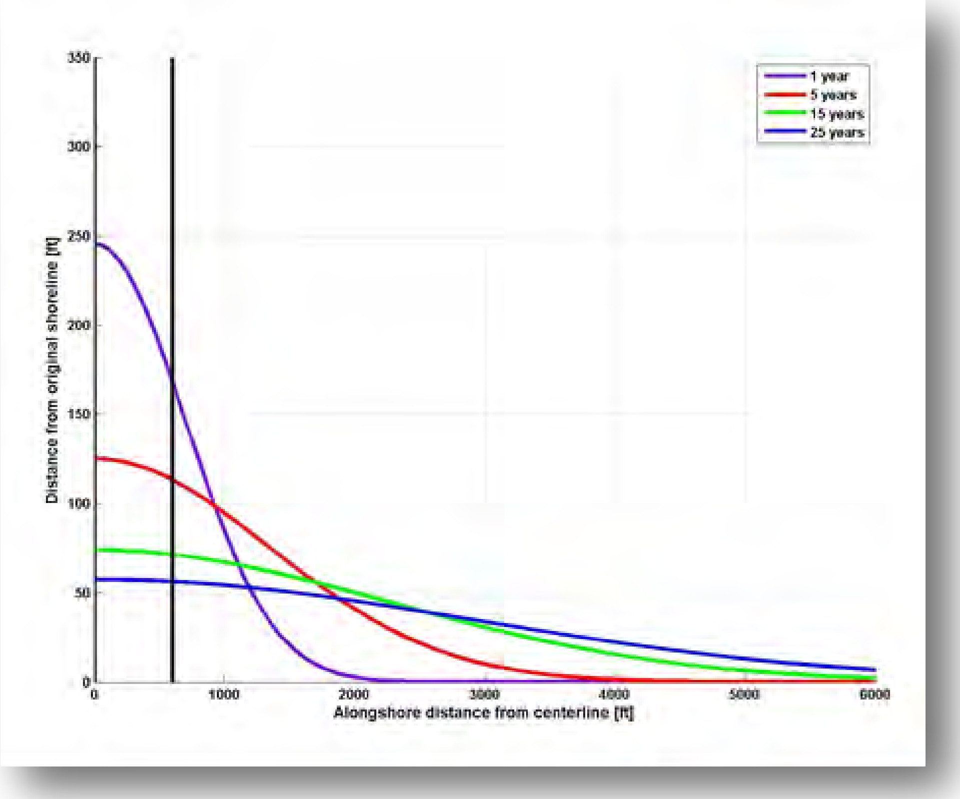


Figure 84. Temporal evolution of an example, idealized, rectangular beach nourishment project. Since the nourishment spreading is symmetrical in this simple case, only half the fill distance is presented.

Using the first idealized approach (assuming the projects were renourished at the authorized volumes, intervals, and distances to represent a contiguous nourishment), Figure 85 presents the performance of the authorized projects for Cape May City, Lower Cape May Meadows, and a combined nourishment scenario that would nourish both projects simultaneously. Performance is expressed in terms of amount of material remaining in the initial template region, as a function of time, for project lengths corresponding to the Cape May City (black line), Lower Cape May Meadows and Cape May Point (green line), and a combined nourishment (blue line). Results were adjusted to include a background erosion rate corresponding to the historical performance of the nourishments at Cape May City. In addition to dispersion, an additional amount is eroded due to natural erosion. The percent of initial material remaining is presented along the left hand axis, while the time in years is presented along the bottom axis. After 2 years, approximately 74% and 64% of the initial fill volume is remaining for Cape May City and Lower Cape May Meadows, respectively. For an idealized combined nourishment (blue line), approximately 85% of the initial fill volume remains if the projects were constructed together. This represents a potential significant improvement in project performance. The increases in the percent remaining after 2 years (CMC) and 4 years (LCMM/CMP) represent the authorized periodic nourishments.

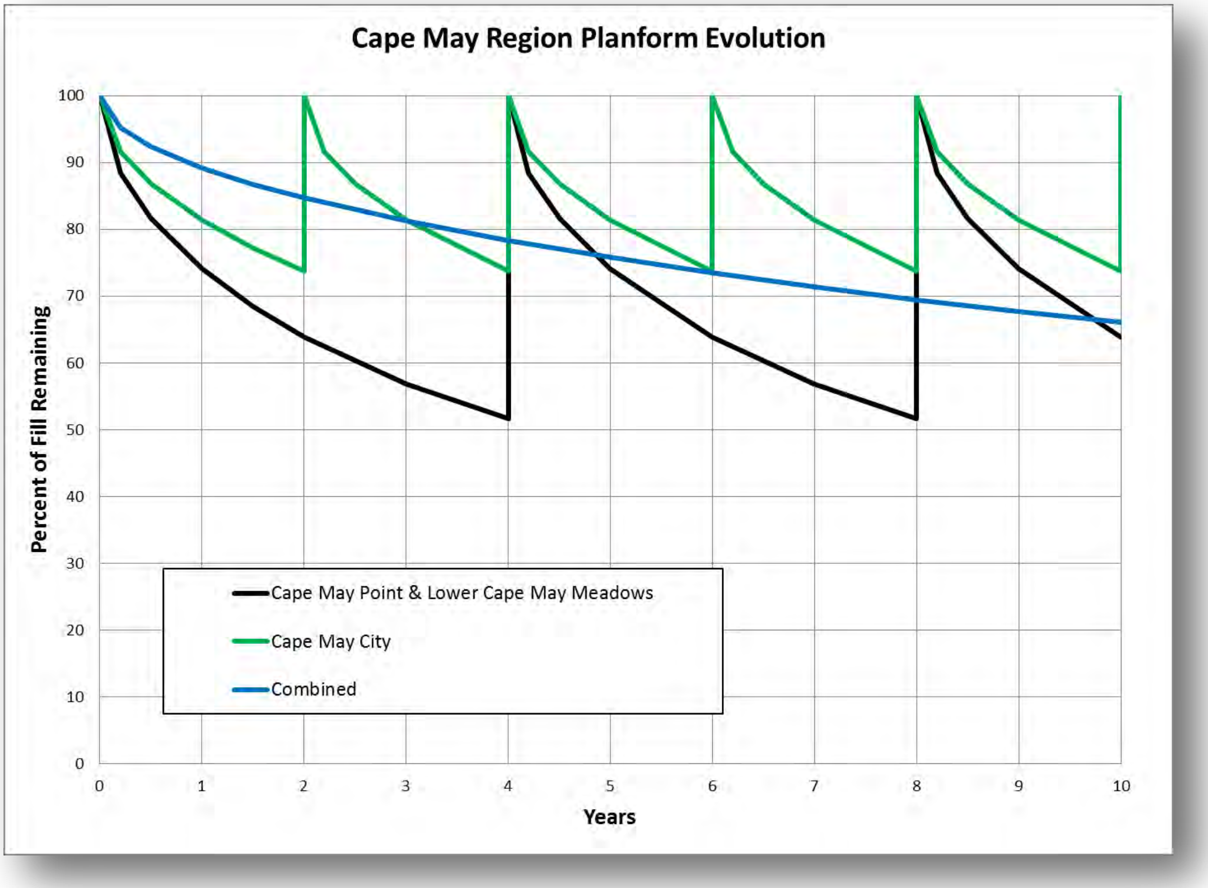


Figure 85. Estimated beach nourishment performance for the authorized projects at Cape May City and Cape May Point/Lower Cape May Meadows, as well as for combination of the two projects. This analysis assumes the projects were constructed as authorized.

Currently, the Lower Cape May Meadows project has a 4 year periodic nourishment cycle, while the Cape May City project has a 2 year periodic nourishment cycle. Nourishment cycles would need to be re-adjusted to result in a combined project. Analysis indicates through combining the projects, the Cape May City periodic nourishment cycle should be able to be extended to four years, and possibly even 6 years. For example, after four years, the combined project indicates approximately 78% of the material would remain in the template area. This is more remaining than at two years (approximately 74%) for the Cape May City alone nourishment. Theoretically, the larger combined nourishment would make it feasible to increase the periodic nourishment interval.

As discussed, the actual periodic nourishment efforts for the Cape May City (CMC) project have not followed the originally has authorized layout. Actual implementation of the authorized CMC project consisted of nourishment for only a portion of the authorized length. Due to accelerated erosion at the U.S. Coast Guard Training Facility, no periodic nourishment sediment has been placed southwest of Wilmington Avenue since 1999. While the periodic nourishment has been required for a portion of the CMC area, the borough of Cape May City and area southwest of Wilmington Avenue has not needed to be nourished as expected. Figure 86 shows the cumulative volume of periodic nourishment added to CMC since 1993 (blue line) and the authorized cumulative volume of periodic nourishment (green line) over the same time period. Since approximately 2002, the actual nourishment placed has decreased and the periodic volumes are less than the authorized amount. For example, the expected nourishment in 2013 is only 139,000 cy, significantly less than the authorized 360,000 cubic yard amount. Since the nourishment efforts since 1999 have been in the Coast Guard Training area directly adjacent to Cape May Inlet, the periodic nourishments may be acting as a feeder beach by delivering sediment to the downdrift shorelines. In other words, the successive periodic nourishment efforts may be successfully stabilizing the downdrift beaches by providing sediment to the remaining CMC authorized area and the LCMM/CMP authorized area.

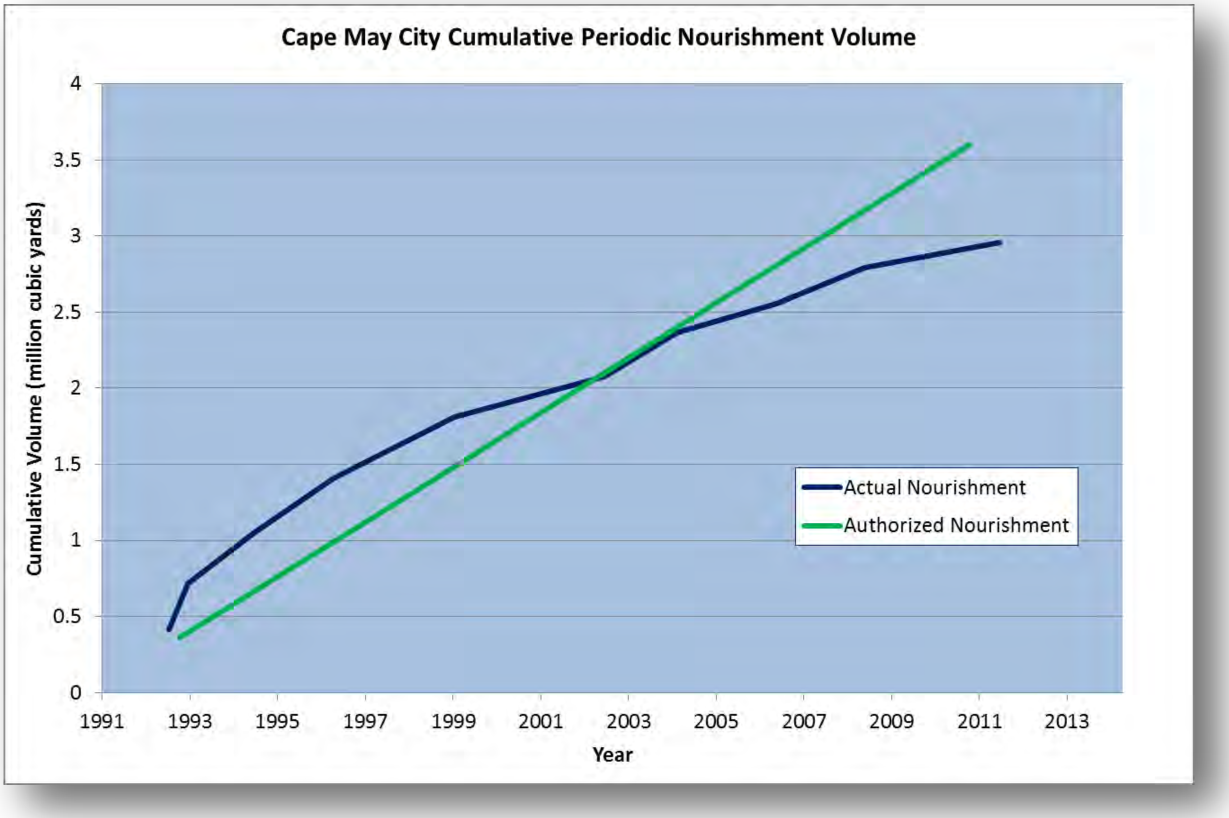


Figure 86. Actual and authorized cumulative volume of periodic nourishment added to Cape May City area.

The second approach to evaluating the interaction between the CMC and LCMM/CMP projects assessed cumulative effect of the CMC periodic nourishments and the ability of the CMC nourishment to reduce the periodic nourishment needs at LCMM/CMP. Figure 87 an idealized planform representing the shoreline from Cape May Inlet (zero on the horizontal axis) to the Central Ave. groin at CMP. The vertical axis shows beach berm width in feet. The blue line represents the approximate berm width increase after the placement of periodic nourishment at both CMC and LCMM/CMP. The periodic nourishment is assumed to be placed at the U.S. Coast Guard Training Facility (using it as a feeder beach) and Lower Cape May Meadows and Cape May Point, and placing no additional sand at Cape May City. This represents the placement approach for renourishment material since approximately 1999. The subsequent lines indicate the expected dispersion of the berm width as a function of time (years following the periodic nourishment). Figure 87 shows the evolution of one periodic nourishment, and does not show any subsequent periodic nourishments, to more easily assess dispersion of material throughout the domain.

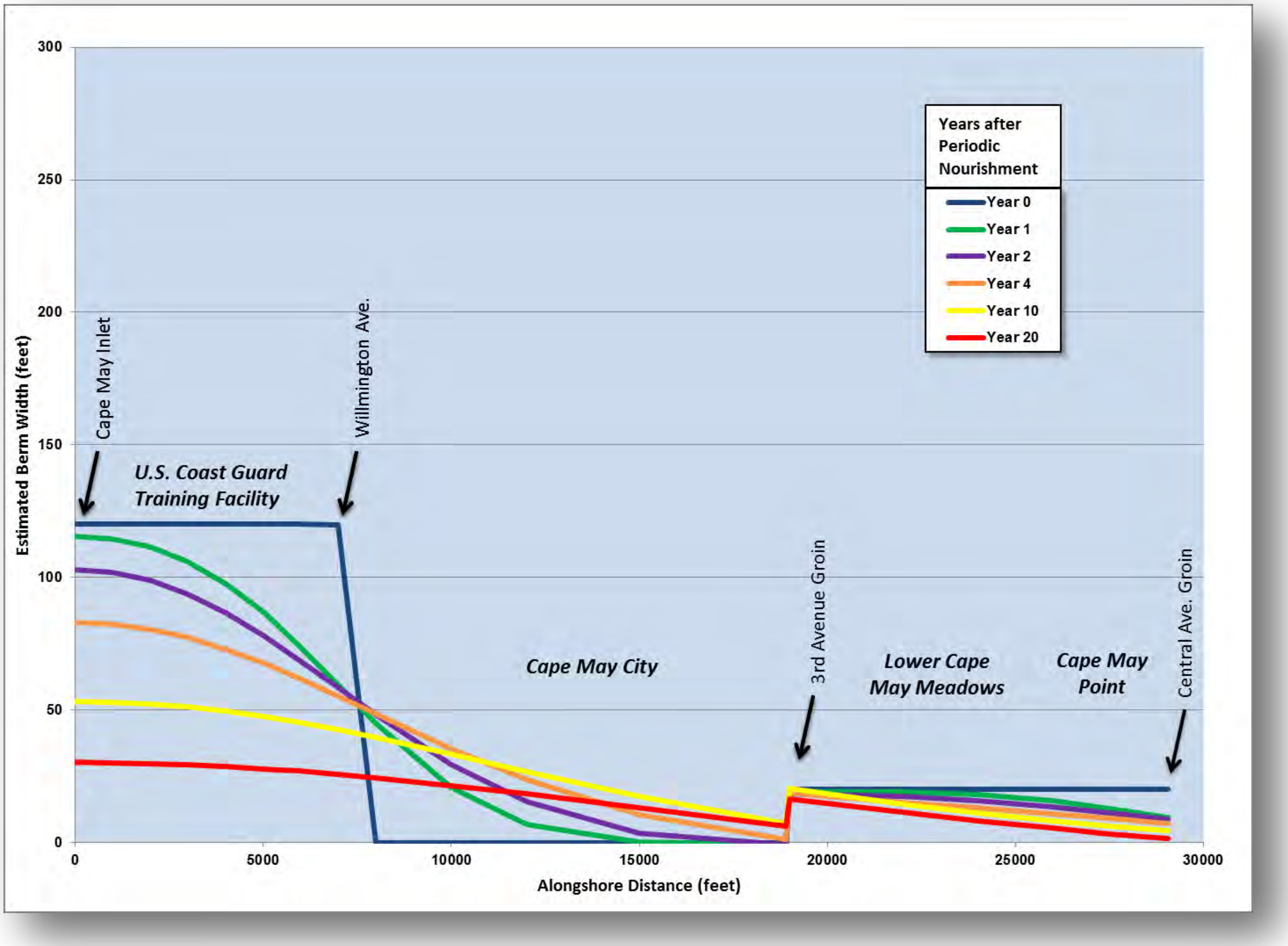


Figure 87. Spreading of a single periodic nourishment at Cape May City and Lower Cape May Meadows.

Under this scenario, the Cape May City region receives dispersed sediment from the U.S. Coast Guard Training Facility Area and increases in width between 15 to 50 ft. After approximately 4 years, sediment from the U.S. Coast Guard Training Facility area begins to disperse into the Lower Cape May Meadows area. This additional sediment slows the rate of erosion in this area, and reduces the periodic nourishment requirements for the LCMM region. The first periodic nourishment for the LCMM/CMP of only 139,000 cy (much less than the authorized amount of 650,000 cy) is scheduled to occur by March 2013 in selected areas of concern. Since the actual amount is less than expected, there appears to be influx of material from the ongoing nourishment efforts at Cape May City (2.9 million cy since 1993).

Figure 88 presents a similar analysis showing the same planform view and beach nourishment dispersion; however, Figure 88 also includes subsequent periodic nourishments at both CMC (every 2 years) and LCMM/CMP (every 4 years). Dashed lines show berm width before a periodic nourishment, while solid lines show after a periodic nourishment. Although not an exact representation of the actual periodic nourishment placements (which are likely varied based on need), this idealized case shows the general trend of the dispersion throughout the region and demonstrates the effectiveness of the feeder beach concept for both Cape May City and Lower Cape May Meadows. The results indicate after approximately 2 periodic nourishment events (4 years) at CMC, the required periodic nourishment for LCMM/CMP would be reduced, and after approximately 24 years no periodic nourishment would be required as long as CMC continues to be nourished and serve as a feeder beach.

Although this one-line modeling approach is a simplified analysis of beach nourishment performance, and its application may not be directly applicable to the complex nature of the LCMM/CMP region (which features a curved shoreline, groins, and the influence of tidal currents in and out of Delaware Bay, etc.), the analysis provides a preliminary assessment of the relative impacts of potential combined nourishments, cumulative effects, and feeder beach impacts. To ensure results of the preliminary analysis are reasonable, the volume of material predicted to be lost was compared to the periodic nourishment volume added over the last 20 years. Since 1993, the Cape May City project has lost approximately 20-25% of the total volume every 2 years based on periodic nourishment cycles. Assuming each periodic nourishment attempts to return the beach to the approximate original construction template, the modeled performance can be compared to this observed volumetric loss. Figure 85 indicates the Cape May City nourishment loses approximately 25% in the first two years after returning the template to 100%, and corresponds well to observed performance. The presented analysis represents a reasonable preliminary estimate of how the nourishment longevity may improve through various nourishment effects and approaches.

Using the same cost assumptions as presented in strategy A (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), the feeder beach effects would result in a cost savings of approximately $78 million over a 50-year time horizon due to reduced periodic renourishment with reduced volume. This continues the practice of periodic nourishment every 2 years of approximately 360,000 cy to return the nourishment to the original construction template at Cape May City, and reduced periodic nourishment through time for Lower Cape May Meadows. The analysis also assumes some material (approximately 40,000 cy) would be required every 4 years at Cape May Point due to the change in shoreline orientation and expected sediment loss due to tidal currents. Cost benefits of this strategy are compared to current operations and other strategies in the summary section. Additional cost savings may be realized from reduced contracting and management requirements.

The reduced number of periodic nourishment episodes and reduced long-term volume requirements will also have an environmental benefit since there will be less frequent disturbance of the offshore borrow site areas, reduced disturbance on the beaches of LCMM, reduced overall sediment needs (approximately 5 million cy less over 50 years) and reduced overall pollution (e.g., noise, air, etc.).

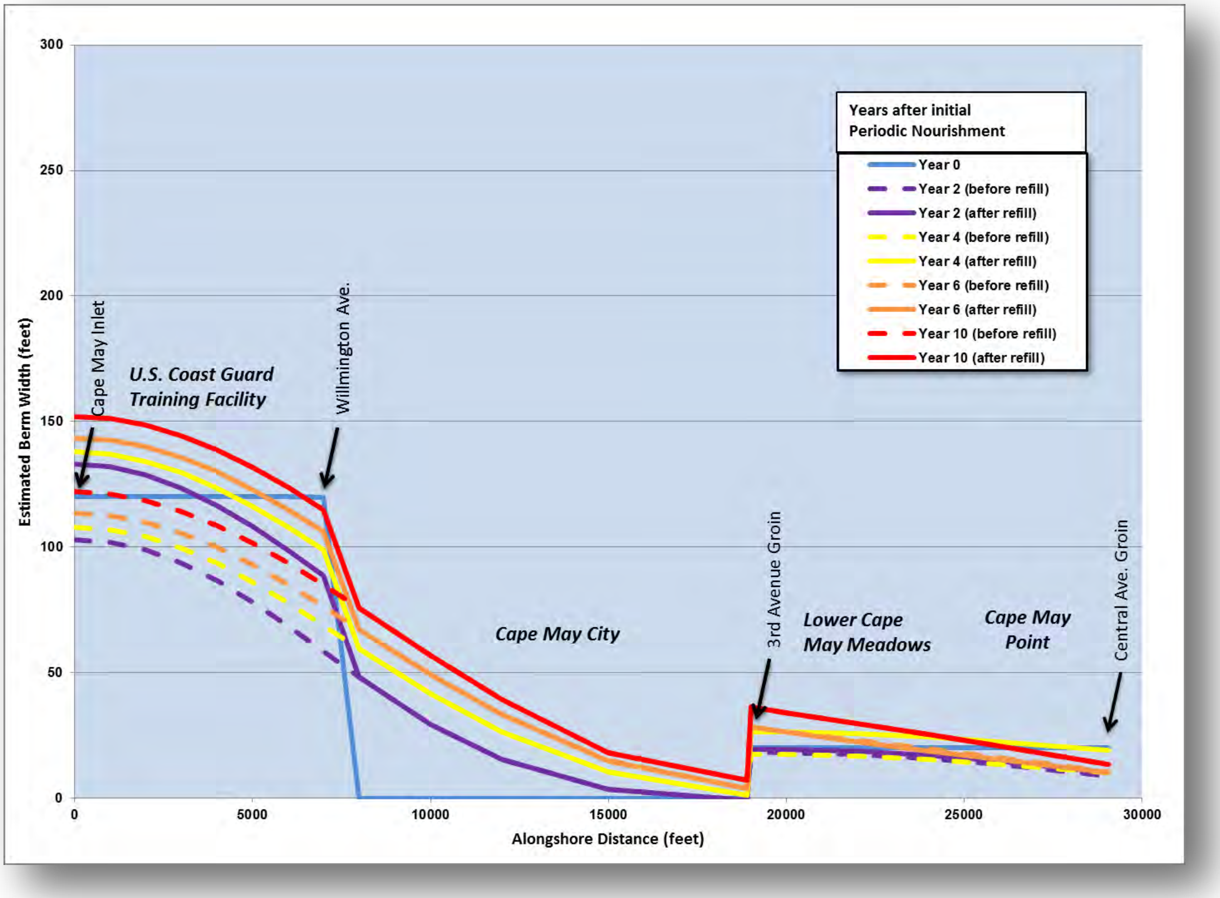


Figure 88. Spreading of periodic nourishments at Cape May City and Lower Cape May Meadows.

Based on the periodic nourishment history, this strategy is currently being conducted at a certain level by the Corps. Therefore, no new or modified authorization would be required to continue the current practices (feeder beach approach) for nourishment that are being conducted under the authorization. If the projects were to be formally combined, new construction authorization would be required since the combined projects may be different in scale than the individual projects. A new feasibility study would have to be performed to determine the extent of federal interest in a new plan and to address the environmental requirements of a new plan. There is also a significant potential that the cost sharing may change as a result of the new plan as well as the timing and amount of non-federal funds required. Borrow areas would have to be revisited and sufficient borrow sites identified and evaluated as part of the reanalysis. The study itself could be accomplished under the existing New Jersey shore study authority and would likely require a feasibility study cost sharing arrangement. Finally, if a project is recommended and authorized for construction, a new Project Cooperation Agreement (PCA) would have to be executed. If, however, the project templates remain the same scale as the currently authorized projects, it may be more reasonable to implement this approach in an informal synchronization (Strategy A) and achieve the same benefits.

Implementation of this strategy has minimal additional constraints, limited to availability of dredging equipment and borrow site quantities, which already are constraints of the current operations.

Table 31 presents a summary of the criteria evaluated for the feeder beach strategy and ranks this strategy as a high priority with a Tier level of 1.

Table 31. Feeder Beach Strategy Summary.

Criteria	Summary
1. Authorization	For continued implementation of the feeder beach approach, no authorization change is required. If a formal combination is considered, Depending on the exact nature of the combination or modification to the project scale, it is likely that a new construction authorization will be required.
2. Constraints	No additional non-authorization requirement constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$78 million over 50-year time horizon for feeder beach approach
4. Service Life	Relatively significant increase in project longevity and service life with reduced nourishment of downdrift beaches
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale and reduced overall volumetric sand requirements in long-term
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	If formal combination is sought, site-specific, detailed analysis of LCMM/CMP and CMC areas, including detailed beach nourishment dispersion analysis with sediment transport modeling.

C. *Beneficial Re-use of Cape May Inlet Dredge Material*

This strategy intends to beneficially use sediment dredged from the Cape May Inlet (Cold Springs) authorized navigational project for the Cape May City authorized shore protection project, and is in direct concurrence with the Regional Sediment Management Initiative.

Cape May Inlet, one of five federally authorized navigational projects along the NJ coastline, was stabilized in 1911 with two parallel rubblemound jetties approximately 4,500 ft long. Maintenance dredging of the inlet started in approximately 1919 and annual USACE reports provide information on the quantity dredged each fiscal year. Up until 1988, sediment dredged from the inlet was removed from the littoral system and deposited offshore. Since 1988, the USACE has maintained the channel using the sidecasting dredges the Merritt, Schweitzer, and Fry. Most of the work is conducted at a shoal near the entrance to the inlet inside the end of the southwest jetty. Typical sidecasting dredge quantities have been approximately 95,000 cy per year. In 1986-1988, and more recently (2005 and 2009) the USACE hopper dredge Currituck has maintained the channel, and placed sand west of the inlet in the nearshore zone (bar) of Cape May City.

To determine the average annual amount of material dredged from Cape May Inlet, the USACE annual reports were used to calculate the cumulative maintenance dredging completed prior to sidecasting practices, independent of location or sediment type. Sidecasting volumes were not included in the analysis, since this dredging does not remove sediment from the inlet. Figure 89 presents the cumulative sediment volume dredged from Cape May Inlet from 1918 to 1988. Each black dot in the figure represented a dredging event, and shows the cumulative volume dredged as a function of time. The blue line in the figure represents a linear fit to the data and provides an average dredge quantity of approximately 60,000 cy per year, consistent with earlier USACE studies of Cape May Inlet dredging (USACE EM 1110-2-1616, 1991). Historically, non-sidecasting dredge frequency has been every 2.2 years.

The more recent dredging in Cape May Inlet, primarily completed by sidecasting, consists of a greater volume (approximately 95,000 cy/yr) and increased frequency (approximately twice a year) than historic dredging. This is likely due to the side casting methodology, which does not remove sediment from the inlet. Tidal currents redistribute material relatively quickly and return it to the navigational channel. At the same time, the limited, recent hopper dredging events (in 2005 and 2009) only dredged an average of 26,000 cy, likely due to the much more frequent sidecast dredging distributing shoaled sediment throughout the inlet.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this strategy would result in a cost savings of approximately $45 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments. This assumes periodic nourishment is conducted as every 2 years for Cape May City. This analysis also assumes that:

- the historic rate of 60,000 cy/yr and frequency (every 2 years) of dredging at Cape May Inlet continues;
- the dredged material is beach compatible;
- the dredged material can be placed in the littoral zone or directly on the beach, such that adequate storm damage protection can be provided; and
- any incremental cost of placing the material on the beach is relatively insignificant, since periodic nourishment would be required concurrently with the inlet dredging to supplement the needed quantity of material.

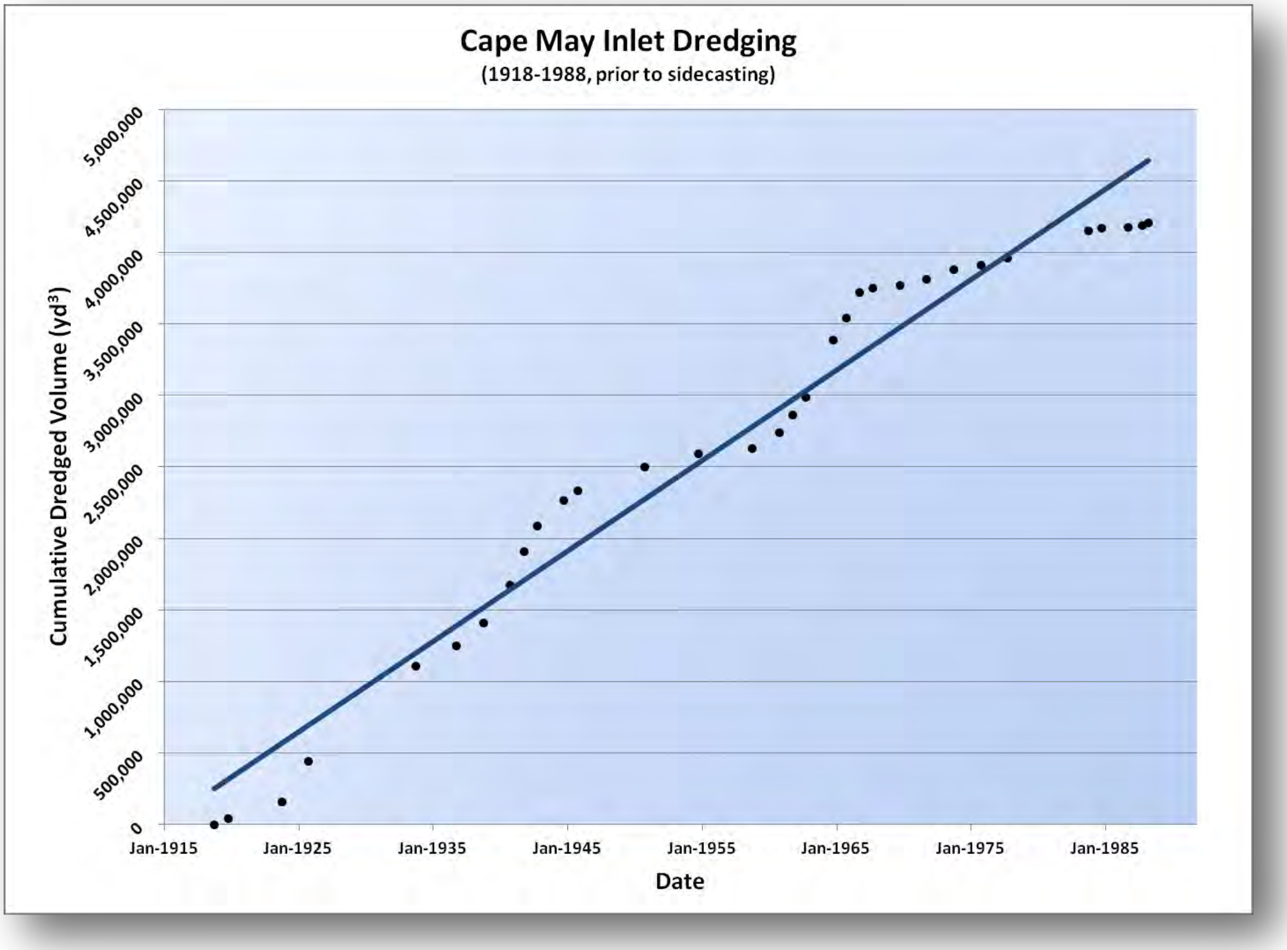


Figure 89. Cumulative dredge volume extracted from Cape May Inlet from 1919 to 1988.

This strategy reduces the overall offshore borrow site sediment needs (approximately 3 million cy less over 50 years) and provides interagency team building while supporting the overall RSM initiative.

There are two pathways to implement this strategy assuming the dredged material is suitable for direct placement on the beach. The first would involve developing a beneficial re-use project using the Cape May City authorities for implementation. However, the authority to construct the project does not include a provision for this type of beneficial reuse. As such, it would likely have to be modified to include this, and the project cost sharing adjusted to reflect a new purpose. Documentation would have to be developed to accomplish this, as well as a new PCA reflecting today's model agreement would have to be negotiated and signed. The second way to implement this is through existing Cape May Inlet navigation project authorities. Under the existing authorities, if the material is suitable, the federal government could request the material be placed directly on the beach. Permits are required to do so, but they can be obtained under the authorized navigation project. If there is a cost differential to the navigation project, the State would likely have to pay the difference.

Implementation of this strategy has limited additional constraints; however, sediment compatibility of the Cape May Inlet dredge material has to be determined. Previous investigations revealed that overdredging areas may not be feasible due to poor sediment quality at depth, although regular shoaled material should be of good quality. This may also be complicated by the fact that dredged material may be of varying compatibility levels. For example, the shoal near the inlet entrance may be compatible, while the material closer to the Harbor region may be of more mixed compatibility with finer grain sediment. Incremental dredge cost increases would need to be determined.

Table 32 presents a summary of the criteria evaluated for the beneficial re-use of the Cape May Inlet strategy and ranks this strategy as a high priority with a Tier level of 2. As long as dredged sediment is compatible for beach nourishment or nearshore placement and the quantity of dredging remains approximately the same as historic levels, this strategy should be further pursued since it is directly in line with RSM strategies and initiatives. Additionally, every effort should be made to coordinate inlet dredging (navigation project) with the periodic nourishment (shore protection project) to minimize dredge mobilization costs.

Table 32. Beneficial Re-use Strategy Summary.

Criteria	Summary
1. Authorization	Implement under federally-authorized navigational project
2. Constraints	Questionable sediment compatibility in some areas, incremental cost increases for dredge material placement
3. Cost Savings	$45 million over 50-year time horizon
4. Service Life	No change to existing service life of shore protection project or navigational dredging
5. Other Benefits	Reduced offshore sediment source requirements. Interagency and state team building, RSM initiative
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Evaluate sediment compatibility obtain permits for placement of dredged material on beaches

D. Sediment Bypassing of Cape May Inlet

This strategy would involve implementation of sediment bypassing methodology to move sediment from the northerly updrift beaches and jetty fillet region of Cape May Inlet to nourish beaches downdrift of the inlet. A number of previous studies evaluated conceptual designs and methodologies for bypassing sediment around Cape May Inlet (USACE, EM 1110-2-1616, 1991; U.S. Army Engineer District, Philadelphia, 1987; USACE, 2004). The Phase I General Design Memorandum (USACE, 1980) indicated the updrift fillet of Cape May Inlet should be considered for periodic nourishment of Cape May City. Therefore, sediment bypassing of Cape May Inlet has been considered a potential option for decades, but has yet to be implemented or demonstrated.

Various bypassing alternatives have been considered at a conceptual design level and evaluated in preliminary analyses. For example, the Philadelphia District of the U.S. Army Corps of Engineers (2004) evaluated a fixed bypass plant, a floating dredge plant using Cape May fillet sediment, and a floating dredge plant using Wildwood Beach sediment. Previous studies (USACE, EM 1110-2-1616, 1991) also evaluated a fixed bypass plant and dredge adjacent to the updrift Cape May Inlet jetty.

For this preliminary analysis, it is assumed that a semi-mobile bypass system would be installed to bypass sand around Cape May Inlet. Additional alternatives (e.g., a floating dredge plant) should also be considered in a more detailed analysis of potential bypassing approaches. In this preliminary analysis, a sediment bypassing plant (similar to the system operated at Indian River Inlet in Delaware – see Figure 90) is considered as a baseline approach to bypassing. The USACE Philadelphia District (2004) developed an initial cost estimate for a fixed bypass system. The cost estimate included initial construction costs, Operation and Maintenance (O&M) costs for the sand bypassing plant, Engineering and Design (E&D) costs, Construction Management (S&A) costs, as well as a contingency factor. Detailed breakdown of the cost estimate can be found in USACE (2004). These values were used in the current analysis as well, with a 3% annual inflation factor applied, and are intended to provide a first-order estimate of cost impacts:

- An initial construction cost of $6,345,000 for the fixed bypass plant
- O&M costs of $613,000 annually. Bypassing efforts would take place from September to April, 5 days per week, 6 hours per day, bypassing between 150,000 – 180,000 cy/yr.
- Replacement of the pump system every 12-13 years at a fixed cost of $600,000
- Refurbishing/replacement of the system at year 25 for $6,345,000

This strategy would result in a cost savings of approximately $122 million over a 50-year time horizon, assuming approximately 150,000 - 180,000 cy of sediment is bypassed each year to match the authorized periodic nourishment cycle. The cost savings does not include additional savings realized due to reduction in dredging requirements of Cape May Inlet. Navigational dredging requirements would be reduced due to the bypassing of material.

Figure 90. Indian River Inlet, Delaware fixed bypassing system (Photo courtesy of Tony Pratt, DNREC).

Based on the recent sediment budget completed for the New Jersey coastline (USACE, 2004), as well as the Cape May Inlet sediment budget completed as part of this feasibility report (Cape May Inlet authorized navigational project), it is expected there will be adequate sediment available updrift of Cape May Inlet for bypassing. If additional sediment is needed in the bypassing region, sediment forepassing (via truck or other methods) from the Wildwood area (that has a surplus of sediment that has become problematic) to the area updrift of Cape May Inlet could be considered to manually assist the natural littoral processes and provide additional material for bypassing.

In addition to the more cost-effective periodic nourishment of Cape May City and the USCG Training area, this strategy provides additional benefits, including, but not limited to:

- Reduced reliance on deleted, permitted offshore borrow sites.
- Minimizing environmental impacts to offshore borrow sites.

- Promoting RSM approach through appropriate redistribution of sediment already in the littoral system.
- Reduced navigational dredging of Cape May Inlet.
- Reduced sediment surplus at Wildwood, which may assist in alleviating clogged storm water outfalls, beach access length, and ponding of water in low–lying berm regions.
- Improved stakeholder relations and community team building.

The authorization for the Cape May City Shore Protection Project does include a specific authority to bypass sediment. In addition , it may be possible to use the existing federal navigation project at the inlet to address whether bypassing sand significantly alters the maintenance of the inlet and is cost effective. While there is a cost share associated with the shore protection project, since the maintenance responsibility is all federal, the possibility should be investigated that no new cost sharing or PCA would be required. Additionally, rather than attempt to change the CMC shore protection authority, value engineering could be applied to determine the effectiveness of bypassing at reducing the long-term nourishment costs compared to the sediment bypassing implementation cost. The long-term maintenance of such a facility (e.g., fixed bypass plant) would likely be the responsibility of the non-federal sponsor, although it may be possible to make it a shared cost (similar to the project itself).

However, prior to implementation, environmental clearances would be required. The property immediately updrift of the Cape May Inlet jetties is occupied by the U.S. Coast Guard; however, the property directly to the north of the Coast Guard is managed by the U.S. Fish and Wildlife Service as a National Wildlife Refuge. This property has strict regulations, and may be impacted by extraction of the fillet for bypassing. There is endangered piping plover nesting habitat with the Coast Guard property areas. Impacts and potential mitigation for this sensitive area would need to be evaluated in more detail prior to obtaining permits for project implementation.

Table 33 presents a summary of the criteria evaluated for the sediment bypassing strategy and ranks this strategy as a high priority with a Tier level of 2. This strategy should be further pursued, as long-term cost savings are significant, other benefits are considerable (e.g., reduce or eliminate dependence on offshore sediment sources, reduce sediment surplus at Wildwood, etc.), and the approach takes advantage of beach compatible sediment already in the system. Next steps would involve a more detailed study of potential impacts caused by fillet extraction on adjacent beaches, finalization and design of a demonstration project, and determining the right authorization approach and pathway to implement the bypassing project.

Table 33. Sediment Bypassing Strategy Summary.

Criteria	Summary
1. Authorization	May reduce maintenance requirements of Cape May Inlet navigational project making authorization less problematic. Additionally, value engineering could be applied to implement
2. Constraints	Significant environmental questions remain (e.g., endangered species habitat). Need to check sediment compatibility
3. Cost Savings	$122 million over 50-year time horizon, plus reduced maintenance dredging costs of Cape May Inlet
4. Service Life	No change to existing service life of shore protection project; however, reduced navigational dredging requirements of Cape May Inlet
5. Other Benefits	Eliminate offshore sediment source requirements and environmental impacts. Improved management of sediment in littoral system. Reduced sediment surplus at Wildwood. Improved stakeholder relations. Reduced maintenance dredging, etc.
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	More detailed study of potential impacts caused by fillet extraction. Finalize and design project. Use existing authorization for construction.

E. Optimization of Nearshore Berm Placement

Recently (2005 and 2009), material dredged from Cape May Inlet was placed in a nearshore berm offshore of the Cape May City area expecting the sediment to naturally migrate onshore and serve as a feeder berm/bar to the beach. This strategy involves potential expansion of this process with future dredged material. The placement of dredged sediment in a nearshore berm/bar, rather than directly on the beach, was performed due to the lack of pump out capabilities of the *Currituck*. Monitoring of this placement has been limited, and initial assessment indicates it has not had any significant benefit on the Cape May City project performance (Gebert, 2011).

The analysis of the strategy is geared towards determining if the potential placement of dredged material in a nearshore berm/bar is worth pursuing further by better quantifying the potential success of the nearshore berm/bar actively feeding the beach. Active sites occur where sustained shoreward migration of the nearshore berm/bar results in landward dispersion of the placed sand, as well as beach accretion. Stable sites show a low potential for shoreward transport and do not actively feed the beach; however, the beach may benefit from reduced wave energy as the nearshore berm/bar serves to attenuate incoming waves. Long-term near-bed velocity (u_{dmax}) distributions following the method of Hands and Allison (1991) were used to classify the sites as stable or active using Equation 6.

Equation 6:

$$u_{dmax} = \pi \frac{H}{T} + \sinh \frac{2\pi d}{L}$$

where WIS wave hindcast data (station 63152) were used to include the effects of wave height (H), length (L), period (T), and water depth (d). These wave data were transformed to the approximate location of the nearshore placement site. The long-term near-bed velocities (u_{dmax}) were then calculated and ranked from highest to lowest. Hands and Alison (1991) determined from monitoring of real world berms that near-bed velocities at the 75th percentile in excess of 40 cm/sec, or velocities at the 95th percentile in excess of 70 cm/sec can be used to classify sites as active. Velocities below these thresholds were indicative of stable berm sites.

Figure 91 presents the results, with the near-bed velocities presented on the horizontal axis and the exceedance probability presented on the vertical axis. In this case, the 75th percentile is 37 cm/s, while the 95th percentile is 68 cm/s. Therefore, the nearshore berm/bar at Cape May Inlet is considered stable, and would not be expected to migrate naturally onshore. In addition, this analysis did not consider the wave sheltering that likely occurs from the Cape May Inlet jetties, which would reduce the mobility of the nearshore berm/bar, further decreasing the likelihood of onshore migration. It appears unlikely this strategy is viable for any significant performance gains or cost savings related to the shore protection project at Cape May City.

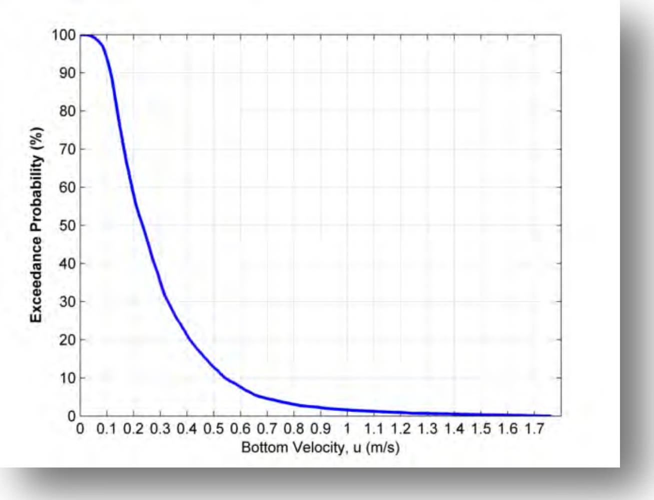


Figure 91. Nearshore berm stability analysis for Cape May City region using WIS data at station 63152.

If this strategy was to be pursued further, a more detailed study of potential nearshore placement could be accomplished under value engineering of the project. If the practice proves cost effective and reduces long term nourishment requirements then implementation would require requisite environmental clearances.

Table 34 presents a summary of the criteria evaluated for the nearshore berm placement strategy and ranks this strategy as a low priority with a Tier level of 1. This strategy is not recommended, as the historic placement has not proven effective and the technical analysis presented herein does not indicate reasonable chance for success. If monitoring of nearshore berm/bar placements indicates that the berms/bars are successful at other coastal locations (as monitored by ERDC), then this strategy could be re-visited in the future.

Table 34. Optimization of Nearshore Berm Placement Strategy Summary.

Criteria	Summary
1. Authorization	Implementable under value engineering with appropriate environmental permits
2. Constraints	Nearshore berm placement has been completed in the past, so limited to no constraints
3. Cost Savings	Neutral
4. Service Life	No change to existing service life of shore protection project or navigational dredging
5. Other Benefits	Minimal
6. Priority	Low
7. Tier Level	Tier 1
8. Next Steps	Wait and re-evaluate nearshore berm performance in other areas (USACE ERDC)

F. Offshore Borrow Area Expansion or Establishment

As presented in Table 29, sediment sources for initial construction of the Cape May City project, as well as most of the periodic nourishments have been offshore borrow sites. Currently, the permitted offshore borrow sites are nearly depleted and the most recent periodic nourishment material source was upland. Unless sediment needs of the shore protection project cane be reduced (e.g., beach nourishment performance is enhanced), or alternative sediment sources are utilized (e.g., bypassing, inlet dredge sediment, etc.), additional offshore borrow location will be required.

This strategy is not specifically geared towards providing a cost savings, but rather at maintaining current operations costs since upland sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., track traffic, road repairs, time of construction, etc.).

Over a 50 year time horizon, the remaining periodic nourishment sediment needs at Cape May City are approximately 9,000,000 cy, and at nearby Lower Cape May Meadows and Cape May Point are 8,125,000 cy. These two projects have shared offshore borrow sites in the past, and would likely be able to share new borrow sites in the future. Overall, the LCMM/CMP and CMC projects require approximately 17,125,000 cy over a 50-year time horizon.

The original offshore borrow site (M1) for the Cape May City authorized shore protection project has been depleted. Additional sites in the area (borrow locations 4 and 5) used for the Lower Cape May Meadows and Cape May Point nourishments have limited material remaining (approximately 400,000 cy). Recently permitted borrow area K contains approximately 10.7 million cy (if dredged 15 ft in depth). As such, there is a deficit of approximately 6 million cy for the combined CMC and LCMM/CMP projects. If the Cape May Inlet is used as an additional sediment source (approximately 3 million cy over 50 years), there remains a deficit of approximately 3 million cy for the reach.

Continued expansion of existing sites or searches for new borrow sites is needed for this region. For example, the Area K extension area should be considered (as additional 7.5 million cy with a dredge cut of 15 ft). Potential searches in Federal waters also may be warranted through cooperation with the Bureau of Ocean Energy Management (BOEM).

This strategy can be accomplished under the existing project authorities as the provision of borrow areas for the life of the project is part of the authorization. It would require cost sharing likely at the same level as the project. Appropriate studies and environmental clearances would be needed.

The primary constraints with expansion or establishment of offshore borrow sites are environmental. Establishing offshore borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Analyses of impacts to wave and sediment transport processes also are needed. The physical and environmental delineation would add cost; however, once permitted, the construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 35 presents a summary of the criteria evaluated for the offshore borrow area expansion and establishment strategy and ranks this strategy as a high priority with a Tier level of 1. This strategy should be pursued in advance of potential need, so new borrow areas are established for future use. Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted offshore sites available if needed for storm events or unforeseen circumstances is essential. Next steps for this strategy would be to initialize studies and surveys needed to expand or establish new borrow sites for this region, which has a known deficit and coordinate

with BOEM for any potential federal waters borrow sites.

Table 35. Offshore Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Initiate studies and surveys. Coordinate with BOEM

G. *Refine Beach Nourishment Template*

This strategy involves applying adjustments to the authorized beach nourishment template at Cape May City to determine if modifications to the template may result in increased performance or improved storm damage protection. A successful beach nourishment project consists of more than simply placing sediment on a beach. Beach nourishment projects are engineered. A beach nourishment template, which consists of numerous design parameters, is based on the characteristics of the site and the needs of a project. Every beach nourishment design is unique, since different beaches in different areas have different physical, geologic, environmental, and economic characteristics, as well as different levels of required protection. The design must consider climatology, the shape of the beach, type of native sand, volume and rates of sediment transport, erosion patterns and causes, waves and water levels, historical data and previous storms, probability of certain beach behaviors at the site, existing structures and infrastructure, and past engineering activities in the area.

A nourishment template is designed to yield a protective barrier that also provides material to the beach. A higher and wider beach berm is designed to absorb wave energy. Dunes may need to be constructed or existing dunes improved to reduce damage, including potential upland flooding, from storms. Figure 92 depicts a beach berm and dune on a typical beach profile. Nourishment length, berm height and width, dune height, and offshore slope are critical elements of a beach nourishment design. Periodic nourishment intervals are also usually a part of the nourishment design. The renourishment interval will vary based on the initial design, wave climate, sand used, frequency of storms, and project age. In addition, beach nourishment is not an exact science; variables and uncertainties exist. Actual periodic nourishment intervals may differ from planned intervals based on conditions at the nourished beach and frequency and intensity of storms.

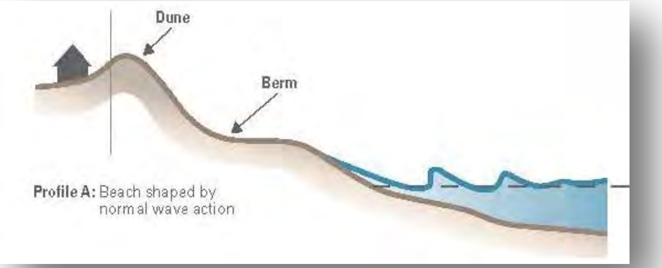


Figure 92. Typical beach profile and features (from Coastal Engineering Manual, 2003).

This proposed strategy evaluates potential improvements to project performance, storm damage protection, and subsequent cost savings realized by modifying currently authorized beach nourishment template.

Feasibility studies for authorized projects typically evaluate a range of proposed beach nourishment template designs using alongshore and cross-shore analysis and/or modeling efforts to assess performance and storm damage protection afforded. USACE policy has been to not consider increases to the natural berm elevation for the design template or to see if changes to the natural berm height result in performance gains or improved storm damage protection. Additionally, the currently authorized design template has not been re-evaluated following monitoring of the performance of the system. Monitoring data may lead to modifications to the template. This strategy involves assessing changes to the beach nourishment template that may yield cost savings over the long-term. An example of this type of analysis is presented herein by evaluating change in berm height and width on the performance of the CMC project.

Similar analyses could be completed for a number of parameters including:

- Nourishment length – Expanding the nourishment length, specifically through combining or syncing projects could be evaluated.
- Berm Width – The width of the berm could be modified to see if there is a cost benefit that could be attained. This also may involve a spatially variable berm width modification (e.g., overfilling the Coast Guard Training Area).
- Berm Height – The height of the berm could be modified to determine impact on storm damage protection.
- Offshore slope – The offshore slope of the nourishment can be changed.
- Grain size – The grain size of the source material for the nourishment may affect the performance of the projects. For example, coarser nourishment material may result in improved project performance (lower erodibility and hence more protection.

To assess potential changes in berm width and height at Cape May City, the computer model SBEACH (Larson and Kraus 1989) was used to assess cross-shore evolution. SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and further developed and verified based on field measurements (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990). The model predicts time-dependent evolution of existing or design beach and dune profiles for specified water levels and wave conditions. The model requires a time series of wave heights, wave periods and water levels as forcing inputs. The specific storm information required by SBEACH is a time history of total water level (tide plus surge) and wind wave height and period. The WIS hindcast information, FEMA FIS still water storm surge elevation, and extremal analysis were used to develop a simulated 10-year storm for this analysis.

Figure 93 presents results of varying the berm height (blue line) and width (green line) of the Cape May City authorized beach nourishment template. The horizontal axis shows percent of material eroded from the nourishment template area caused by a 10-year, 24-hour storm for various berm heights and widths. The left hand vertical axis shows berm height (NAVD88, feet), while the right hand vertical axis shows berm width (feet). The variable width scenarios use a constant 6.7 ft NAVD88 berm height, while the variable height scenarios use a constant 100 ft berm width. The currently authorized template consists of a berm height of 6.7 ft NAVD88 and a berm width of 100 ft. Figure 93 shows the changes in expected sediment lost from the template area for increased berm height and width. For example, the currently authorized project template loses more than 100% of the periodic nourishment (360,000 cy every 2 years) during the 10-year, 24-hour storm. Increasing the berm width by 40 ft reduces the percentage of material lost to approximately 25%. Increasing berm width further results in decreased losses, but also requires additional nourishment volumes, and additional sediment sources and finances. There is a point of diminishing returns on the amount of required sand needed to extend the berm width and the increased performance gained. Refinded analysis is needed to evaluate the sensitivity of various parameters in the beach nourishment design, potential impacts on overall cost of the project, and to identify the most cost-effective design template.

For example, the modified 140 ft berm width requires approximately 800,000 cy of additional sediment to gain the required berm width during the initial increased periodic nourishment; however, the performance is improved over each 2 year cycle, so the amount of sediment required for each periodic nourishment is reduced.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this example approach to template modification would result in a cost savings of approximately $37 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments, or increased renourishment intervals. The required periodic nourishments could be reduced to every 4 to 8 years if the performance gains respond as estimated. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Modification of the beach nourishment template may have other additional benefits. For example, the modified template may result in improved storm damage protection and reduced potential upland damage costs. Examples of other potential benefits include habitat enhancement, reduced ponding or upland flooding, and reduced environmental impacts offshore due to reduced offshore sediment needs.

Relative to the current authorization, the existing template defines the authorized project and the NED plan. Changing the template implies the authorized plan was no longer the NED plan and the project would have to be reanalyzed. To do so would require the use of the existing New Jersey shore study authority to determine the degree of federal interest, secure the requisite environmental clearances, and recommend a change in the authorized plan. This would require the existing project authority to be modified by the Congress. It would also likely require a new study cost sharing agreement to be signed, as well as a non-federal sponsor willing to contribute 50% of the study costs and agree to any changes in the construction and long-term cost sharing. A new PCS conforming to the model agreement would have to be signed.

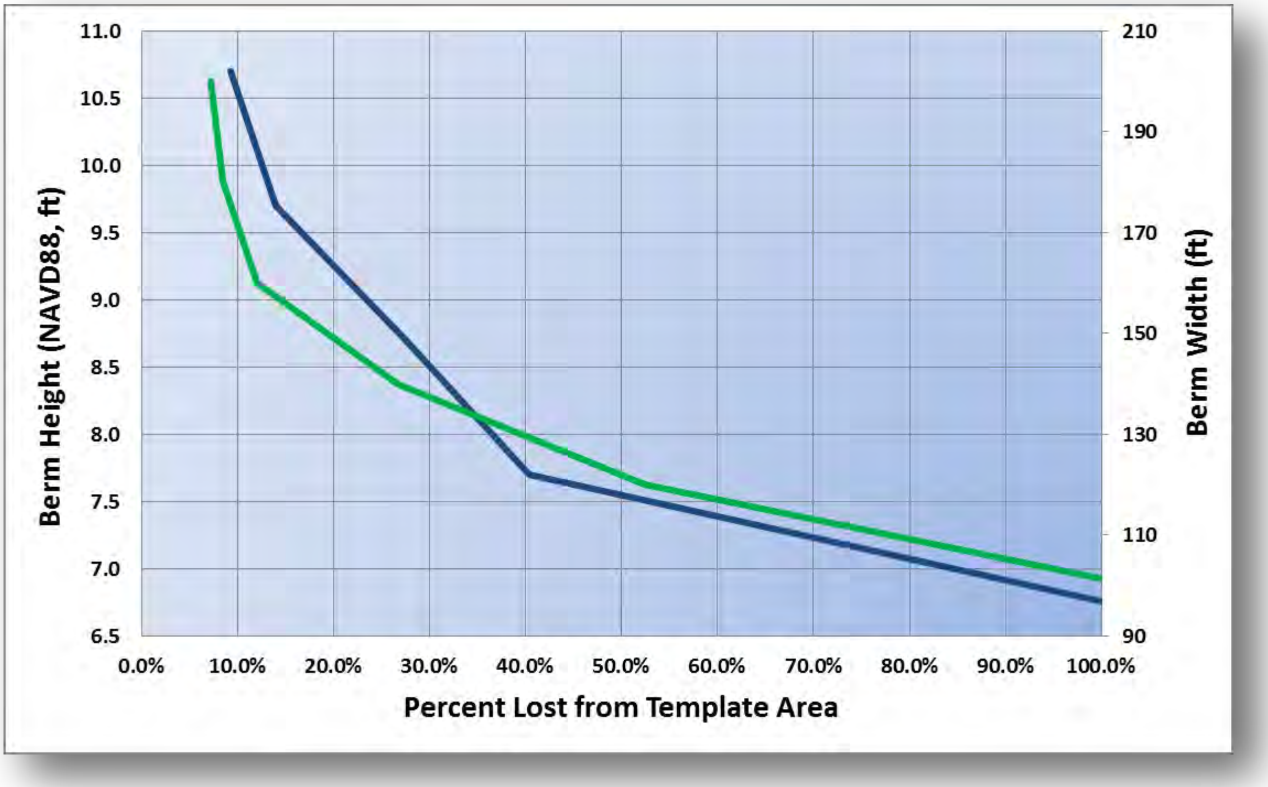


Figure 93. Eroded beach volume as a function of template berm height and width for the Cape May City nourishment project in response to a 24-hour, 10-year return period storm event.

Potential constraints associated with modification of the beach nourishment template include environmental concerns (e.g., occupying a larger offshore footprint), political and local community concerns that would limit the ability to change the template (e.g., communities may not want an increase berm height), and logistical concerns associated with modification of the authority to construct the project.

Table 36 presents a summary of the criteria evaluated for the refined beach nourishment template strategy and ranks this strategy as a low to intermediate priority with a Tier level of 2. Next steps for this strategy would be to conduct more detailed studies to assess if template modifications are warranted. The studies would focus on the cost benefit aspects of template modification.

Table 36. Beach Nourishment Template Refinement Strategy Summary.

Criteria	Summary
1. Authorization	Requires a change to the authorized plan and would include new study, permits, and cost-sharing agreements
2. Constraints	Logistic, political, local community, and environmental concerns
3. Cost Savings	Depends on template modification, $37 million for the example provided.
4. Service Life	Increase service life of beach nourishment expected
5. Other Benefits	Improved storm damage protection, habitat enhancement, reduced offshore environmental impacts
6. Priority	Low to Intermediate
7. Tier Level	Tier 2
8. Next Steps	USACE Philadelphia District decide if the strategy is warrants further study

H. Adjustment of Coastal Engineering Structures

This strategy proposes to adjust coastal engineering structures within the Cape May City region to provide potential cost savings and improved beach nourishment performance for the region. Although there are a significant number of structures within the project area, there are limited opportunities to make changes to the existing structures that will result in performance enhancements. Most of the Cape May City groins have been performing adequately. The Cape May City shoreline in the vicinity of the groins has remained relatively stable since the nourishment project was implemented.

There are two specific structural modifications that may warrant consideration.

1. Extending the Baltimore Avenue groin, constructed in 1990 as part of this authorized project, to slow the loss of sediment from the Coast Guard training center region and slightly reduce the transport into the Cape May City region. Figure 94 presents the conceptual design for this structural modification. The upper panel in the figure shows an oblique aerial view of the Baltimore Avenue groin in 1991, while the bottom view shows the conceptual extension of the structure on a 2011 oblique aerial. The original groin has been covered with sediment from the beach nourishment efforts along the shoreline, and is not functioning during most conditions.

2. Notching or lowering a portion of the 3rd Avenue groin to allow more sediment transport into the Lower Cape May Meadows region. Figure 95 presents the conceptual design. Since this modification has a more potential impact on the Lower Cape May Meadows/Cape May Point project. The preliminary analysis of this modification is presented fully in the Lower Cape May Meadows/Cape May Point strategy section.

Figure 94. The groin at Baltimore Avenue in 1991 (upper panel) and conceptual proposed extension on 2011 aerial (lower panel).

To provide a preliminary evaluation of the potential modification of the groin at Baltimore Avenue, the cross-shore distribution of the longshore transport was evaluated using relationships proposed by Longuet-Higgins (1970, 1970a). Using the cross-shore distribution, the effect of a shore-perpendicular structure on reducing or increasing the longshore sediment transport can be estimated.

The cross-shore distribution of longshore transport can be determined using a theoretical radiation stress approach (Longuet-Higgins and Stewart, 1962). This momentum based theory describes the energy imparted on the bottom of a nearshore breaking zone by shallow water waves.

When shallow water waves break at an oblique angle to the coastline, the result is a net force that pushes a parcel of water along the coast. In the case of a series of multiple waves breaking at a similar angle; a net current results that continually forces water along the shore (or alongshore). The total volume flow rate, Q, is given as a function of velocity, v_o, as

Equation 7:

$$Q = \frac{1}{3s} {h_B}^2 v_0 = \frac{1}{3} h_B |x_B| v_0$$

where h_B is the depth of water at the breaker line, s is the slope of bottom, and x_B is the normalized distance to the breaker line.

Horizontal mixing is the result of waves breaking at different locations and wave-induced eddies varying the profile of the cross-shore velocity distribution. To account for this variability due to mixing, a quadratic equation is used to create a typical cross-shore flow profile. The shape of this new function is dependent the known variability of the wave conditions and a horizontal eddy parameter. Figure 96 is a schematic representation of the long-shore velocity profile as a function of normalized offshore distance to the breaker line. The broken line represents the values without mixing. After applying a quadratic equation and its mixing coefficients, the longshore velocity profile looks like the solid line. The area under both lines equals to the volume flow rate, Q.

This distribution is calculated based on site-specific physical processes data (e.g., WIS hindcast information) for the Cape May City region, and is presented in Figure 97. The distribution can then be applied to assess different lengths (cross-shore direction) of structure by determining the fraciton of littoral transport intercepted by the structures.

Figure 95 Conceptual design of the groin at 3rd Avenue, impacts evaluated in the Lower Cape May Meadows project strategy section.

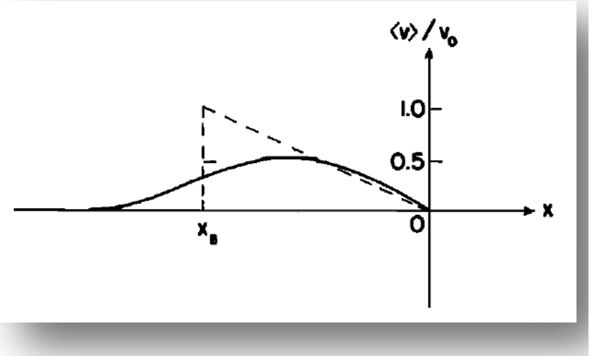


Figure 96 Example cross-shore distribution of alongshore velocities.

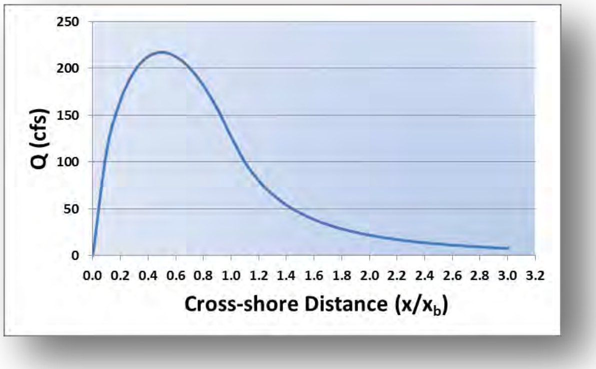


Figure 97. Cross-shore distribution of along shore flux for Cape May City area.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this structural modification (increasing the Baltimore Avenue structure by a distance of 100 ft from the current Mean High Water (MHW) line) would result in a cost savings of approximately $9 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments at the Coast Guard Training facility. This cost analysis assumes:

- Groin extension construction costs of $1.1 million based on previous structural cost bids.
- A net southward littoral drift rate of 137,000 cy/yr (USACE, 2006).
- Periodic nourishment conducted as currently authorized (every 2 years for Cape May City).
- The structure maintains its same rate of effectiveness over the 50-year service life.
- Reduced sediment flow towards Cape May City does not significantly impact the stability of the shoreline. Given the historic seaward growth of the shoreline during the nourishment activities (shoreline change rates), this appears to be a reasonable assumption.

Extensions of other various lengths were also be evaluated. For example, an extension of 200 ft represents a cost savings of $24 million over a 50 year time horizon. However, the structure should not be extended so far as it would negatively impact the Cape May City shoreline by intercepting too much of the cross-shore distribution of alongshore sediment movement. The final configuration would be specified through final design.

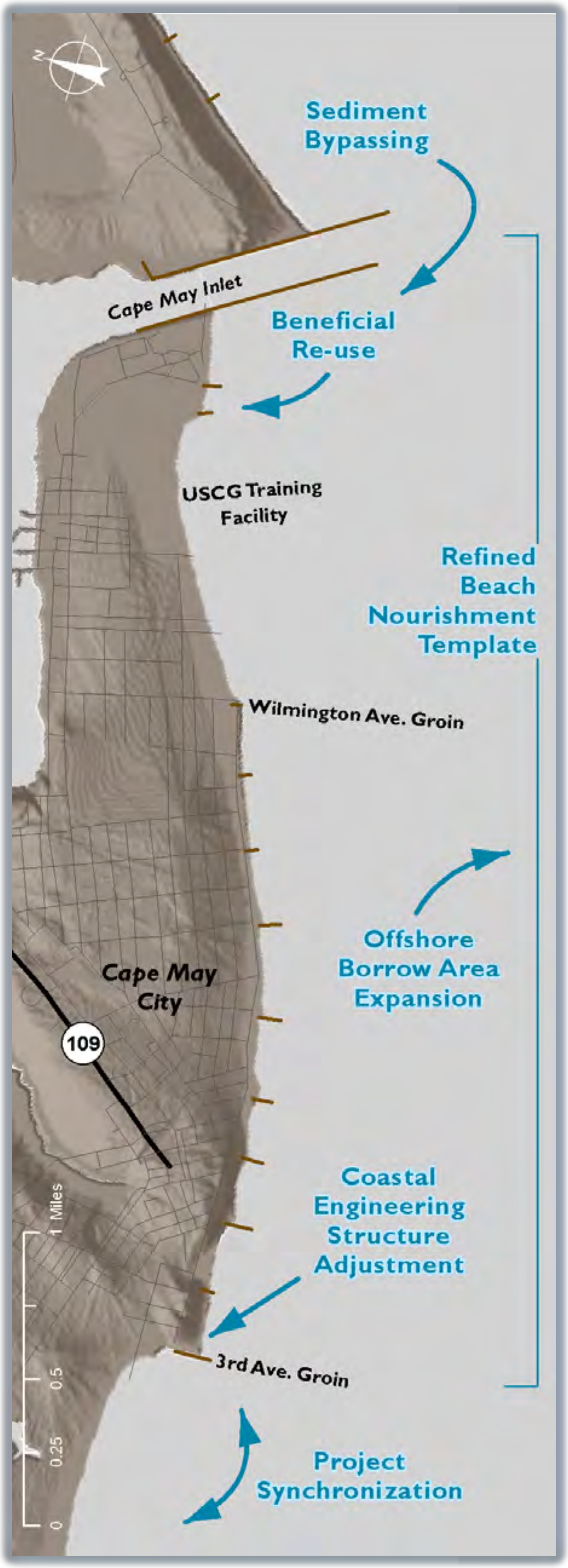
Structural modifications could be evaluated under the existing New Jersey Shore authority. It would require study cost sharing, a non-federal sponsor and if it meets the criteria for implementing a new construction authorization.

Constraints for this strategy include potential environmental impacts, and coastal processes evaluations to refine proposed structural modifications.

Table 37 presents a summary of the criteria evaluated for the structural modification strategy and ranks this strategy as a low to intermediate priority with a Tier level of 3. Next steps for this strategy would be to initialize more detailed studies to assess the impact of proposed structural modifications from a physical and environmental impact basis. The studies would also focus on the cost benefit aspects of the structural modification proposal(s).

Table 37. Adjustment of Coastal Engineering Structures Strategy Summary.

Criteria	Summary
1. Authorization	Requires study of cost sharing and a non-federal sponsor to implement construction authorization
2. Constraints	Environmental impacts need to be evaluated, coastal processes assessment to evaluate impact of structural modification
3. Cost Savings	$9 million for structural modification presented herein
4. Service Life	Potential beach nourishment performance enhancement, structural service life expected to be 50 years
5. Other Benefits	Reduced environmental impacts to offshore resources
6. Priority	Low to Intermediate
7. Tier Level	Tier 3
8. Next Steps	Coastal processes and environmental studies to determine relative cost benefit of structural modifications



Summary

This section presents a brief summary of the strategies presented for Cape May City. The focus is on the potential cost savings and priority levels associated with the strategies to assist identification and selection of strategies to more cost effectively manage sediment within the Cape May City project.

Figure 98 provides a summary of the estimated total cost savings (compared to current operations) over a 50-year time horizon for a number of the potential strategies (those that indicated a cost saving could be realized) for comparison purposes. Similarly, Figure 99 presents the cumulative cost savings for the same project strategies over that 50-year time horizon. Additional analysis could be completed to evaluate the potential cost savings associated with combining various strategies.

Table 38 presents an overarching summary of strategies focused on the prioritization and Tier level. The strategies presented in Table 38 are listed in order of priority and estimated ease of implementation.

Table 38. Cape May City Strategy Summary.

Strategy	Prioritization	Tier
A. Project Cycle Synchronization	High	1
B. Feeder Beach	High	1
C. Beneficial Re-use at Cape May Inlet	High	2
D. Sediment Bypassing	High	1
F. Offshore Borrow Site Expansion	High	1
G. Refined Beach Nourishment Template	Low to Intermediate	2
H. Coastal Engineering Structure Adjustment	Low to Intermediate	3
E. Nearshore Berm	Low	1

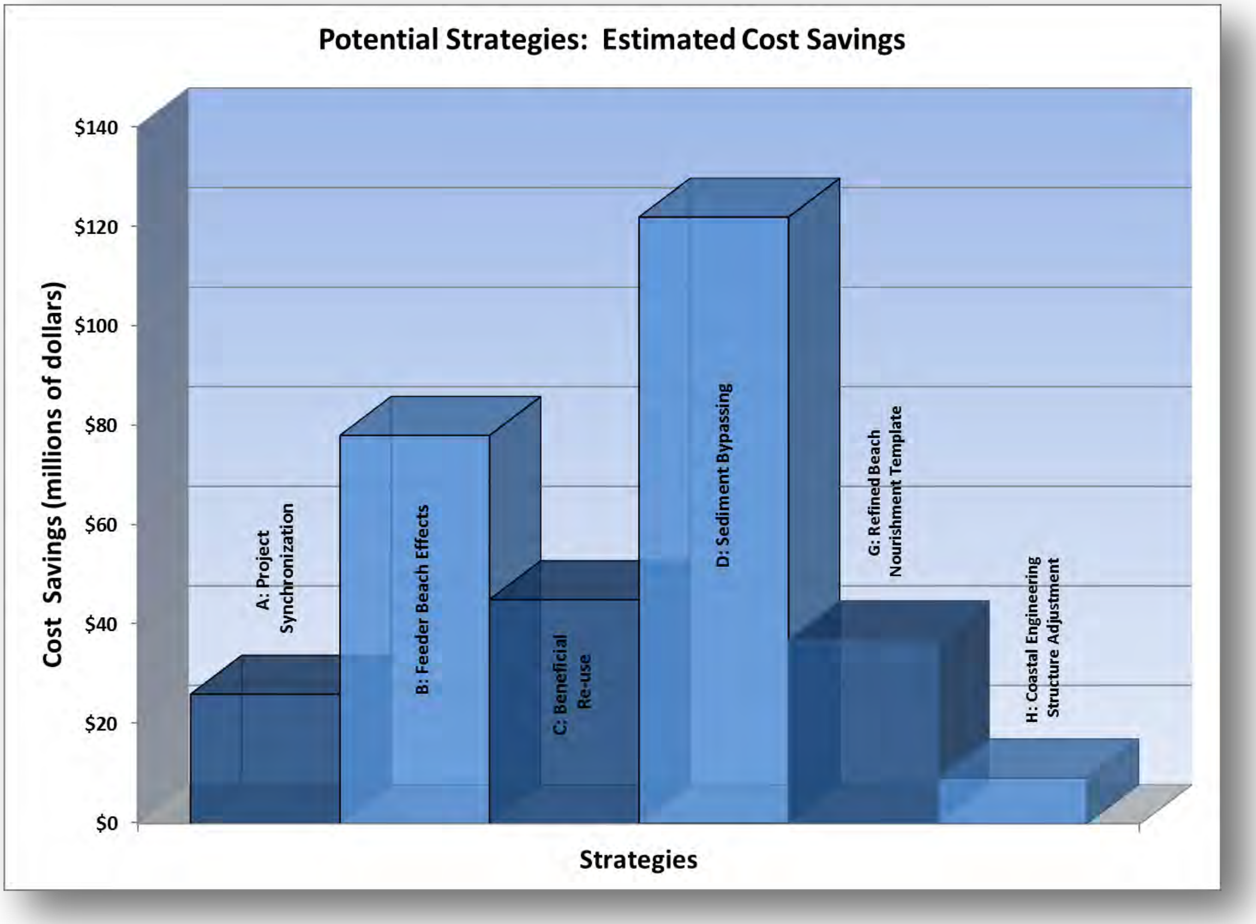


Figure 98. Estimate cost savings (compared to current operations) over a 50-year time horizon for select Cape May City strategies.

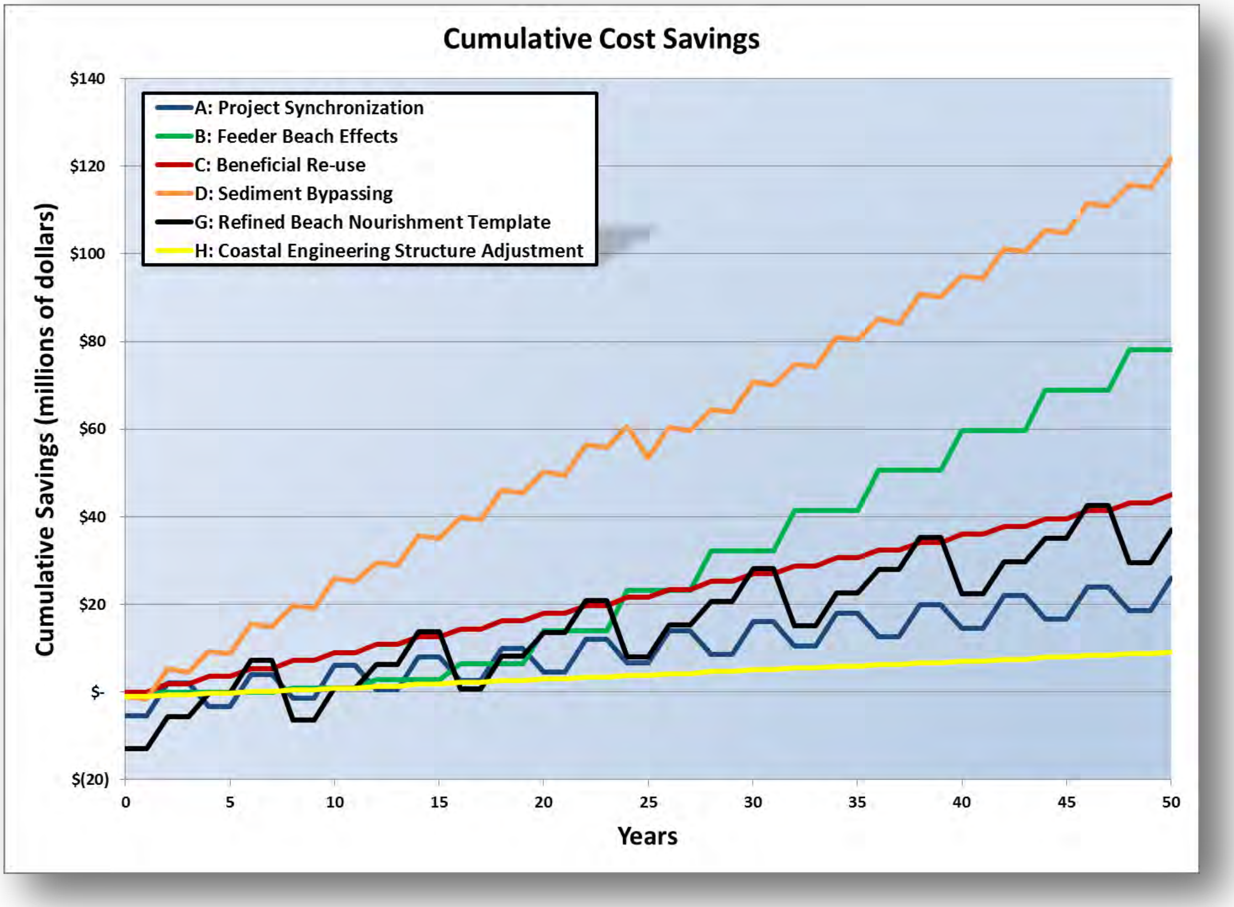


Figure 99. Cumulative cost savings (compared to current operations) over a 50-year time horizon for select Cape May City strategies.

AVALON AND STONE HARBOR

Project Description

The Townsends Inlet to Cape May Inlet Shore Protection Project was authorized for construction by the Water Resources Development Act of 1999. The project area extends for approximately 15 miles along the south coast of New Jersey, including the barrier islands of 7-Mile Island and 5-Mile Beach, as well as Townsends and Hereford Inlets. The authorized project includes dune and berm restoration on 7-Mile Island in the Boroughs of Avalon and Stone Harbor using sand dredged from nearby inlets. Periodic nourishment every 3 years is authorized to maintain the design template. The project also includes ecosystem restoration at Stone Harbor Point using nourishment, dune construction, and vegetation. Seawall construction along the Townsends Inlet frontage of Avalon and the Hereford Inlet frontage of North Wildwood are also authorized. Additional shore protection for 5-Mile Beach is not included due to healthy and extensive beach resources in North Wildwood, Wildwood, and Wildwood Crest.

The design berm in Avalon and Stone Harbor is 150 ft wide at an elevation of 7.25 ft NAVD88. The berm extends seaward to meet the natural grade at a slope of 1V:30H. The dune crest is 25 ft wide at an elevation of 14.75 ft NAVD88, with side slopes of 1V:5H. The total length of fill in Avalon is 7,000 linear ft, extending from the 8th Street groin to 32nd Street. The Stone Harbor beachfill is 15,500 ft long, from 71st Street to the groin south of 122nd Street. Dune grass planting over 50 acres and 42,500 linear ft of sand fencing are also included. The project authorizes an initial construction volume of 3,111,000 cy, with periodic nourishment of 746,000 cy every 3 years. Borrow areas at Townsends and Hereford Inlets are permitted as sources for the 7-Mile Island shore protection project. Figure 100 shows the components of the authorized project.

Ecosystem restoration at Stone Harbor Point includes a 150 to 275 ft wide beach berm at an elevation of 7.25 ft NAVD. The dune crest ranges in elevation from 10.75 to 8.75 ft NAVD with side slopes of 1V:5H. A fill volume of 1,366,000 cy is authorized to construct the project. Dune grass plantings over 2.7 acres and bayberry/eastern red cedar plantings over 64 acres are included, along with 1,500 linear ft of sand fencing to stabilize the dune.

The seawall authorized for Avalon extends 2,970 linear ft along the Townsends Inlet frontage between the 8th Street groin and Inlet Drive North. The crest elevation for the stone seawall is 12.75 ft NAVD with a slope of 1V:2H. In North Wildwood, the seawall extends 8,660 linear ft along the inlet frontage of Hereford Inlet. The crest elevation is 11.75 ft NAVD and the slope is 1V:2H. Figure 100 shows the seawall locations in Avalon and North Wildwood.

Project History

7-Mile Island has a history of major flooding, beach erosion, and structural damage during storms. Since 1992 the island has been declared a Federal Disaster Area on 7 separate occasions. Long-term erosion has reduced the height and width of the beach, exacerbating potential for storm damage. In addition, valuable fish and wildlife habitat along the southern end of Stone Harbor has been lost to erosion.

Different types of coastal engineering structures have been used to control erosion. Bulkheads fronted by stone revetments were constructed in the 1960s and 1970s at the north end of Avalon, through much of Stone Harbor, and at North Wildwood. A total of

23 groins were also installed in the same areas: 4 in Avalon; 8 in Stone Harbor; and 11 in North Wildwood. In 1993 sand filled geotextile tubes were installed along the inlet frontage in Avalon to function as a perched beach, and to minimize the loss of sand placed along the shoreline. In 1994 submerged concrete reefs were placed in combination with sand fill along 1,000 ft of oceanfront in Avalon south of the 8th Street groin. These structures were constructed by municipal, county, and state interests to combat erosion of ocean facing and inlet shorelines. Long-term erosion also threatened valuable wildlife habitat at Stone Harbor Point, causing the only large mixed-species heronry in coastal New Jersey to retreat northward towards more developed areas of the island.

The Townsends Inlet to Cape May Inlet Shore Protection Project was authorized to mitigate ongoing erosion and restore critical habitat areas at Stone Harbor Point. Initial nourishment/dune construction and ecosystem restoration were completed in 2002. Approximately 4,400,000 cy of sand from Townsends and Hereford Inlets were placed in Avalon, Stone Harbor, and Stone Harbor Point. Periodic nourishment has been delayed due to inadequate funding. The seawall construction portions of the project in Avalon and North Wildwood were completed between 2004 and 2007.

Figure 100. Townsends Inlet to Cape May Inlet (7-Mile Island) Authorized Shore Protection Project.

Since initial construction of the federal project, beach erosion has continued and municipal interests have teamed with the State of NJ to nourish critically eroded beaches in Avalon, Stone Harbor, and North Wildwood. For example, the beaches at the north end of Avalon have been nourished approximately once per year since 2005, placing nearly 2.1 million cys of sand (Table 39). A variety of methods and sand sources have been used, including hydraulic dredging from Townsends Inlet, truck hauling from local gravel pits, and beach scraping from areas south of 31st Street (backpassing).

Table 39. Avalon Nourishment History Post 2002.

Date	Volume (cy)	Method
2005	57,000	Backpassing
2006	50,000	Backpassing
2006	350,000	Dredging
2007	108,000	Trucking
2008	225,000	Dredging
2009	117,000	Trucking
2009/2010	81,000	Trucking
2010	643,000	Dredging
2011	450,000	Dredging

In 2009 the State of NJ worked with the communities of Stone Harbor and North Wildwood to nourish beaches using sand dredged from Hereford Inlet. A total of 245,000 cubic yards was placed in Stone Harbor between 98th and 111th Streets, and 1,186,400 cy was placed along the oceanfront in North Wildwood immediately south of the inlet (Figures 101 and 102).

Project Observations

Since initial construction of the Townsends Inlet to Cape May Inlet Shore Protection Project a number of observations have been made:

- During the 3 years following initial construction of the Avalon and Stone Harbor beachfill, the majority of sand at the north end of Avalon was eroded from the design template. The material appears to have been transported south of the project and into the offshore region.

Figure 101. Area of nourishment completed in 2009 by State of NJ and Borough of Stone Harbor.

Figure 102. Area of nourishment completed in 2009 by State of NJ and City of North Wildwood.

- High rates of erosion in the Borough of Avalon have created a "hot spot" between 9th Street and 18th Street. Spreading of the "hot spot" south to 26th Street threatens homes, the boardwalk and gazebo at 21st Street, and the Borough's beachfront storm water pump station at 22nd Street.

- The Avalon and North Wildwood seawalls have been successful at controlling inlet migration and associated shoreline erosion.

Potential Strategies

This section presents the potential strategies for the Townsends Inlet to Cape May Inlet Shore Protection Project that are intended to provide improved project performance, cost savings, or other benefits. These strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. In addition, some of the strategies include a first-order technical analysis to evaluate the relative merit of the proposed strategy. These analyses are not intended to be detailed assessments and include some assumptions and simplifications. Rather, they are geared towards providing a preliminary estimate of the potential benefits that may be realized if the strategy is implemented. In other words, the analyses presented herein can be used as initial screening tools to determine if a strategy warrants further consideration. For some strategies, a more detailed analysis may be required if the strategy is more formally pursued.

A. Project Cycle Synchronization

The project cycle synchronization strategy represents informally synchronizing the construction of authorized shore protection projects that are in close proximity. The intent is to reduce mobilization and demobilization costs by combining re-nourishments. For the Townsends Inlet to Cape May Inlet Shore Protection Project, coordination of the Avalon and Stone Harbor periodic nourishment (746,000 cy every 3 years) with the Ludlam Island (Sea Isle City) periodic nourishment (1,820,000 cy every 5 years) should be considered.

A first-order analysis of potential cost savings from combining the periodic nourishment efforts at Avalon and Stone Harbor with Sea Isle City was conducted. It is assumed that the authorized five year periodic nourishment cycle for Ludlam Island could be extended to a six year cycle and nourished jointly with the Avalon and Stone Harbor projects.

A brief analysis, which combines the conservation of sediment equation with the linearized transport equation, was conducted to determine if the Ludlam Island periodic renourishment could be extended to six years. The *Pelnard-Considére* (1956) equation (Equation 8) is used to obtain theoretical results to establish design and performance standards for the Ludlam Island nourishment. A more detailed description of the derivation of the equations and their applications can be found in Dean (2002).

Equation 8:

$$M(t) = \frac{2\sqrt{Gt}}{l\sqrt{\pi}}\left(e^{-\left(\frac{l}{2\sqrt{Gt}}\right)^{2}} - 1\right) + erf\left(\frac{l}{2\sqrt{Gt}}\right)$$

where *M(t)* is the proportion of sand remaining in the placed location, G is the alongshore diffusivity parameter, t is time, and l is the project (nourishment) length. The alongshore diffusivity (Equation 9) is presented by *Pelnard-Considére* (1956).

Equation 9:

$$G = \frac{KH_b^{5/2}\sqrt{g/\kappa}}{8(s-1)(1-p)(h_* + B)}$$

where K is the sediment transport coefficient, which is a function of sediment size, B is the berm elevation, H_b is the breaking wave height, h_* is the depth of closure, p is the *in-situ* sediment porosity (approximately 0.35 to 0.40), s is the sediment specific gravity (approximately 2.65), and κ is the ratio of wave height to water depth within the surf zone (approximately 0.78).

The *Pelnard-Considére* equation can be applied to determine the performance of a beach nourishment project. For this analysis, the Wave Information Study (WIS) time series of wave and wind data, developed by the United States Army Corps of Engineers, were used to describe the wave climate offshore of New Jersey. The WIS, performed by the USACE, has met a critical need for wave information in coastal engineering studies since the 1980s and is widely accepted for design purposes for United States shorelines by many coastal engineers and scientists (http://wis.usace.army.mil/). WIS contains time series information of spectrally-based, significant wave height, peak period, peak direction, and wind speed and direction produced from a computer hindcast (prediction) model. The hindcast wave model, WISWAVE (Resio and Tracy, 1983) is simulated using wind information (speed and direction) at selected coastal locations around the United States. Wave measurements made by NOAA during the 1980s made verification of the WIS results possible by comparing the statistics and the distributions of wave heights and periods from different time periods (Hubertz et al., 1993). The availability of long-term records makes WIS data attractive when considering average or seasonal wave conditions. Twenty years of wave hindcast data from WIS station 63147 were used for analysis of the Ludlam Island nourishment.3

In addition, since the offshore wave environment can be complex, calculation of the alongshore diffusivity was based on the wave energy distribution for average annual directional approach bins. Data were segregated by direction of approach and an energy distribution, as a function of frequency, was generated from all the waves in each directional bin. The energy associated with each frequency was then summed to create an energy distribution for each approach direction. In essence, a representative two-dimensional spectrum was generated for each approach direction bin based on the sum of all the waves approaching from that mean direction. This was combined with the percentage of occurrence to create a 20 year evaluation of wave impacts at the shoreline. This energetic directional bin approach has been successfully utilized in transformation modeling (Byrnes et al., 2000) and identifies all potential approach directions, including those that may occur only a small percentage of time during a typical year, but potentially have significant impact on sediment transport. Values of alongshore diffusivity were computed for each directional bin and used for modeling beach nourishment performance.

Since the material spreads over time, it is possible to evaluate the longevity of the nourishment by looking at the amount of material left in the project area. Subsequently, nourishment alternatives can be compared to one another based on their longevity. The service life of the beach nourishment can be based upon the percent of the initial beach nourishment material left within the boundary of the initial fill area. The percentage remaining will decrease with time, but that material is not necessarily lost from the system, it has just spread to regions outside of the original nourishment template. For example, sediment may have been transported offshore or along the beach. Therefore, although the sediment no longer falls within the initial nourishment template, it has not completely disappeared from the system.

Figure 103 presents the projected performance of the Ludlam Island authorized project. The performance is expressed in terms of amount of material remaining in the initial template region, as a function of time. The percent of initial material remaining is presented along the left hand axis, while the time in years is presented along the bottom axis. For example, after 6 years, approximately 75% of the initial fill volume is remaining, or approximately 3.86 million cy of the initial 5.15 million cubic yard nourishment. A total of approximately 1.3 million cy would be required in a periodic nourishment to return the nourishment template to the design, which is less than the authorized periodic nourishment of 1.82 million cy on a 5 year cycle. Therefore, it appears reasonable to assume that the Ludlam Island periodic nourishment could be extended from 5 to 6 years.

Mobilization and demobilization costs constitute a significant portion of typical dredging contracts, and these costs do not necessary always get reduced with increased contract size (e.g., larger dredging projects). A number of factors contribute to the variations in dredging contract costs, including market conditions at the time, proximity of the borrow area to the nourishment site, and the limited number of capable dredging contractors. As such there can be large uncertainties when forecasting beach nourishment dredging and placement costs. Recent dredging contracts (2002-2009) for nourishment efforts in New Jersey and Delaware (Gebert, 2010) show that mobilization and demobilization costs can account for 10% to 60% of the total winning bid, and average mobilization and demobilization costs are approximately $2 million per nourishment effort, regardless if it is an initial or periodic nourishment effort. The unit cost of sand over that same time period ranged from approximately $4 to $15/cy. Therefore, the preliminary analysis presented herein also assumes dredge mobilization and demobilization costs of $2 million, and a conservative unit price of $15/cy for sand.

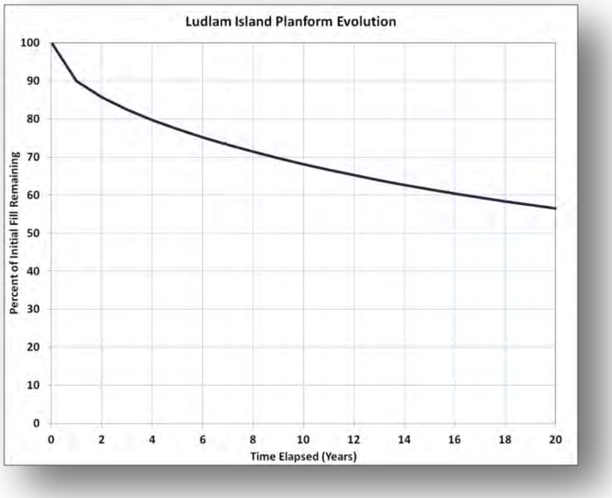


Figure 103. Estimated beach nourishment performance for the authorized project at Ludlam Island. This analysis assumes the project is constructed as authorized.

Since many strategies may involve integration of projects with different remaining authorized lifetimes, a 50-year time horizon is used for comparison purposes irrespective of the remaining authorized project life. Use of a single standard time period also allows direct comparison between various strategies across projects and for those involving initial construction costs and maintenance (O&M) costs.

Over a 50-year time horizon, there is a cost savings of $14 million based solely on the reduced number of nourishment events realized by synchronization of the projects every 6 years, while still nourishing the Avalon and Stone Harbor regions every 3 years as authorized. Additional cost savings may be realized from reduced contracting and management requirements. A comparison to current operations and to other strategies is presented in the summary section.

Fewer periodic nourishment episodes will also have an environmental benefit since there will be less frequent disturbance (reduced by 30%) of the offshore borrow site areas, reduced disturbance on the beaches, and reduced overall air and noise pollution.

This strategy can be implemented at any time since existing authorities do not preclude any re-nourishment from being done as part of a combinded contract as long as the funds for each are available and are not comingled. Further, all requisite environmental clearances must be accomplished before award of such a contract. The implementation of this strategy has minimal constraints; limited to availability of dredging equipment and borrow site quantities, which are already constraints of current operations.

Table 40 presents a summary of the criteria evaluated for the project cycle synchronization strategy, which ranks as a high priority and easily implementable (Tier 1 level). This strategy should be pursued since the pathway to implementation is straightforward and there are no significant constraints.

B. Offshore Borrow Area Expansion or Establishment

Over a 50 year time horizon, the remaining periodic nourishment sediment needs at Avalon and Stone Harbor are approximately 12,682,000 cy. Sediment sources for the initial construction of the Avalon and Stone Harbor nourishments, as well as most of the nourishments performed by the state (Table 39), have been from Hereford and Townsends Inlet borrow sites. Currently, the permitted borrow sites in the vicinity of 7 Mile Island do not provide enough sediment to meet the required need (Broad Regional Strategies, Table 15). Although some of the offshore borrow areas to the north (L1, L3) could be utilized to nourish Avalon and Stone Harbor, these areas are also need for periodic nourishments at Ludlam Island. Therefore, unless the sediment needs of the shore protection project can be reduced (e.g., beach nourishment performance is enhanced), or alternative sediment sources are utilized (e.g., expanded inlet dredging, etc.), additional borrow locations will be required. These additional borrow locations could either be identified offshore (strategy B) or from expanded areas in Townsends or Hereford Inlets (strategy C).

Table 40. Project Cycle Synchronization Strategy Summary.

Criteria	Summary
1. Authorization	No existing authorization limitations
2. Constraints	No constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$14 million over 50-year time horizon
4. Service Life	No change to service life
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on a temporal scale
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Evaluate potential storm damage impacts, coordinate dredging, and implement strategy

This strategy is not specifically designed to provide a cost savings, but rather to maintain current operations costs since upland sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., track traffic, road repairs, time of construction, etc.).

The Hereford (G, A-1, A-2) and Townsends Inlet (E) borrow sites used for the initial nourishment may have limited amounts of sediment remaining (3.1 million cy) and/or the dredging of these areas may have modified the infilling rates and sediment movement in the area. There are potential additional borrow sites that have initial been proposed in offshore waters (identified as A & B) for the region, as well as additional expansions of the Hereford and Townsends Inlet dredge area (as discussed in Strategy C). Due to the expected sand deficit for this region, continued expansion of existing sites or searches for new borrow sites is needed for this region. Potential searches in Federal waters also may be warranted through cooperation with the Bureau of Ocean Energy Management (BOEM). For example, MMS-B may be potential borrow site in Federal waters that may be utilized.

This strategy can be accomplished under the existing project authorities because the provision of borrow areas for the life of the project is part of the authorization. It would require cost sharing likely at the same level as the project. Appropriate studies and environmental clearances would be needed. Construction funds can be used to accomplish this as it is a part of the process of continuing construction.

The primary constraints with expansion or establishment of offshore borrow sites are environmental. Establishing offshore borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave and sediment transport processes also are needed. The physical and environmental delineation would add cost, but once permitted, the construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 41 presents a summary of the criteria evaluated for the offshore borrow area expansion or establishment strategy, which ranks as a high priority for this region with a Tier level of 1. It is recommended that this strategy is pursued in advance of potential need, such that the borrow areas are established for future use. Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted offshore sites available if needed for storm events or unforeseen circumstances is good planning. Next steps for this strategy would be to initialize any studies and surveys needed to expand or establish new borrow sites for this region, which has a known deficit and coordinate with BOEM for any potential federal waters borrow sites.

Table 41. Offshore Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analyses required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Initiate studies and survey, coordinate with BOEM

C. *Increased Dredging of Townsends or Hereford Inlet*

The increased dredging of Hereford and/or Townsends Inlet strategy seeks to expand the available nearshore borrow areas in the inlets that reside on both ends of 7 Mile Island. The intent of the strategy is to identify and expand inlet based borrow areas that will help alleviate the long-term deficit of sand for Avalon and Stone Harbor nourishment projects.

There is a history of dredging and beneficial reuse at Hereford Inlet. Documentation of federal activity and investigation in Hereford Inlet is available in the Townsends Inlet to Cape May Inlet Feasibility Study (USACE, 1997). Federal dredging of the ebb shoal of Hereford Inlet occurred in 1967, and the state performed annual maintenance of the channel until 1976 (after which maintenance occurred as needed). The feasibility study identified a 145 acre area within Hereford Inlet with an estimated 2,500,000 cy of compatible sand. The study acknowledged the existence of greater reserves, but reduced the borrow area footprint to preserve the ebb shoal and maintain inlet hydraulics and benthic resources. USACE later refined this borrow area to include three permitted borrow areas (G, A-1, A-2) in Hereford Inlet. The estimated pre-project borrow area quantity for these areas was 4,050,000 cy based on feasibility studies. In 2009, the State of NJ removed 1,431,400 cy from Hereford Inlet to nourish beaches in Stone Harbor and North Wildwood. Based on this information, the remaining available sand from the Hereford Inlet borrow area was approximately 2,620,000 cy.

The Hereford Inlet to Cape May Inlet Feasibility Study Project Management Plan (USACE, 2005) indicates that USACE/CERC has identified additional potential borrow sources in Hereford Inlet that will require further investigation. As a preliminary estimate of the extents and volume of these potential borrow sites, an investigation of historical aerial photography was completed. The assessment suggested that the shoals of Hereford Inlet are substantial but migratory. Therefore, potential borrow areas are delineated based on the location of the ebb and flood tidal shoals in the latest available imagery (Google Earth, June 2011) to provide an estimate of the most probable location of sediment sources. Figure 104 delineates these potential borrow areas, shown in green, and also shows the existing permitted borrow areas in Hereford Inlet (white shaded areas).

The flood tidal shoal at Hereford Inlet is approximately 60 acres. At an average thickness of 10 to 15 ft, the flood tidal shoal borrow area could yield between 970,000 and 1,460,000 cy. The ebb tidal shoal at Hereford Inlet is approximately 200 acres. At an average thickness of 10 to 15 ft, the ebb tidal shoal borrow area could yield between 3,270,000 and 4,900,000 cy. This would provide additional future nourishment material for the Stone Harbor and Avalon areas, although additional borrow areas will still be required over a 50-year time horizon.

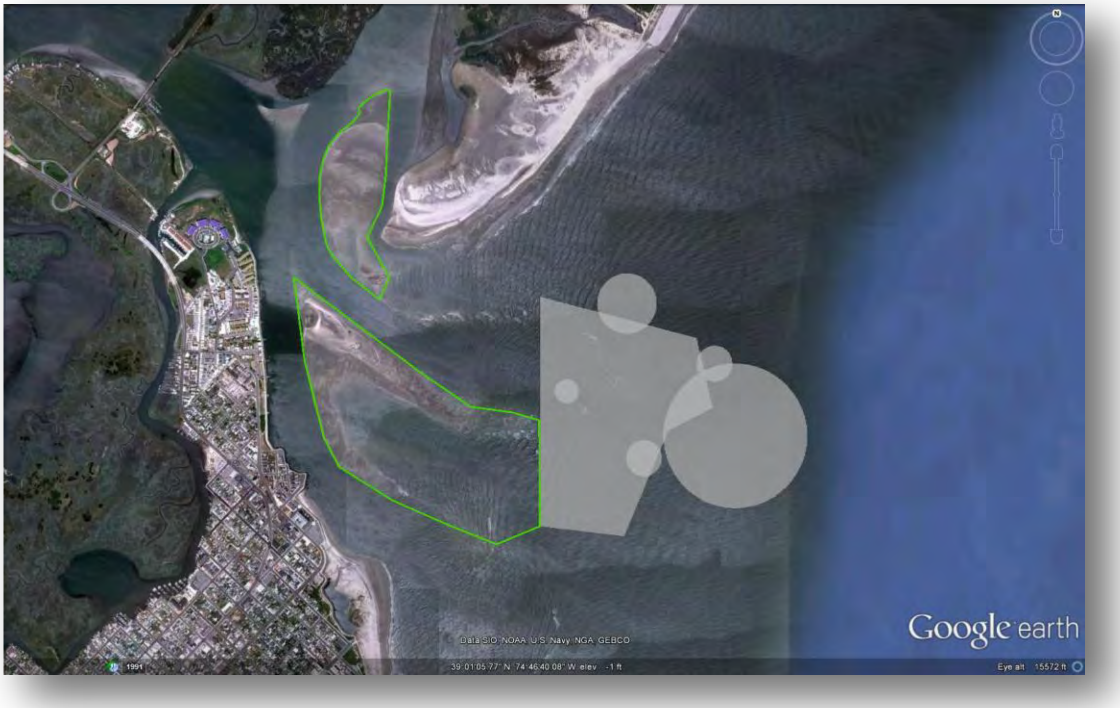


Figure 104. Potential borrow areas (green) at the ebb and flood tidal shoals of Hereford Inlet. Permitted borrow areas shown as shaded white. Image courtesy of Google Earth©.

Therefore, increased dredging of Townsends Inlet was also considered to expand the available nearshore borrow areas in the vicinity of Avalon. There is also a history of dredging and beneficial reuse of the sediment at Townsends Inlet, with most of the nourishment being conducted at Avalon. Annual side-cast navigation dredging from 1950 to 1977 nourished the inlet-facing beaches of Avalon. Between 1967 and 1974 this beneficial reuse averaged 26,200 cy per year, with dredging events ranging between 1,726 to 40,160 cy (Everts et al., 1980). In 1977 and 1984, large-scale dredging operations in Townsends Inlet provided nourishment material to Sea Isle City beaches to the north. In 1987, Townsends Inlet provided approximately 1,380,000 cy to severely eroded Avalon beaches. Periodic nourishment of Avalon occurred eight times between 1990 and 2001, with dredging volumes from Townsends ranging between 72,000 and 635,000 cy. In 2002, USACE constructed a nourishment effort at Avalon, pumping 1,300,000 cy to Avalon beaches from Townsends Inlet. Periodic nourishment also occurred at Avalon in 2006, 2008, 2010 and 2011 using Townsends Inlet material and volumes ranging from 225,000 to 643,000 cy. Table 42 summarizes the history of dredging activity at Townsends Inlet from 1967, showing the approximate quantity of material removed from the inlet.

The Townsends Inlet to Cape May Inlet Feasibility Study (USACE, 1997) identified a 248 acre area within Townsends Inlet with an estimated 3,500,000 cy of compatible sand. The study acknowledged the existence of greater reserves, but reduced the borrow area footprint from 400 acres to preserve the ebb shoal and maintain inlet hydraulics and benthic resources. Based on survey and a thickness range of 10 to 15 ft, the estimated pre-project borrow quantity for Townsends Inlet is between 1,745,259 and 2,617,888 cy. Because of the demand for existing permitted sand sources in Townsends Inlet at Avalon, and because the majority of permitted borrow area sand available to projects at Sea Isle City and Peck Beach originates offshore, additional nearshore borrow areas in closer proximity to the shore protection projects may reduce operational costs for these projects.

Table 42. Summary of dredging activity at Townsends Inlet.

Year	Quantity (cy)	Placement Location
1967	40,190	Avalon Inlet Shoreline
1968	14,690	Avalon Inlet Shoreline
1969	21,460	Avalon Inlet Shoreline
1970	40,160	Avalon Inlet Shoreline
1971	10,420	Avalon Inlet Shoreline
1972	17,560	Avalon Inlet Shoreline
1973	1,726	Avalon Inlet Shoreline
1974	37,250	Avalon Inlet Shoreline
1978	574,000	Sea Isle City
1984	820,000	Sea Isle City
1987	1,380,000	Avalon
1990	400,000	Avalon
1992	350,000	Avalon
1993	347,000	Avalon
1995	635,000	Avalon
1997	376,000	Avalon
1998	411,000	Avalon
1999	72,000	Avalon
2001	307,000	Avalon
2002	1,362,000	Avalon
2006	350,000	Avalon
2008	225,000	Avalon
2010	643,000	Avalon
2011	450,000	Avalon

As a preliminary estimate of extents and volume of these potential borrow sites, an investigation of historical aerial photography was completed. The assessment suggested that the shoals of Townsends Inlet are substantial and fairly stable. Potential borrow areas are delineated based on the location of the ebb and flood tidal shoals in the latest available imagery (Google Earth, June 2011) to provide an estimate of the location of potential expanded sediment sources. Figure 105 delineates these potential borrow areas, and also shows the existing permitted borrow areas in Hereford Inlet (white shaded areas).

The flood tidal shoal at Townsends Inlet is approximately 14 acres. At an average thickness of 10 to 15 ft, the flood tidal shoal borrow area could yield between 229,000 and 345,000 cy. The ebb tidal shoal at Townsends Inlet is approximately 100 acres. At an average thickness of 10 to 15 ft, the ebb tidal shoal borrow area could yield between 1,650,000 and 2,480,000 cy. Combined with the potential borrow sites within Hereford Inlet, this would provide enough sediment to meet the requirements of the Stone Harbor and Avalon shore protection projects over a 50 year time horizon.

These expanded borrow areas within the inlets could be authorized by developing a beneficial re use project using the coastal projects authorities to implement. The authority to construct this project does not include beneficial reuse. It would have to be modified to include this and the project cost sharing adjusted to reflect a new purpose. Documentation would have to be developed to accomplish this as well as a new PCA reflecting today's model agreement would have to be negotiated and signed.

The primary constraints with expansion of the inlet borrow sites are environmental. Establishing borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave, tidal currents, and sediment transport processes are also needed, especially to determine the potential impct from removal of a significant portion of the ebb or flood tidal shoals. The physical and environmental delineation would add cost, but once permitted, the construction costs associated with obtaining the nearshore material are significantly lower than for upland material, and also lower than offshore sources due to the close proximity of the inlet material to the beach nourishment project(s).

Table 43 presents a summary of the criteria evaluated for the increased dredging in Hereford and Townsends Inlets and ranks this strategy as an intermediate priority for this region with a Tier level of 2. It is recommended that this strategy is pursued in advance of potential need, such that the borrow areas are established for future use. Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted sites with adequate volume to meet the shore protection needs in the future is beneficial. If storm events or unforeseen circumstances arise, having the sediment available would be critical. Next steps for this strategy would be to initialize any studies and surveys needed to expand the inlet borrow sites.

Table 43. Increased Dredging of Townsends or Hereford Inlet Strategy Summary.

Criteria	Summary
1. Authorization	Requires modification of authority to include beneficial re-use of inlet material
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Some cost savings expected due to close proximity of borrow sites
4. Service Life	No change to shore protection service life
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	Intermediate
7. Tier Level	Tier 2
8. Next Steps	Initiate studies and surveys

Figure 105. Potential borrow areas (green) at the ebb and flood tidal shoals of Townsends Inlet. Permitted borrow areas shown as shaded white. Image courtesy of Google Earth$^{©}$.

D. Sediment Backpassing to Avalon

This strategy involves extracting sediment from a portion of the shoreline that is accreting and moving the material to an updrift location that is more erosional. This methodology, called sediment backpassing, is intended to work with the natural littoral drift within a system by recycling sand back updrift to the location where it had initially resided. For example, nourishment material placed at Avalon is transported south of 32nd street to an area where the shoreline is advancing and sediment is plentiful. The sediment backpassing strategy would recycle a portion of this material back to Avalon, as shown conceptually in Figure 106.

Figure 106. Sediment backpassing strategy for Avalon.

As part of the Hereford Inlet to Cape May Inlet Feasibility Study, Clausner and Welp (2008) investigated the feasibility of mobile hydraulic back-passing for the Wildwood area. The study determined that in a time frame of two to four months, as much as 200,000 cy of sand could be back-passed distances of up to 15,000 ft using the mobile system they evaluated. Clausner and Welp (2008) also determined that the cost associated with the mobile system (a hydraulic pumping system mounted on a boom equipped crawler) would be approximately $10/cy. Using the costs developed by Clausner and Welp (2008), and assuming compatible sediments on all reaches of Seven Mile Island, a preliminary cost analysis was performed on the applicability of sand back-passing to complement current nourishment efforts at Avalon.

Using historic shoreline change data, shoreline accretion occurs within 13,000 ft to the south of the nourished areas (Avalon, NJ). In this region, there is an average rate of shoreline accretion of approximately 4.6 ft/yr (1.4 m/yr). To determine the potential volume available for backpassing, the existing profiles of the accretionary area were translated landward (a distance equivalent to the rate of advance) using equilibrium beach profile theory. Therefore, only sediment that was accreting was identified as available for backpassing, and the shoreline would remain stable and not turn into an erosional area. Using this approach, the volume of sediment accreting in the area south of Avalon was calculated to be 83,000 cy annually, or almost 200,000 every three years. However, not all of this excess material is available for extraction. Assuming the use of a 160 ft boom mounted pumping system, 25,000 cy/yr of sand are available to be backpassed to Avalon. More sediment could potentially be extracted using sheet piles and temporary earthworks, and the swath of the mobile dredging equipment can be increased to provide additional sand for back-passing, but at an additional, undetermined cost.

The total amount of sediment available for backpassing is not enough to eliminate the need for periodic nourishment, but utilizing backpassed material reduces the amount of material needed.

Over a 50-year time horizon, there is a cost savings of $6 million if 25,000 cy/yr of sediment backpassing was implemented. This assumes that the mobile backpassing system is readily available and could be utilized at the 7 Mile Island location. Additional cost savings may be realized from reduced contracting and management requirements. Reduced impacts to offshore borrow sites would be another benefit to this strategy. A comparison to current operations and to other strategies is presented in the summary section.

Constraints involve the potential impact to the beach where sand is extracted. This includes the ability of the beach to adequately serve the same function and level of protection as before the sediment removal. This strategy would also increase disturbance on the beaches, and overall air and noise pollution.

The potential authorization for this project does not include specific authority to backpass sand. However, the Corps' value engineering authority could be used to determine the effectiveness of backpassing at reducing the long term nourishment costs compared to its implementation cost. The need to develop benefit numbers is also reduced by this approach; the benefits are just the reduced nourishment costs. Appropriate environmental clearances would also be required.

Table 44 presents a summary of the criteria evaluated for the sediment backpassing strategy and ranks it as a high priority and Tier Level 2.

Table 44. Sediment Backpassing to Avalon Strategy Summary.

Criteria	Summary
1. Authorization	Use value engineering to determine the effectiveness of backpassing at reducing the long term nourishment costs compared to implementation cost
2. Constraints	Dredge equipment availability, potential impacts to source beach
3. Cost Savings	$6 million over 50-year time horizon
4. Service Life	No change to service life
5. Other Benefits	Reduced impacts to offshore borrow sites.
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Use value engineering to implement; assess environmental impacts on source beach.

E. Refine Beach Nourishment Template

This strategy involves applying adjustments to the authorized beach nourishment template along 7 Mile Island, and specifically at Stone Harbor and Avalon, and to determine if modifications to the template may result in increased performance or improved storm damage protection. A successful beach nourishment project consists of more than simply placing sediment on a beach; they are highly engineered projects. A beach nourishment template, which consists of numerous design parameters, is based on the specific characteristics of the site and the needs of a project. Every beach nourishment design is unique, since different beaches in different areas have different physical, geologic, environmental, and economic characteristics, as well as different levels of required protection. The design must consider climatology, the shape of the beach, type of native sand, volume and rates of sediment transport, erosion patterns and causes, waves and water levels, historical data and previous storms, probability of certain beach behaviors at the site, existing structures and infrastructure, and past engineering activities in the area.

The structure of a nourishment template is designed to yield a protective barrier that also provides material to the beach. A higher and wider beach berm is designed to absorb wave energy. Dunes may need to be constructed or existing dunes improved to reduce damage, including potential upland flooding, from storms. Figure 107 depicts a beach berm and dune on a typical beach profile. Nourishment length, berm height and width, dune height, and offshore slope are critical elements of a beach nourishment design, as well as periodic nourishment intervals. The renourishment interval will vary based on the initial design, wave climate, sand used, frequency of storms, and project age. However, beach nourishment is not an exact science; variables and uncertainties exist. Actual periodic nourishment intervals may differ from planned intervals based on conditions at the nourished beach and the frequency and intensity of storms.

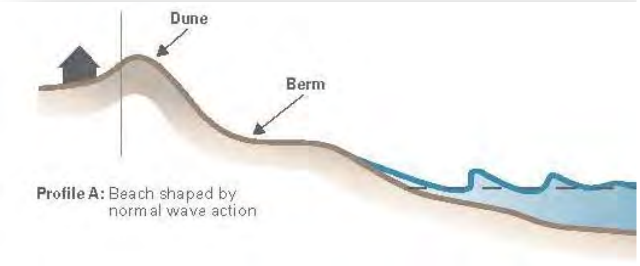


Figure 107. Typical beach profile and features (from Coastal Engineering Manual, 2003).

This proposed strategy evaluates potential improvements to project performance, storm damage protection, and subsequent cost savings that can be realized by modifications to the currently authorized beach nourishment template.

The feasibility studies for the authorized projects typically evaluate the a range of proposed beach nourishment template designs using alongshore and cross-shore analysis and/or modeling efforts to assess performance and storm damage protection afforded by the proposed nourishment template. However, the USACE policy has been to not consider increases to the natural berm elevation for the design template or to see if changes to the natural berm height result in performance gains or improved storm damage protection. Additionally, the currently authorized design template has not been re-evaluated following monitoring of the performance of the system. Monitoring data may reveal potential insight that could lead to modifications to the template. Therefore, this strategy involves assessing changes to the beach nourishment template that may yield cost savings over the long-term. An example of this type of analysis is presented herein by evaluating change in berm height and width on the performance of the 7 Mile Island project as a preliminary analysis of potential template modification.

Similar analyses could be completed for a number of parameters that are components of beach nourishment design; including:

- <u>Nourishment length</u> – Expanding the nourishment length, specifically through combining or syncing projects could be evaluated.
- <u>Berm Width</u> – The width of the berm could be modified to see if there is a cost benefit that could be attained. This might also involve a spatially variable berm width modification (e.g., overfilling the Coast Guard Training Area).

- Berm Height – The height of the berm could be modified to determine impact on storm damage protection.
- Offshore slope – The offshore slope of the nourishment can be changed.
- Grain size – The grain size of the source material for the nourishment may affect the performance of the projects. For example, coarser nourishment material may result in improved project performance (lower erodibility and hence more protection).

To assess potential changes in berm width and height at Cape May City, the computer model SBEACH (Larson and Kraus 1989) was used to assess cross-shore evolution. SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and further developed and verified based on field measurements (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990). The model predicts the time-dependent evolution of existing or design beach and dune profiles for specified water levels and wave conditions. In addition to the proposed nourishment template, the model requires a time series of wave heights, wave periods and water levels as forcing inputs. The specific storm information required by SBEACH is a time history of total water level (tide plus surge) and wind wave height and period. The WIS hindcast information, FEMA FIS still water storm surge elevation, and extremal analysis were used to develop a simulated 10-year storm for this analysis.

Figure 108 presents results of varying the berm height (blue line) and width (green line) of the 7 Mile Island authorized beach nourishment template. The horizontal axis shows the percent of material lost from the nourishment template area caused by a 10-year, 24-hour storm for various berm heights and widths. The left hand vertical axis shows berm height (NAVD88, ft), while the right hand vertical axis shows berm width (ft). The variable width scenarios use a constant 7.2 ft NAVD88 berm height, while the variable height scenarios use a constant 150 ft berm width, since the currently authorized template consists of a berm height of approximately 7.2 ft NAVD88 and a berm width of 150 ft. Figure 108 shows the changes in expected sediment lost from the template area for increased berm height and width. For example, the currently authorized project template loses approximately 95% of the periodic nourishment during the 10-year, 24-hour storm. However, by increasing the berm height a foot (8.2 ft NAVD88) the percentage of material lost is reduced to approximately 43%. Increasing the berm width further results in decreased losses, but also requires additional nourishment volumes, additional sediment sources, and finances. As such, there is a point of diminishing returns on the amount of required sand needed to extend the berm width and the increased performance gained. Adding more sand to the system may result in better performance, but also may not be worth the added cost of the additional sand. This type of analysis could be conducted to evaluate the sensitivity of various parameters in the beach nourishment design, their potential impacts on overall cost of the project, and identify the most cost-effective design template.

For example, the 8.2 ft berm height modified design requires approximately 943,000 cy of additional sediment to gain the required berm height during the initial increased periodic nourishment; however, the performance is improved over each 3 year cycle, such that the amount of sediment required for each periodic nourishment is reduced.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this example approach to template modification would result in a cost savings of approximately $2 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments, or increased renourishment intervals. For this particular shore protection project, the added sediment needed for the modified template does not provide significant financial benefit. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

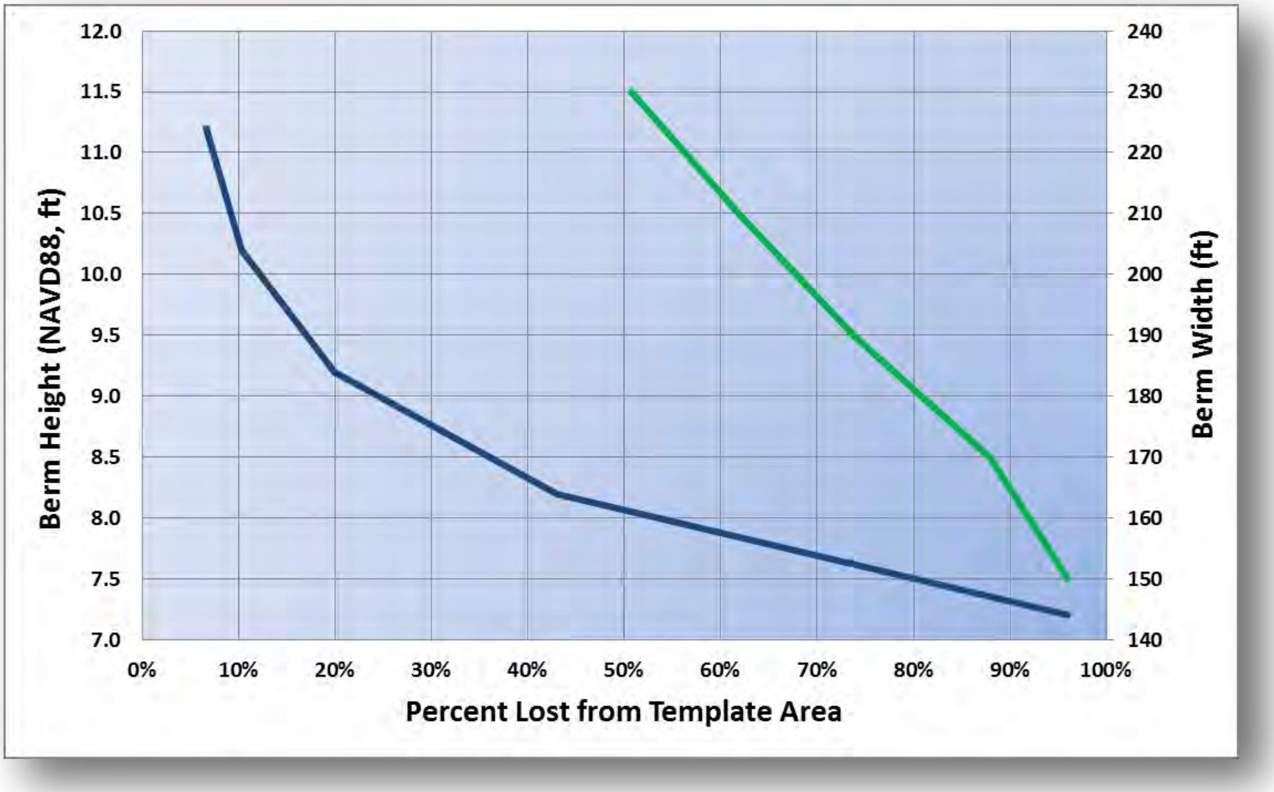


Figure 108. Eroded beach volume as a function of template berm height (blue) and width (green) for the 7 Mile Island (Stone Harbor and Avalon) nourishment project in response to a 24-hour, 10-year return period storm event.

In addition to the cost savings estimated from the reduced sediment volume requirements for periodic nourishments, modification of the beach nourishment template may have other additional benefits as well. For example, the modified template may result in improved storm damage protection and reduce potential upland damage costs. Examples of other potential benefits include habitat enhancement, reduced ponding or upland flooding, and reduced environmental impacts offshore due to reduced offshore sediment needs.

Relative to the current authorization, the existing template defines the authorized project and the NED plan. Changing the template would imply that the authorized plan was no longer the NED plan and the project would have to be reanalyzed. To do so would require the use of the existing New Jersey shore study authority to determine the degree of federal interest, get the requisite environmental clearances, and recommend a change in the authorized plan. This would require the existing project authority to be modified by Congress. It would also likely require a new study cost sharing agreement to be signed, as well as a non-federal sponsor willing to contribute 50% of the study costs and agree to any changes in the construction and long-term cost sharing. A new PCS conforming to the model agreement would have to be signed.

Potential constraints associated with modification of the beach nourishment template include environmental concerns (e.g., occupying a larger offshore footprint), political and local community concerns that would limit the ability to change the template (e.g., communities wouldn't want an increase berm height), and logistical concerns associated with modification of the authority to construct the project.

Table 45 presents a summary of the criteria evaluated for the refined beach nourishment template strategy and ranks it as a low priority, due to the low cost savings for this project area, and a Tier level of 2. Next steps for this strategy would be to conduct more detailed studies to assess if template modifications are warranted. The studies would focus on the cost benefit aspects of template modification.

F. Additional/ModifiedCoastal Engineering Structures

This strategy proposes to add terminal groin structures at the downdrift end of both the Avalon and Stone Harbor nourishment templates. This would consist of constructing a terminal groin in the vicinity of 30th to 32nd Street in Avalon (Figure 109), and bolstering (heightening and/or extending) the existing groin (Figure 110) at the southern end of Stone Harbor in order to provide potential cost savings and improved beach nourishment performance for the region.

Table 45. Refined Beach Nourishment Template Strategy Summary.

Criteria	Summary
1. Authorization	Requires a change to the authorized plan and would include new study, permits, and cost-sharing agreements
2. Constraints	Logistic, political, local community, and environmental concerns
3. Cost Savings	Minimal savings for this particular project; depends on template modification, $2 million for case evaluated
4. Service Life	Increased service life of beach nourishment expected
5. Other Benefits	Improved storm damage protection, habitat enhancement, reduced offshore environmental impacts
6. Priority	Low
7. Tier Level	Tier 2
8. Next Steps	USACE Philadelphia district to decide if the strategy is warrants further study

To provide a preliminary evaluation of the terminal groins, the cross-shore distribution of the longshore transport was evaluated using relationships proposed by Longuet-Higgins (1970, 1970a). In this way, the effect of a shore-perpendicular structure on reducing or increasing the longshore sediment transport can be estimated.

Figure 109. Potential location of a terminal groin for the Avalon beach nourishment template.

Figure 110. Existing groin at the southern end of Stone Harbor.

The cross-shore distribution of longshore transport can be determined using a theoretical radiation stress approach (Longuet-Higgins and Stewart, 1962). This momentum based theory describes the energy imparted on the bottom of a nearshore breaking zone by shallow water waves.

When shallow water waves break at an angle that is not perpendicular to the coastline, the result is a net force that pushes a parcel of water in the direction of the oblique angle. In the case of a series of multiple waves breaking at a similar angle; a net current results that continually forces water along the shore (or alongshore). The total volume flow rate, Q, is given as a function of velocity, v_o, as

Equation 10:

$$Q = \frac{1}{3s} {h_B}^2 v_0 = \frac{1}{3} h_B |x_B| v_0$$

where h_B is the depth of water at the breaker line, s is the slope of bottom, and x_B is the normalized distance to the breaker line.

Horizontal mixing is the result of waves breaking at different locations and wave-induced eddies varying the profile of the cross-shore velocity distribution. To account for this variability due to mixing, a quadratic equation is used to create a typical cross-shore flow profile. The shape of this new function is dependent on the known variability of the wave conditions and a horizontal eddy parameter. Figure 111 is a schematic representation of the long-shore velocity profile as a function of the normalized offshore distance to the breaker line. The dashed line represents the values without mixing. After applying a quadratic equation and its mixing coefficients, the longshore velocity profile looks like the solid line. The area under both lines equals the volume flow rate, Q.

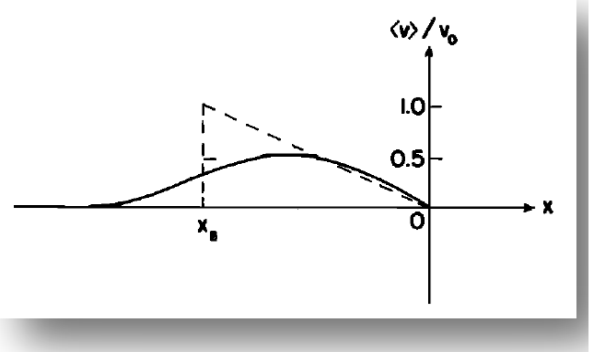


Figure 111. Example cross-shore distribution of alongshore velocities.

This distribution is calculated based on site-specific physical processes data (e.g., WIS hindcast information) for the 7 Mile Island region, and is presented in Figure 112. The distribution can then be applied to assess different lengths (cross-shore direction) of structure by determining the amount of littoral transport that may be intercepted by the structures.

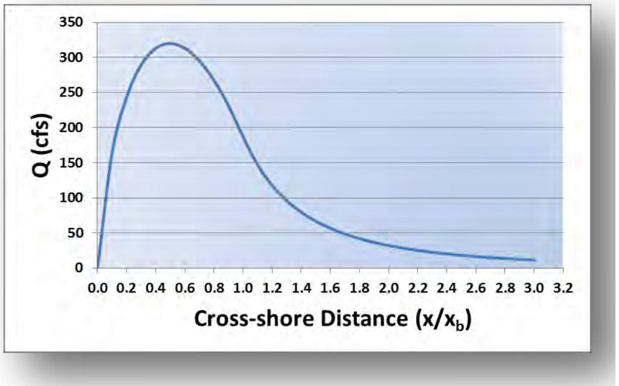


Figure 112. Cross-shore distribution of alongshore flux for 7 Mile Island area.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this structural addition at Avalon and modification at Stone Harbor would result in a cost savings of approximately $12 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments. The analysis evaluated an Avalon terminal groin of 100 ft from the current Mean High Water (MHW) line, and a sand tightening, slight extension, and slight raising of the Stone Harbor Terminal Groin. This cost analysis assumes:

- Groin extension and construction costs of $1.1 million based on previous structural cost bids
- A net southward littoral drift rate of 251,000 to 450,000 cy/yr (USACE, 2006)
- Periodic nourishment conducted as currently authorized (every 3 years for both Avalon and Stone Harbor)
- The structure maintains its same rate of effectiveness over the 50-year service life
- Reduced sediment flow towards the center of 7 Mile Island and the southern end of 7 Mile Island does not significantly impact the stability of the shoreline (given the historic seaward growth of the shoreline during the nourishment activities (shoreline change rates), this appears to be a reasonable assumption).

Extensions of other various lengths can also be evaluated in this manner. However, the structure should not be extended so far as it would negatively impact the downdrift shorelines by intercepting too much of the cross-shore distribution of alongshore sediment movement. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Structural modifications could be evaluated under the existing New Jersey Shore authority. However, it would require study cost sharing, a non-federal sponsor and if it meets the criteria for implementation, it would also require a new construction authorization.

Constraints for this strategy include potential environmental impacts that need to be assessed and coastal processes evaluations that should evaluate the impact of proposed structural additions and/or modifications.

Table 46 presents a summary of the criteria evaluated for the structural modification strategy and ranks it as a low to intermediate priority with a Tier level of 3. Next steps for this strategy would be to initialize more detailed studies to assess the impact of proposed structural modifications from a physical and environmental impact basis. The studies would also focus on the cost benefit aspects of the structural modification proposal(s).

Table 46. Additional/Modified Coastal Engineering Structures Strategy Summary.

Criteria	Summary
1. Authorization	Requires study of cost sharing and a non-federal sponsor to implement construction authorization
2. Constraints	Environmental impacts need to be evaluated, coastal processes assessment to evaluate impact of structural modification
3. Cost Savings	$12 million for structural additions presented herein
4. Service Life	Potential beach nourishment performance enhancement, structural service life expected to be 50 years
5. Other Benefits	Reduced environmental impacts to offshore resources
6. Priority	Low to Intermediate
7. Tier Level	Tier 3
8. Next Steps	Coastal processes and environmental studies to determine relative cost benefit of structural modifications

G. Site-Specific Coastal Processes Evaluation

This strategy involves developing a comprehensive, coastal processes based understanding of the prominent erosion that occurs in the Borough of Avalon, at the northern end of 7 Mile Island. A site-specific study, intended to focus on detailing the coastal processes (waves, tidal currents, wave-induced currents, sediment transport, etc.), would be recommended to identify potential alternatives that may improve the existing shore protection authorization, or provide a better understanding of how to potentially modify the shore protection approach.

Avalon has had a history of beach erosion and numerous attempts have been made to mitigate damage and maintain a recreational beach, particularly in the north section in the Borough of Avalon (between 8th and 26th street). A long-term investment has been made in Avalon's beaches. However, despite best efforts, erosion continues to plague the area, threatening valuable infrastructure and limiting the recreational opportunities. Nearly 7.4 million cy of sand have been added to the beaches since 1987. The need for local action also is heightened with the reduced federal funding for renourishment. Maintenance has been solely borough and/or state funded, which is a difficult investment to support in the long-term.

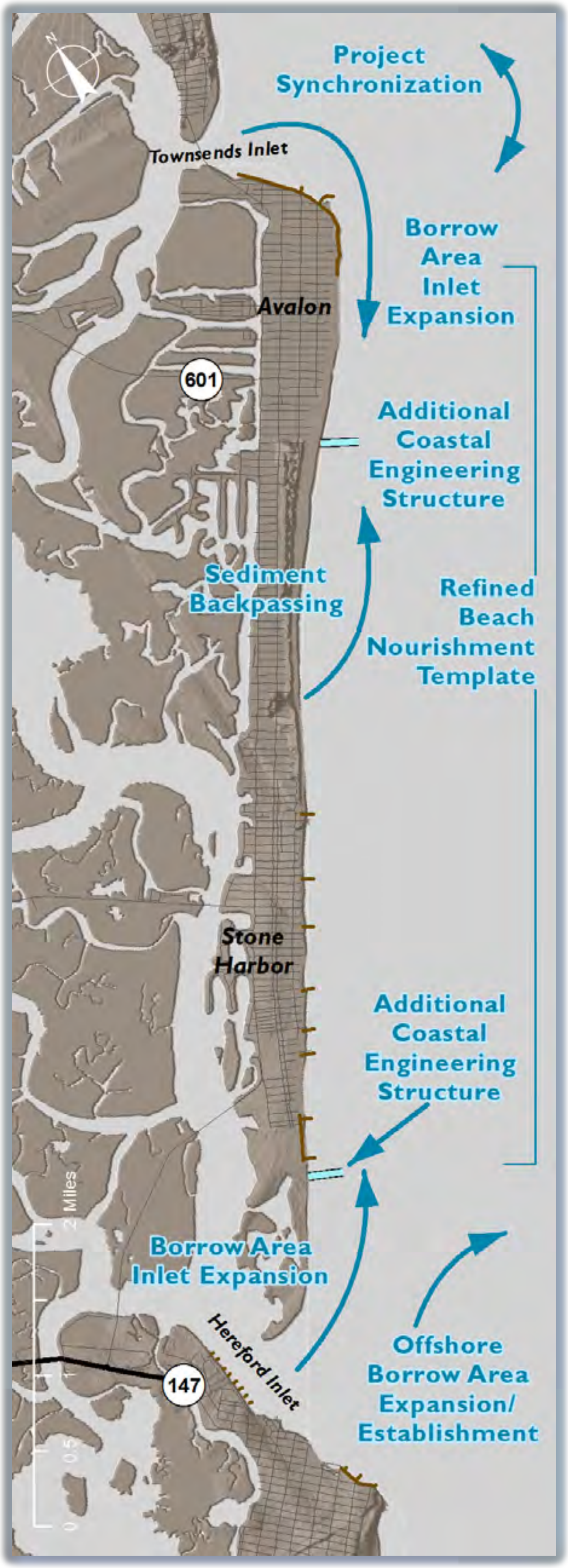
Despite the Federal project that brought 1.3 million cy of sand to this area in 2002, and subsequent municipal and state efforts to maintain a protective beach through annual renourishment, the ocean facing beach at the north end of Avalon has continued to erode, placing public and private infrastructure at risk. A number of studies have been conducted to evaluate alternatives for shore protection in Avalon, and monitoring data have been collected that document the beach loss; however, a comprehensive study that defines the cause and effect relationship between the dominant coastal processes and shoreline erosion has not been performed. This proposed strategy is therefore geared to address the knowledge gaps in the existing work.

Table 47. Site-Specific Coastal Processes Evaluation.

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings, potential future savings
4. Service Life	Not applicable
5. Other Benefits	An improved understanding of the coastal processes and potential mitigation options for Avalon
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study

The intent of this strategy is to provide an improved understanding of the causes and nature of the significant erosion, including the short service life of the nourishment projects that are conducted. The study should be rooted strongly in applying scientific and engineering tools (i.e., data and models) to understand the erosional processes. This should include coupled hydrodynamic, wave, and sediment transport modeling, supported by field observations. Essentially if the coastal processes and causes of the elevated erosions are better understood, then perhaps a more advantageous mitigation approach could be implemented.

Table 47 presents a summary of the criteria evaluated for the site-specific coastal processes evaluation strategy (although many of the criteria are not applicable for this particular strategy) and ranks it as an intermediate priority with a Tier level of 1. Although there is no immediate cost savings associated with implementation of this strategy, future financial savings could be significant for the given investment (expected to be approximately $200,000). The local Borough of Avalon may have already initialized a similar evaluation to assess the coastal processes and erosion along their shoreline.



Summary

This section presents a brief summary of all the strategies presented for 7 Mile Island (Stone Harbor and Avalon). The focus is on the potential cost savings and priority levels to assist in the identification and selection of strategies that could be implemented immediately and/or further pursued to more cost effectively manage sediment within the project area.

Figure 113 provides a summary of the estimated total cost savings (compared to current operations) over a 50-year time horizon for a number of the potential strategies (those that indicated a cost saving could be realized) for comparison purposes. Additional analysis could be completed to evaluate the potential cost savings associated with combining various strategies as well.

Table 48 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies presented in Table 48 are listed in order of priority and estimated ease of implementation.

Table 48. Avalon and Stone Harbor Strategy Summary.

Strategy	Prioritization	Tier
A. Project Cycle Synchronization	High	1
D. Sediment Backpassing	High	2
B. Offshore Borrow Site Expansion	High	1
G. Site-specific Coastal Processes Evaluation	Intermediate	1
C. Increased Dredging of Townsends and Hereford Inlets	Intermediate	2
H. Additional Coastal Engineering Structure	Low to Intermediate	3
E. Refined Beach Nourishment Template	Low to Intermediate	2

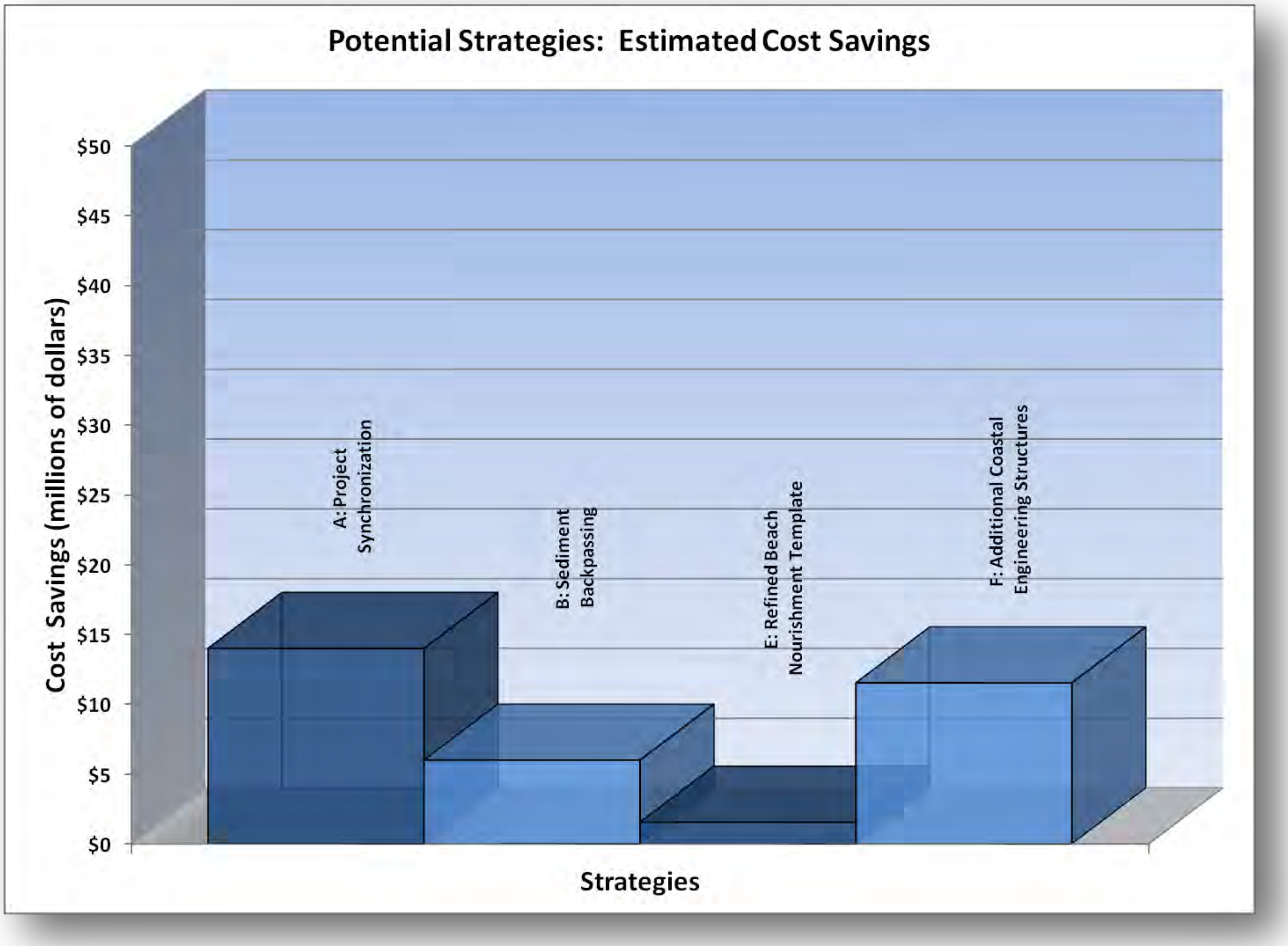


Figure 113. Estimate cost savings (compared to current operations) over a 50-year time horizon for select 7 Mile Island (Stone Harbor and Avalon) strategies.

LUDLAM ISLAND AND PECK BEACH

Project Description

The Great Egg Harbor Inlet to Townsends Inlet Shore Protection Project was authorized for construction by Section 1001 of the Water Resources Development Act of 2007. The project area extends 16 miles along the south coast of New Jersey and includes the barrier islands of Peck Beach and Ludlam Island, as well as Great Egg Harbor and Corson Inlets. The authorized project includes a protective berm and dune along the south end of Peck Beach in the community of Ocean City. A berm and dune are also authorized for the entire oceanfront of Ludlam Island in the communities of Strathmere and Sea Isle City. The Peck Beach portion of the project includes periodic nourishment every 3 years and the Ludlam Island portion includes periodic nourishment every 5 years. The northern end of Peck Beach is included in another Federal Shore Protection Project that specifically addresses north Ocean City.

The design berm for Ocean City is 100 ft wide at an elevation of 7.0 ft NAVD. The fill extends seaward at a slope of 1V:30H to 1V:25H to meet the natural grade of the foreshore. The dune crest is 25 ft wide at an elevation of 12.8 ft NAVD, with side slopes of 1V:5H. The total length of fill in Ocean City is 14,000 linear ft, extending from 34th Street to 59th Street. The project authorizes an initial construction volume of 1,603,000 cy from offshore borrow area M8, with periodic nourishment of 306,000 cy every 3 years. The initial beachfill design includes sand for advanced nourishment. Dune grass planting and sand fencing are also included to help maintain dune stability. Figure 114 shows the authorized project along the south end of Peck Beach.

The Ludlam Island design includes a 50 ft wide berm at an elevation of 6.0 ft NAVD. The slope of the beachfill ranges from 1V:50H to 1V:30H. The dune crest is 25 ft wide at an elevation of 14.8 ft NAVD, with side slopes of 1V:5H. The 35,376 ft long beachfill extends from north of Seaview Avenue in Strathmere to Pleasure Avenue in Sea Isle City. The project also includes a 734 ft taper into Corson's Inlet State Park and a 66 ft taper into the terminal groin south of 93rd Street. A volume of 5,146,000 cy is authorized for initial construction from offshore borrow sites L1, L3, and C1. The initial design includes sand for advanced nourishment. A 5-year cycle of periodic nourishment with 1,383,000 cy is also included. Dune grass planting and sand fencing are authorized to help maintain dune stability. Figure 115 shows the authorized shore protection project at Ludlam Island.

Project History

Peck Beach and Ludlam Island have a long history of flooding and storm-induced erosion. The south end of Ocean City is highly vulnerable to storm damage; in most sections the existing bulkhead is the only protection available during storms. Little to no protective dunes exist for much of the south Ocean City coast, and the high tide shoreline extends nearly to the bulkhead in many areas. In response to this long-term erosion, the State of NJ and local stakeholders implemented a beachfill project in the summer of 1995. Since this time, storm-related erosion has removed much of the nourishment.

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Figure 114. Great Egg Harbor to Townsends Inlet Authorized Shore Protection Project at Peck Beach.

Figure 115. Great Egg Harbor to Townsends Inlet Authorized Shore Protection Project at Ludlam Island.

Similar to the south end of Ocean City, Ludlam Island is also highly vulnerable to storm damage. In Strathmere, the high tide shoreline encroaches on the existing bulkhead, and wave overtopping during storms causes flooding and wave-induced damages to residential structures. A localized beachfill was placed at the northern most portion of Strathmere by local interests in 1999 to reduce storm damage vulnerability.

Further to the south in the community of Whale Beach, the narrow barrier supports only one road, which is overtopped during major storm events. Protective dunes are nonexistent in this area, and the important evacuation route is often impassable during storms. A dune restoration project sponsored by FEMA was constructed in 1995, but offered minimal protection as the dunes were destroyed during a storm in January 1996.

At Sea Isle City along the south end of Ludlam Island, beach erosion has caused retreat of the shoreline. Water level at high tide currently reaches the existing bulkhead meant to protect the promenade and nearby residential developments. A major storm would cause extensive damage and possible destruction of multiple structures. Along the Townsends Inlet area of Sea Isle City, severe erosion on the order of 32 ft/yr eroded away the beach and protective dunes, leaving the area directly vulnerable to storm damage.

Over the years different types of coastal engineering structures have been used to control erosion along this stretch of coastline. Most of the developed area at the south end of Ocean City is protected by a bulkhead and stone revetment, and a series of 18 groins are present. In Strathmere, a small two block portion of the coast contains a timber bulkhead, and 15 groins are dispersed throughout the community. The narrowest section of Ludlam Island in Whale Beach contains a 4,000 ft long county-sponsored geotextile project. The tubes were placed between 1st and 13th Streets during the winter of 1998 to provide protection during minor storms. The northern portion of Sea Isle City between 29th and 57th Streets is protected by a timber bulkhead and fronting a stone revetment. A series of 19 groins protect this area to 78th Street. A small geotextile tube project is located along the oceanfront near Townsends Inlet, and a stone terminal groin built in 1999, is located south of 93rd Street.

The Great Egg Harbor Inlet to Townsends Inlet Shore Protection Project was authorized to mitigate this ongoing erosion. Initial construction is pending execution of a Project Partnership Agreement (PPA), acquisition of necessary real estate, completion of plans and specifications, and contractor solicitation and award.

In 2009 the State of NJ worked with the communities of Strathmere and Sea Isle City to nourish beaches using sand dredged from Corson Inlet. A total of 891,000 cy was placed in Strathmere, and 394,780 cy was placed between 1st and 15th Streets and 40th and 52nd Streets in Sea Isle City (Figure 116).

Project Observations

The project has not been constructed. Until initial construction of the Great Egg Harbor to Townsends Inlet Shore Protection Project is complete, potential damages during storms will be a concern.

Figure 116. Areas of nourishment completed in 2009 by the State of NJ and the municipalities of Strathmere and Sea Isle City.

Potential Strategies

This section presents the potential strategies for the Great Egg Harbor to Townsends Inlet Shore Protection Project that are intended to provide improved project performance, cost savings, or other benefits. These strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. In addition, some of the strategies include a first-order technical analysis to evaluate the relative merit of the proposed strategy. These analyses are not intended to be detailed assessments and include some assumptions and simplifications. Rather, they are geared towards providing a preliminary estimate of the potential benefits that may be realized if the strategy is implemented. In other words, the analysis presented herein can be used as an initial screening tool to determine if a strategy warrants further consideration. For some strategies, a more detailed analysis may be required if the strategy is more formally pursued.

A. Project Cycle Synchronization

The project cycle synchronization strategy represents informally synchronizing the construction of authorized shore protection projects that are in close proximity. The intent is to reduce mobilization and demobilization costs by combining re-nourishments. For this project, coordination was considered between the Ludlam Island (Sea Isle City and Strathmere) periodic nourishment (1,820,000 cy every 5 years) and the Avalon and Stone Harbor periodic nourishments (746,000 cy every 3 years). Project cycle synchronization of the Peck Beach (Figure 114) and Ocean City periodic nourishments were also considered in a formal combination (Strategy B), and were assumed to be straightforward to sync since they both have the same periodic nourishment cycle.

A first-order analysis of potential cost savings realized by theoretically combining the periodic nourishment efforts at the Avalon and Stone Harbor with Sea Isle City was conducted. It is assumed that the authorized five year periodic nourishment cycle for Ludlam Island could be extended to a six year cycle and nourished jointly with the Avalon and Stone Harbor projects.

A brief analysis, which combines the conservation of sediment equation with the linearized transport equation, was conducted to determine if the Ludlam Island periodic renourishment could be extended to six years. The *Pelnard-Considére* (1956) equation (Equation 11) is used to obtain theoretical results to establish design and performance standards for the Ludlam Island nourishment. A more detailed description of the derivation of the equations and their applications can be found in Dean (2002).

Equation 11:

$$M(t) = \frac{2\sqrt{Gt}}{l\sqrt{\pi}}\left(e^{-\left(\frac{l}{2\sqrt{Gt}}\right)^{2}} - 1\right) + erf\left(\frac{l}{2\sqrt{Gt}}\right)$$

where *M(t)* is the proportion of sand remaining in the placed location, G is the alongshore diffusivity parameter, t is time, and l is the project (nourishment) length. The alongshore diffusivity (Equation 12) is presented by *Pelnard-Considére* (1956).

Equation 12:

$$G = \frac{KH_b^{5/2}\sqrt{g/\kappa}}{8(s-1)(1-p)(h_* + B)}$$

where K is the sediment transport coefficient, which is a function of sediment size, B is the berm elevation, H_b is the breaking wave height, h_* is the depth of closure, p is the *in-situ* sediment porosity (approximately 0.35 to 0.40), s is the sediment specific gravity (approximately 2.65), and κ is the ratio of wave height to water depth within the surf zone (approximately 0.78).

The *Pelnard-Considére* equation can be applied to determine the performance of a beach nourishment project. For this analysis, the Wave Information Study (WIS) time series of wave and wind data, developed by the United States Army Corps of Engineers, were used to describe the wave climate offshore of New Jersey. The WIS, performed by the USACE, has met a critical need for wave information in coastal engineering studies since the 1980s and is widely accepted for design purposes for United States shorelines by many coastal engineers and scientists (http://wis.usace.army.mil/). WIS contains time series information of spectrally-based, significant wave height, peak period, peak direction, and wind speed and direction produced from a computer hindcast (prediction) model. The hindcast wave model, WISWAVE (Resio and Tracy, 1983) is simulated using wind information (speed and direction) at selected coastal locations around the United States. Wave measurements made by NOAA during the 1980s made verification of the WIS results possible by comparing the statistics and the distributions of wave heights and periods from different time periods (Hubertz et al., 1993). The availability of long-term records makes WIS data attractive when considering average or seasonal wave conditions. Twenty years of wave hindcast data from WIS station 63147 were used for analysis of the Ludlam Island nourishment.

In addition, since the offshore wave environment can be complex, calculation of the alongshore diffusivity was based on the wave energy distribution for average annual directional approach bins. Data were segregated by direction of approach and an energy distribution, as a function of frequency, was generated from all the waves in each directional bin. The energy associated with each frequency was then summed to create an energy distribution for each approach direction. In essence, a representative two-dimensional spectrum was generated for each approach direction bin based on the sum of all the waves approaching from that mean direction. This was combined with the percentage of occurrence to create a 20 year evaluation of wave impacts at the shoreline. This energetic directional bin approach has been successfully utilized in transformation modeling (Byrnes et al., 2000) and identifies all potential approach directions, including those that may occur only a small percentage of time during a typical year, but potentially have significant impact on sediment transport. Values of alongshore diffusivity were computed for each directional bin and used for modeling beach nourishment performance.

Since the material spreads over time, it is possible to evaluate the longevity of the nourishment by looking at the amount of material left in the project area. Subsequently, nourishment alternatives can be compared to one another based on their longevity. The service life of the beach nourishment can be based upon the percent of the initial beach nourishment left within the boundary of the initial fill area. The percentage remaining will decrease with time, but that material is not necessarily lost from the system, it has just spread to regions outside of the original nourishment template. For example, sediment may have been transported offshore or along the beach. Therefore, although the sediment no longer falls within the initial nourishment template, it has not completely disappeared from the system.

Figure 117 presents the projected performance of the Ludlam Island authorized project. The performance is expressed in terms of amount of material remaining in the initial template region, as a function of time. The percent of initial material remaining is presented along the left hand axis, while the time in years is presented along the bottom axis. For example, after 6 years, approximately 75% of the initial fill volume is remaining, or approximately 3.86 million cy of the initial 5.15 million cubic yard nourishment. A total of approximately 1.3 million cy would be required in a periodic nourishment to return the nourishment template to the design, which is less than the authorized periodic nourishment of 1.82 million cy on a 5 year cycle. Therefore, it appears reasonable to assume that the Ludlam Island periodic nourishment could be extended from 5 to 6 years.

Mobilization and demobilization costs constitute a significant portion of typical dredging contracts, and these costs do not necessary get reduced with increased contract size (e.g., larger dredging projects). A number of factors contribute to the variations in dredging contract costs, including market conditions at the time, proximity of the borrow area to the nourishment site, and the limited number of capable dredging contractors. As such there can be large uncertainties when forecasting beach nourishment dredging and placement costs. Recent dredging contracts (2002-2009) for nourishment efforts in New Jersey and Delaware (Gebert, 2010) can account for 10% to 60% of the total winning bid, and average mobilization and demobilization costs are approximately $2 million per nourishment effort, regardless if it is an initial or periodic nourishment effort. The unit cost of sand over that same time period ranged from approximately $4 to $15/cy. Therefore, the preliminary analysis presented herein also assumes dredge mobilization and demobilization costs of $2 million, and a conservative unit price of $15/cy for sand.

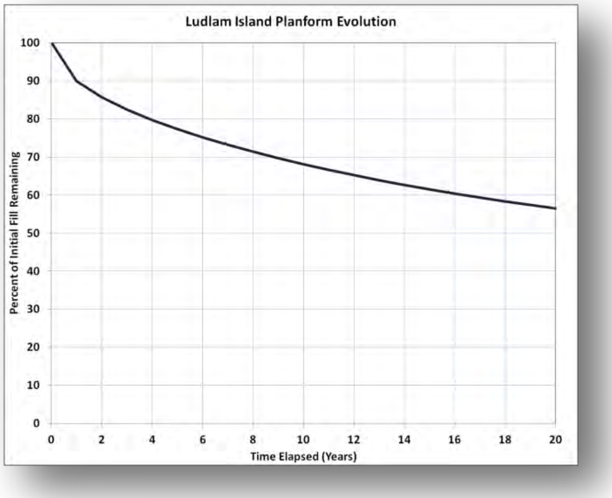


Figure 117. Estimated beach nourishment performance for the authorized project at Ludlam Island. This analysis assumes the project is constructed as authorized.

Since many strategies may involve integration of projects with different remaining authorized lifetimes, a 50-year time horizon is used for comparison purposes irrespective of the remaining authorized project life. Use of a single standard time period also allows direct comparison between various strategies across projects and for those involving initial construction costs and maintenance (O&M) costs.

Over a 50-year time horizon, there is a cost savings of $14 million based solely on the reduced number of nourishment events realized by synchronization of the projects every 6 years, while still nourishing the Avalon and Stone Harbor regions every 3 years as authorized. Additional cost savings may be realized from reduced contracting and management requirements. A comparison to current operations and to other strategies is presented in the summary section.

Fewer periodic nourishment episodes will also have an environmental benefit since there will be less frequent disturbance (reduced by 30%) of the offshore borrow site areas, reduced disturbance on the beaches, and reduced overall air and noise pollution.

This strategy can be implemented at any time since existing authorities do not preclude any re-nourishment from being done as part of one contract as long as the funds for each are available and are not comingled. Further, all requisite environmental clearances must be attained before award of such a contract. The implementation of this strategy has minimal constraints, limited to availability of dredging equipment and borrow site quantities, which are already constraints of current operations.

Table 49 presents a summary of the criteria evaluated for the improved project coordination strategy and ranks it as a high priority and easily implementable (Tier 1 level). This strategy should be pursued since the pathway to implementation is straightforward and there are no significant constraints.

Table 49. Project Cycle Synchronization Strategy Summary.

Criteria	Summary
1. Authorization	No existing authorization limitations
2. Constraints	No constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$14 million over 50-year time horizon
4. Service Life	No change to service life
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Evaluate potential storm damage impacts, coordinate dredging, and implement

B. Formal Project Combination

This strategy involves formally aligning the federal authorizations of the Peck Beach (a component of the Great Egg Harbor to Townsends Inlet Shore Protection Project) and the Ocean City project such that periodic nourishment construction of these projects would always occur at the same time. This combine the nourishment volumes and align periodic nourishment efforts creating a single project. The goal of this strategy is to not only reduce mobilization and demobilization costs, but also provide increased project performance. Thereby, the number of periodic nourishments would be reduced through improved beach sustainability.

The *Pelnard-Considére* equation, as presented above in strategy A, was applied to determine the performance of the individual and combined beach nourishment projects. The same approach was also applied here. However, in this case, the offshore wave information used to assess the beach performance was determined using a WIS station offshore of Ocean City (ST63143).

Figure 118 presents the performance of the authorized projects for Peck Beach (south of Ocean City), Ocean City, and a combined nourishment scenario that would nourish both projects simultaneously. The performance is expressed in terms of amount of material remaining in the initial template region, as a function of time, for project lengths corresponding to the Peck Beach (black line), Ocean City (green line), and a combined nourishment (blue line). All results were adjusted to include a background erosion rate corresponding to the historical shoreline change. That is, in addition to the dispersion that is occurring, an additional amount is eroded due to the natural erosion of the beach. The percent of initial material remaining is presented along the left hand axis, while the time in years is presented along the bottom axis. For example, after 3 years, approximately 76% and 57% of the initial fill volume is remaining for Ocean City and Peck Beach, respectively. For a combined nourishment (blue line), approximately 83% of the initial fill volume remains after 3 years. This represents a significant improvement in project performance.

Since both the Peck Beach and Ocean City nourishments have a 3 year periodic nourishment cycle, it would be straightforward to construct the two projects jointly, and receive benefits from both project cycle synchronization (strategy A) and improved performance (strategy B) . The analysis indicates that through combining the projects, the periodic nourishment cycle for both Peck Beach and Ocean City could be extended to 6 years or longer, or the amount of sediment needed for each 3 year periodic nourishment would be reduced by approximately 575,000 cy. Therefore, the larger combined nourishment would make it feasible to increase the periodic nourishment interval or reduce the sediment requirements at the current periodic interval.

Using the same cost assumptions as presented in strategy A (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this strategy would result in a cost savings of approximately $138 million over a 50-year time horizon due to reduced volume requirements. This assumes periodic nourishment remains at a 3 year interval of approximately 900,000 cy (combined between Peck Beach and Ocean City) to return the nourishment to the original construction template. Cost benefits of this strategy are compared to current operations and other strategies in the summary section. Additional cost savings may be realized from reduced contracting and management requirements.

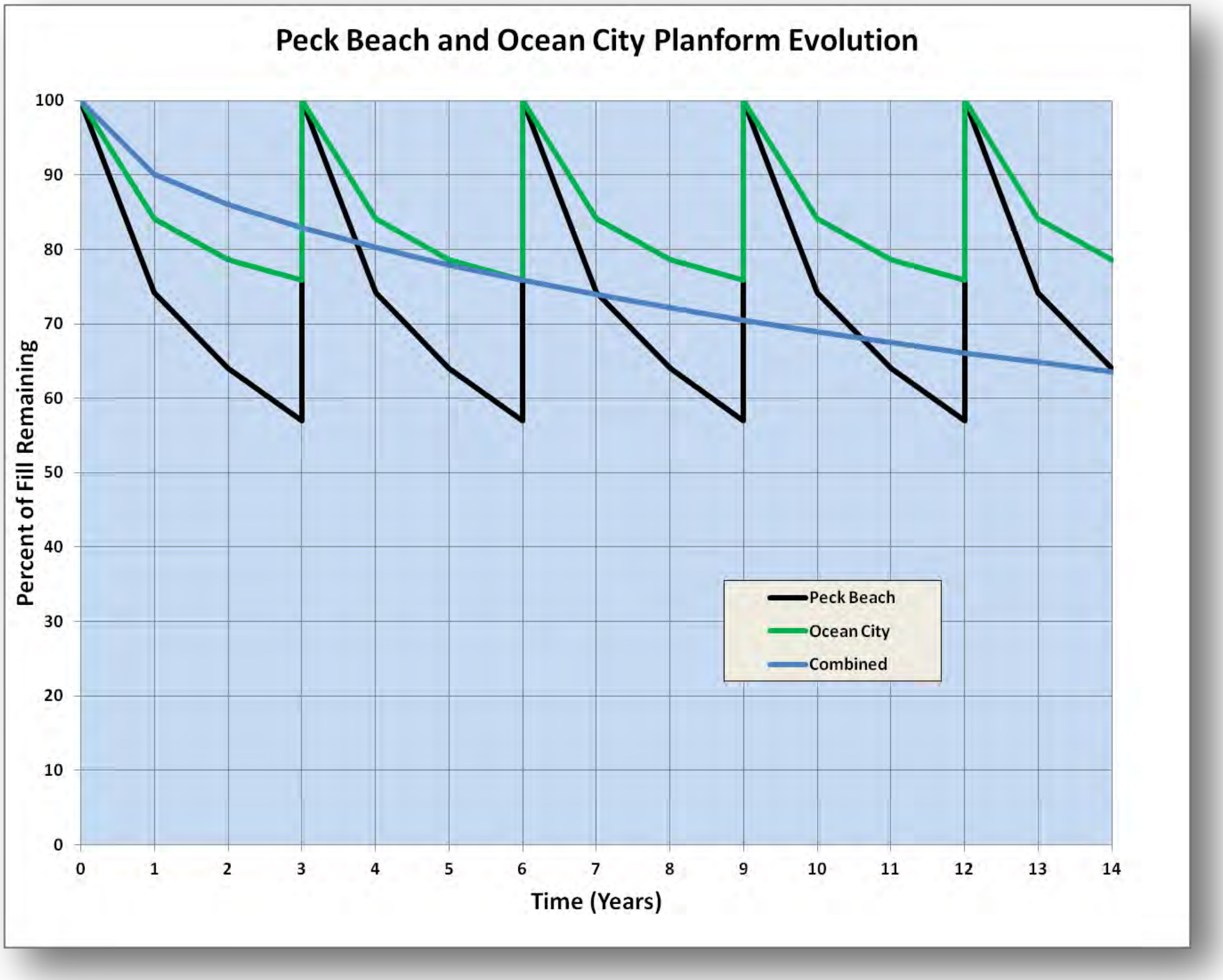


Figure 118. Estimated beach nourishment performance for the authorized projects at Peck Beach (black line), Ocean City (green line), and the combination (blue line) of the two projects.

The reduced number of periodic nourishment episodes and reduced long-term volume requirements will also have an environmental benefit as there will be less frequent disturbance of the offshore borrow site areas, reduced disturbance on the beaches, reduced overall sediment needs (approximately 10 million cy less over 50 years) and reduced overall pollutions (e.g., noise, air, etc.).

This strategy may require a new construction authorization since the combined project would be different in scale than the individual projects. A new feasibility study would have to be performed to determine the extent of federal and to address the environmental requirements of any new plan. There is a significant potential that the cost sharing may change as a result of the new plan as well as the timing and amount of non-federal funds required. Borrow areas would have to be revisited and sufficient borrow sites identified and evaluated as part of the reanalysis. The study itself could be accomplished under the existing New Jersey shore study authority and would likely require a feasibility study cost sharing arrangement. Finally, if a project is recommended and authorized for construction, a new Project Cooperation Agreement (PCA) would have to be signed. However, if the project templates remain the same scale as the currently authorized projects, it may be more reasonable to implement this approach in an informal synchronization (Strategy A) and achieve the same benefits.

The implementation of it has minimal additional constraints, limited to availability of dredge equipment and borrows site quantities, which are constraints of the current operations as well.

Table 50 presents a summary of the criteria evaluated for the project combination strategy and ranks this strategy as a intermediate to high priority with a Tier level of 2 (given the potential time constraints and requirements associated with changing authorizations). Given that the benefits of this strategy may be attained on an informal basis (Strategy A), there may be less urgency formally combine projects.

Table 50. Project Combination Strategy Summary.

Criteria	Summary
1. Authorization	Depending on the exact nature of the combination or modification to the project scale, it is likely that a new construction authorization and other documents will be required.
2. Constraints	No additional non-authorization requirement constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$138 million over 50-year time horizon
4. Service Life	Relatively significant increase in project longevity and service life
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale and reduced overall volumetric sand requirements in long-term
6. Priority	Intermediate to High Priority
7. Tier Level	Tier 2
8. Next Steps	If formal authorization is pursued, need more detailed studies

C. Borrow Area Expansion at Townsends and Corson Inlet Material

This strategy intends toexpand the borrow areas at Townsends and Corson Inlets for periodic nourishments on Ludlam Island (Sea Isle City and Strathmere). This strategy would formalize an activity that already takes place occasionally; the State of New Jersey already conducts some nourishment projects using material from Corson and Townsends Inlets.

There is a history of dredging and beneficial reuse of the sediment at Townsends Inlet, with most of the nourishment being conducted at Avalon. Annual side-cast navigation dredging from 1950 to 1977 nourished the inlet-facing beaches of Avalon. Between 1967 and 1974 this beneficial reuse averaged 26,200 cy per year, with dredging events ranging between 1,726 to 40,160 cy (Everts et al., 1980). In 1977 and 1984, large-scale dredging operations in Townsends Inlet provided nourishment material to Sea Isle City beaches to the north. In 1987, Townsends Inlet provided approximately 1,380,000 cy to severely eroded Avalon beaches. Periodic nourishment of Avalon occurred eight times between 1990 and 2001, with dredging volumes from Townsends ranging between 72,000 and 635,000 cy. In 2002, USACE constructed a nourishment effort at Avalon, pumping 1,300,000 cy to Avalon beaches from Townsends Inlet. Periodic nourishment occurred again at Avalon in 2006, 2008, 2010 and 2011 using Townsends Inlet material and volumes ranging from 225,000 to 643,000 cy. Table 51 summarizes the history of dredging activity at Townsends Inlet from 1967, showing the approximate quantity of material removed from the inlet.

To determine the average annual amount of material dredged from Townsends Inlet, these dredge records were used to calculate the cumulative dredging completed from 1978 (after sidecasting was discontinued) to present. Sidecasting volumes were not included in the analysis, since this dredging approach does not remove sediment from the inlet. Figure 119 presents the cumulative sediment volume dredged in Townsends Inlet from 1978 to 2011. Each black dot in the figure represents a dredging event, and shows the cumulative volume dredged as a function of time. The blue line in the figure represents a linear fit to the data and provides an average dredge quantity of approximately 263,000 cy per year. Historically, dredge frequency has been every 2.1 years.

Table 51. Summary of dredging activity at Townsends Inlet.

Year	Quantity (cy)	Placement Location
1967	40,190	Avalon Inlet Shoreline
1968	14,690	Avalon Inlet Shoreline
1969	21,460	Avalon Inlet Shoreline
1970	40,160	Avalon Inlet Shoreline
1971	10,420	Avalon Inlet Shoreline
1972	17,560	Avalon Inlet Shoreline
1973	1,726	Avalon Inlet Shoreline
1974	37,250	Avalon Inlet Shoreline
1978	574,000	Sea Isle City
1984	820,000	Sea Isle City
1987	1,380,000	Avalon
1990	400,000	Avalon
1992	350,000	Avalon
1993	347,000	Avalon
1995	635,000	Avalon
1997	376,000	Avalon
1998	411,000	Avalon
1999	72,000	Avalon
2001	307,000	Avalon
2002	1,362,000	Avalon
2006	350,000	Avalon
2008	225,000	Avalon
2010	643,000	Avalon
2011	450,000	Avalon

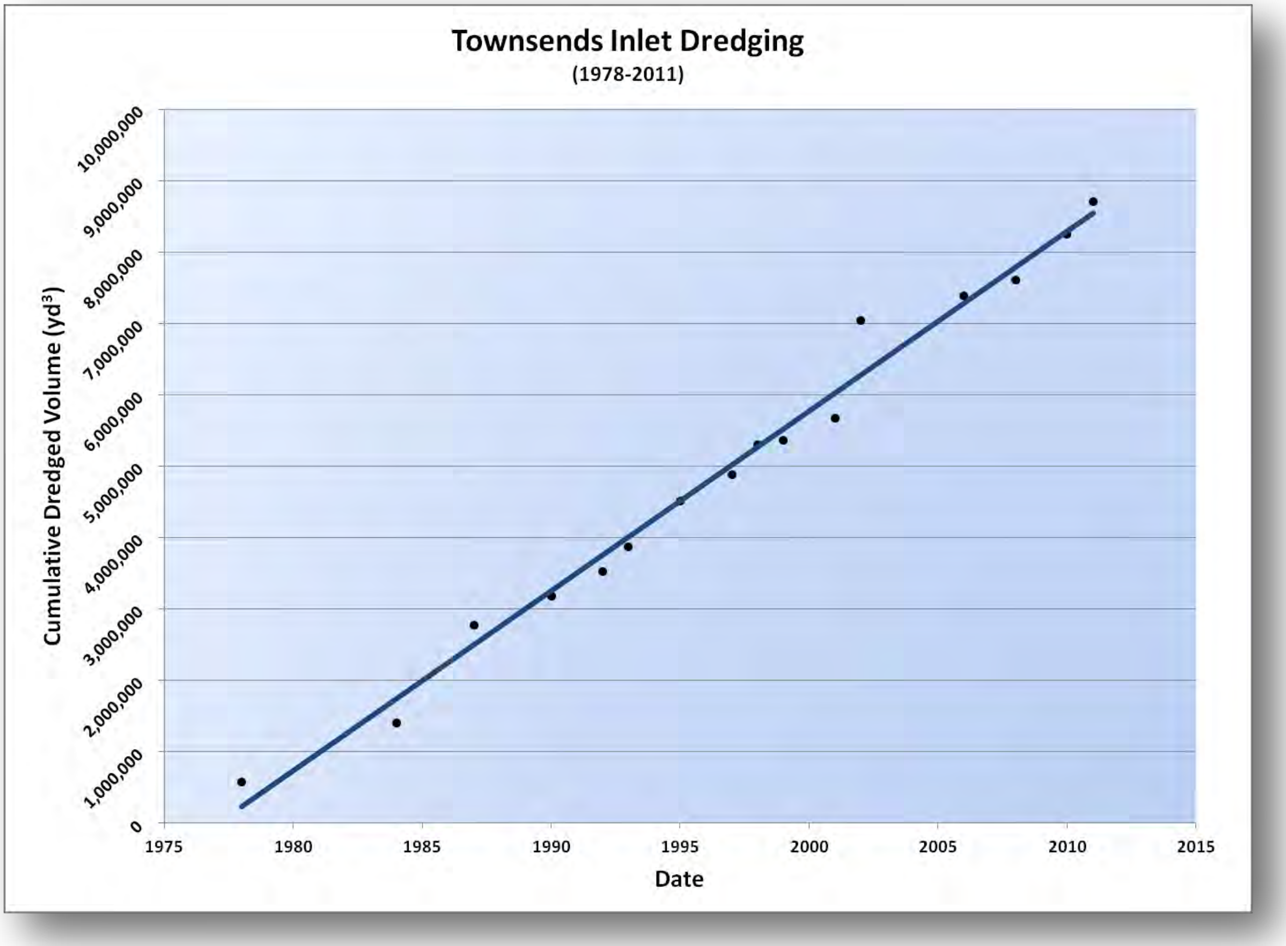


Figure 119. Cumulative dredge volume extracted from Townsends Inlet 1978to 2011.

The amount of material historically dredged from Corson Inlet was also evaluated. However, because there has been limited historic dredging at Corson Inlet, the sediment budget analysis completed by the Philadelphia District (USACE, 2006) was utilized to estimate the amount of material being deposited in Corson Inlet (53,000 cy/yr).

In order to determine the amount of sediment available for nourishing Ludlam Island, periodic nourishment volume requirements for the Avalon or 7-Mile Island were subtracted from the average annual sediment amount available from Townsends Inlet. The remaining material from Townsends Inlet (approximately 186,000 cy/yr) was combined with the material from Corson Inlet (approximately 53,000 cy/yr). Given this remaining volume, the Townsends Inlet material was assumed to fulfill both the Avalon periodic nourishments, as well as those required for Ludlam Island.

Using cost assumptions of dredge mobilization and demobilization costs of $2 million, a unit price of $15/cy for sand for offshore borrow locations, and a unit price of $10/cy for sand from inlet borrow locations, this strategy would result in a cost savings of approximately $60 million over a 50-year time horizon due to reduced costs from focusing dredging on borrow sites in closer proximity to the shoreline. This assumes periodic nourishment is conducted every 5 years at Ludlam Island. This nalysis also assumes that:

- the historic rate of deposition in Townsends and Corson Inlets continue as estimated based on historic dredging and studies;
- the dredged material is beach compatible;
- the dredged material can be placed in the littoral zone or directly on the beach, such that adequate storm damage protection can be provided; and
- that any incremental cost of placing the material on the beach is relatively insignificant, since periodic nourishment would also be required concurrently with the inlet dredging.

For both Townsends and Corson Inlets, there is likely significantly more material available for borrowing (see strategy E). Therefore, the cost savings associated with this beneficial reuse strategy could be even greater. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

This strategy reduces the overall offshore borrow site sediment needs (approximately 12 million cy less over 50 years) and supports the overall RSM initiative.

Assuming the dredged material is suitable for direct placement on the beach, a beneficial reuse project could be developed using the Ludlam Island authority for implementation. However, the current authorization does not include a provision for this type of beneficial reuse. It would likely have to be modified to include a reuse provision, and the project cost sharing would need to be adjusted to reflect this new purpose. All the attendant documentation would have to be developed to accomplish this, and a new PCA would have to be negotiated and signed. Given the above requirements a more efficient way to accomplish this strategy would be to simply utilize the existing project authority to identify the inlets areas as borrow areas. The current authorization has the provision to provide borrow areas for the life of the project. It would likely require cost sharing at the same level as the current project and appropriate studies and environmental clearances would be needed before implementation.

Although implementation of this strategy has limited additional constraints, sediment compatibility of the inlet dredge material has to be determined.

Table 52 presents a summary of the criteria evaluated for the beneficial reuse of material dredged from Townsends and Corson Inlets and ranks it as a high priority with a Tier level of 2. As long as the sediment dredged is compatible for beach nourishment and the quantity of dredging remains approximately the same as historic levels, this strategy should be further pursued since it is directly in line with RSM strategies and initiatives.

D. Sediment Bypassing of Corson Inlet

This strategy would involve implementation of sediment bypassing methodology to move sediment from the northerly updrift beaches of Corson Inlet to nourish beaches downdrift of the inlet. A number of previous studies evaluated conceptual designs and methodologies for bypassing sediment around Cape May Inlet (USACE, EM 1110-2-1616, 1991; U.S. Army Engineer District, Philadelphia, 1987; USACE, 2004), and this information is used to conduct a similar assessment for Corson Inlet bypassing.

Table 52. Borrow Area Expansion at Townsends and Corson Inlets Strategy Summary.

Criteria	Summary
1. Authorization	Requires modification of authority to include beneficial reuse of inlet material
2. Constraints	May be questionable sediment compatibility in some areas
3. Cost Savings	$60 million over 50-year time horizon
4. Service Life	No change to shore protection service life
5. Other Benefits	Reduced offshore borrow site impacts, reutilization of existing shoreline sediments
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Initiate studies and surveys.

Various bypassing alternatives have been considered at a conceptual design level and have been evaluated in preliminary analyses of bypassing of Cape May Inlet (USACE, 2004; USACE, EM 1110-2-1616, 1991). For this preliminary analysis, it is assumed that a semi-mobile bypass system would be installed to bypass sand around Corson Inlet. Additional alternatives (e.g., a floating dredge plant) could also be considered in a more detailed analysis of potential bypassing approaches if this strategy is further pursued. However, in this preliminary analysis, a sediment bypassing plant (similar to the system operated at Indian River Inlet in Delaware – see Figure 120) is considered as a baseline approach to potential bypassing. The USACE Philadelphia District (2004) developed an initial cost estimate for a bypass system. The cost estimate included initial construction costs, Operation and Maintenance (O&M) costs for the sand bypassing plant, Engineering and Design (E&D) costs, Construction Management (S&A) costs, as well as a contingency factor. A detailed breakdown of the cost estimate can be found in the USACE (2004) document. These values were used in the current analysis as well. The following cost estimates were utilized and are intended to provide a first-order estimate of cost impacts:

- An initial construction cost of $6,345,000 for the bypass plant
- O&M costs of $613,000 annually. Bypassing efforts would take place from September to April, 5 days per week, 6 hours per day, bypassing approximately 150,000 cy/yr, as long as the sediment is available.
- Replacement of the pump system every 12-13 years at a fixed cost of $600,000
- Refurbishing/replacement of the system at year 25 for $6,345,000

Figure 120. Indian River Inlet, Delaware fixed bypassing system (Photo courtesy of Tony Pratt, DNREC).

Based on the recent sediment budget completed for the New Jersey coastline (USACE, 2004), it is expected that there would be approximately 53,000 cy/yr of material deposited in Corson Inlet. This analysis assumes that this material could be intercepted on the updrift shoreline prior to getting into the inlet. There is also a potential for additional sediment to be extracted from the updrift shoreline, which is accreting.

This strategy would result in little to no cost savings if only 53,000 cy of sediment was available to bypass per year, and up to $66 million over a 50-year time horizon assuming that approximately 150,000 - 180,000 cy/yr was available for bypassing.

In addition, this strategy provides additional benefits, including, but not limited to:

- Reduced reliance on offshore borrow sites, of which currently permitted borrow sites are becoming depleted.
- Minimizing environmental impacts to offshore borrow sites.
- Promoting RSM approach through appropriate redistribution of sediment already in the littoral system.
- Reduced sediment surplus at in updrift areas

This strategy would not require additional authority if pursued under the concept of value engineering. If bypassing is cost effective, then any necessary environmental clearances needed and the any building costs could be accomplished with authorized construction funds. However, prior to implementation, significant environmental clearances would likely be required, evaluating impacts and potential mitigation for this sensitive area.

Table 53 presents a summary of the criteria evaluated for the sediment bypassing strategy and ranks it as an intermediate priority due to the limited cost savings associated with the low sediment availability associated with Corson Inlet, and a Tier level of 2. This approach should only be considered if it is determined that there is enough sediment available for bypassing. The strategy would have other significant benefits (e.g., reduce or eliminate dependence on offshore sediment sources, reduce sediment surplus on updrift beaches) and would take advantage of beach compatible sediment already in the system. Next steps would involve a more detailed study of potential impacts caused by fillet extraction on adjacent beaches, finalization and design, and determining the right authorization approach and pathway to implement the bypassing project. Because Corson Inlet has a limited sediment supply, it would be useful to firtst implement and evaluate bypassing at a sediment rich inlet.

Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Table 53. Sediment Bypassing Strategy Summary.

Criteria	Summary
1. Authorization	Value engineering could be applied to implement
2. Constraints	Significant environmental questions may remain for impacts on extraction of updrift fillet
3. Cost Savings	$0 to $66 million over 50-year time horizon depending on sediment availability on updrift side of Corson Inlet
4. Service Life	No change to existing service life of shore protection project
5. Other Benefits	Eliminate offshore sediment source requirements and environmental impacts; Improved management of sediment in littoral system; Reduced sediment surplus updrift
6. Priority	Intermediate
7. Tier Level	Tier 2
8. Next Steps	More detailed study of potential impacts caused by fillet extraction; Finalize and design project; Determine authorization approach

E. Borrow Area Expansion or Establishment

Over a 50 year time horizon, the periodic nourishment sediment needs at Ludlam Island and Peck Beach total approximately 26,870,000 cy. Sediment sources for the nourishments performed by the State of New Jersey have been primarily taken from Townsends and Corson Inlet. The authorized projects are awaiting funding have not yet been constructed by the Corps. Currently, the authorized and permitted borrow sites in the vicinity of Ludlam Island and Peck Beach (offshore borrow sites L1 and L3) can provide adequate material to construct the initial and periodic nourishments. Although, there is not an immediate need for additional sediment sources, additional sources may be needed in the long-term or for storm response. These additional borrow locations could either be identified offshore or from expanded dredge areas in Townsends or Corson Inlets.

This strategy is not specifically geared towards providing a cost savings, but rather at maintaining current operations costs since upland sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., track traffic, road repairs, time of construction, etc.).

There are three potential additional sediment sources in the vicinity of Ludlam Island and Peck Beach. These include:

1. Offshore borrow sites L2, M3, MMS-A2, and MMS-A1.
2. Expanded dredging in Townsends Inlet
3. Expanded dredging in Corson Inlet

The Townsends Inlet to Cape May Inlet Feasibility Study (USACE, 1997) identified a 248 acre area within Townsends Inlet with an estimated 3,500,000 cy of compatible sand. The study acknowledged the existence of greater reserves, but reduced the borrow area footprint from 400 acres to preserve the ebb shoal and maintain inlet hydraulics and benthic resources. Based on survey and a thickness range of 10 to 15 ft, the estimated pre-project borrow quantity for Townsends Inlet is between 1,745,259 and 2,617,888 cy.

As a preliminary estimate of additional sand resources at Townsends Inlet, extents and volume of potential borrow sites were investigated using historical aerial photography. The assessment suggested that the shoals of Townsends Inlet are substantial and fairly stable. Potential borrow areas are delineated based on the location of the ebb and flood tidal shoals in the latest available imagery (Google Earth, June 2011) to provide an estimate of the location of potential expanded sediment sources. Figure 121 delineates these potential borrow areas, and also shows the existing permitted borrow areas in Townsends Inlet (white shaded areas).

The flood tidal shoal at Townsends Inlet is approximately 14 acres. At an average thickness of 10 to 15 ft, the flood tidal shoal borrow area could yield between 229,000 and 345,000 cy. The ebb tidal shoal at Townsends Inlet is approximately 100 acres. At an average thickness of 10 to 15 ft, the ebb tidal shoal borrow area could yield between 1,650,000 and 2,480,000 cy.

Corson Inlet was dredged in 1967, 1968 and 1969, using side cast dredging to move 43,680, 5,640 and 1,670 cy from Corson Inlet to the inlet shoreline of Strathmere (Everts et al., 1980). The General Design Memorandum, Corson Inlet and Ludlam Beach, NJ (1976) outlined state plans to dredge and maintain a 300 ft wide navigation channel at Corson Inlet, which, in tandem with a deposition basin borrow area adjacent to a proposed updrift jetty, would provide nourishment material for Ludlam Island. The Great Egg Harbor Inlet to

Townsends Inlet Feasibility Study (USACE, 2000) reported the state never constructed this project, though interest was renewed in the 1981 NJ Shore Protection Master Plan. In 2009, the State of NJ dredged nearly 1,300,000 cy from Corson Inlet for nourishment projects on Strathmere and Sea Isle City beaches.

Figure 121. Potential borrow areas (green) at the ebb and flood tidal shoals of Townsends Inlet. Permitted borrow areas shown as shaded white. Image courtesy of Google Earth©.

The Feasibility Study (USACE, 2000) identified a 197 acre area within Corson Inlet with an estimated 1,000,000 cy of compatible sand. Further study demonstrated that the ebb shoal outside the identified borrow area could further provide a renewable sand source. Based on survey and a thickness range of 10 to 15 ft, the estimated pre-project borrow quantity for the authorized Corson Inlet borrow area (C1) is between 3,201,533 and 4,802,299 cy.

For the current analysis, an investigation of historical aerial photography suggested that the shoals of Corson Inlet are substantial but migratory. Therefore, potential borrow areas are delineated based on the location of the ebb and flood tidal shoals in the latest available imagery (Google Earth, June 2011). Figure 122 delineates these potential borrow areas, as well as the existing permitted borrow area in Corson Inlet. The flood tidal shoal at Corson Inlet is approximately 32 acres. At an average thickness of 10 to 15 ft, the flood tidal shoal borrow area could yield between 517,000 and 775,000 cy. The ebb tidal shoal at Corson Inlet is approximately 40 acres. At an average thickness of 10 to 15 ft, the ebb tidal shoal borrow area could yield between 643,000 and 964,000 cy.

Figure 122. Potential borrow areas (green) at the ebb and flood tidal shoals of Corson Inlet. Permitted borrow areas shown as shaded white. Image courtesy of Google Earth©.

This strategy can be accomplished under the existing project authorization, since it includes the provision of borrow areas for the life of the project. It would likely require cost sharing at the same level as the current project. Appropriate studies and environmental clearances would be needed. Construction funds can be used to accomplish this as it is a part of the process of continuing construction.

The primary constraints with expansion or establishment of inlet or offshore borrow sites are environmental. Establishing expanded borrow locations requires sand source delineation, which typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave and sediment transport processes are also needed. Although the physical and environmental delineation would add cost, once permitted, construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 54 presents a summary of the criteria evaluated for the borrow area expansion and establishment strategy and ranks it as a low to intermediate priority for this region (due to adequate authorized borrow areas) with a Tier level of 1. It is recommended that this strategy is pursued in advance of potential need, such that the borrow areas are established for future use. Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted offshore sites available if needed for storm events or unforeseen circumstances is good planning. Next steps for this strategy would be to initialize any studies and surveys needed to expand or establish new borrow sites for this region, which has a known deficit, and coordinate with BOEM for any potential federal waters borrow sites.

Table 54. Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	Low to Intermediate
7. Tier Level	Tier 1
8. Next Steps	Initiate studies and surveys. Coordinate with BOEM

F. Refined Beach Nourishment Template

This strategy involves applying adjustments to the authorized beach nourishment template along Ludlam Island to determine if changes could result in increased performance or improved storm damage protection. A successful beach nourishment project consists of more than simply placing sediment on a beach. Beach nourishment projects are engineered. A beach nourishment template, which consists of numerous design parameters, is based on the specific characteristics of the site and needs of a project. Every beach nourishment design is unique, since different beaches in different areas have different physical, geologic, environmental, and economic characteristics, as well as different levels of required protection. The design must consider climatology, the shape of the beach, type of native sand, volume and rates of sediment transport, erosion patterns and causes, waves and water levels, historical data and previous storms, probability of certain beach behaviors at the site, existing structures and infrastructure, and past engineering activities in the area.

The structure of a nourishment template is designed to yield a protective barrier that also provides material to the beach. A higher and wider beach berm is designed to absorb wave energy. Dunes may need to be constructed or existing dunes improved to reduce damage, including potential upland flooding, from storms. Figure 123 depicts a beach berm and dune on a typical beach profile. Nourishment length, berm height and width, dune height, and offshore slope are critical elements of a beach nourishment design. Periodic nourishment intervals are also usually a part of the nourishment design. The renourishment interval will vary based on the initial design, wave climate, sand used, frequency of storms, and project age. However, beach nourishment is not an exact science; variables and uncertainties exist. Actual periodic nourishment intervals may differ from planned intervals based on conditions at the nourished beach and the frequency and intensity of storms.

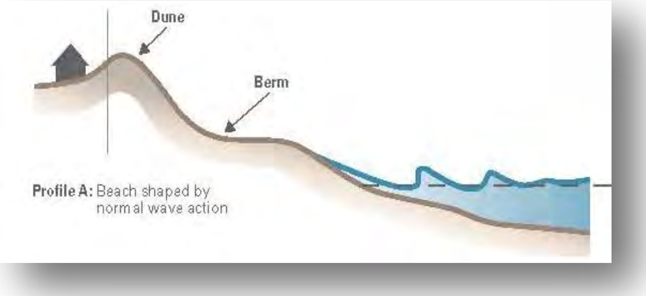


Figure 123. Typical beach profile and features (from Coastal Engineering Manual, 2003).

This proposed strategy evaluates potential improvements to project performance, storm damage protection, and subsequent cost savings that can be realized by modifications to the currently authorized beach nourishment template.

The feasibility studies for the authorized projects typically evaluate the a range of proposed beach nourishment template designs using alongshore and cross-shore analysis and/or modeling efforts to assess performance and storm damage protection afforded by the proposed nourishment template. However, the USACE policy has been to not consider increases to the natural berm elevation for the design template or to see if changes to the natural berm height result in performance gains or improved storm damage protection. Additionally, the currently authorized design template has not been re-evaluated following monitoring of the performance of the system. Monitoring data may reveal potential insight that could warrant modifications to the template. Therefore, this strategy involves assessing changes to the beach nourishment template that may yield cost savings over the long-term. An example of this type of analysis is presented herein by evaluating change in berm height and width on the performance of the Ludlam Island project as a preliminary analysis of potential template modification.

Similar analyses could be completed for a number of parameters that are components of beach nourishment design; including:

- Nourishment length – Expanding the nourishment length, specifically through combining or syncing projects could be evaluated.
- Berm Width – The width of the berm could be modified to see if there is a cost benefit that could be attained. This also may involve a spatially variable berm width modification
- Berm Height – The height of the berm could be modified to determine impact on storm damage protection.
- Offshore slope – The offshore slope of the nourishment can be changed.
- Grain size – The grain size of the source material for the nourishment may affect the performance of the projects. For example, coarser nourishment material may result in improved project performance (lower erodibility and hence more protection.

To assess potential changes in berm width and height at Ludlam Island, the computer model SBEACH (Larson and Kraus 1989) was used to assess cross-shore evolution. SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and further developed and verified based on field measurements (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990). The model predicts the time-dependent evolution of existing or design beach and dune profiles for specified water levels and wave conditions. In addition to the proposed nourishment template, the model requires a time series of wave heights, wave periods and water levels as forcing inputs. The specific storm information required by SBEACH is a time history of total water level (tide plus surge) and wind wave height and period. The WIS hindcast information, FEMA FIS still water storm surge elevation, and extremal analysis were used to develop a simulated 10-year storm for this analysis.

Figure 124 presents results of varying the berm height (blue line) and width (green line) of the Ludlam Island authorized beach nourishment template. The horizontal axis shows the percent of material lost from the nourishment template area caused by a 10-year, 24-hour storm for various berm heights and widths. The left hand vertical axis shows berm height (NAVD88, feet), while the right hand vertical axis shows berm width (feet). The variable width scenarios use a constant 6.0 ft NAVD88 berm height, while the variable height scenarios use a constant 50 ft berm width, since the currently authorized template consists of a berm height of approximately 6.0 ft NAVD88 and a berm width of 50 ft. Figure 124 shows the changes in expected sediment lost from the template area for increased berm height and width. In this case, the berm width has already been fairly well optimized for the given berm height, as increased widths show minimal response differences. However, increases in berm height did show improved response to the 10 year storm. For example, the currently authorized project template loses approximately 38% of the periodic nourishment during the 10-year, 24-hour storm. However, by increasing the berm height by two ft (8.0 ft NAVD88) reduces the percentage of material lost to approximately 32%. Increasing the berm height further results in decreased losses, but also requires additional nourishment volumes, additional sediment sources, and finances. As such, there is a point of diminishing returns on the amount of required sand needed to extend the berm height and the increased performance gained. Adding more sand to the system may result in better performance, but also may not be worth the added cost. This same type of analysis could be conducted to evaluate the sensitivity of other parameters in the beach nourishment design, their potential impacts on overall cost of the project, and identify the most cost-effective design template.

The 8.0 ft berm height modified design requires approximately 388,000 cy of additional sediment to gain the required berm height during the initial increased periodic nourishment. However, since the performance is improved over each 3 year cycle, the amount of sediment required for each periodic nourishment is reduced.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this example approach to template modification would result in a cost savings of approximately $16 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments, or increased renourishment intervals. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

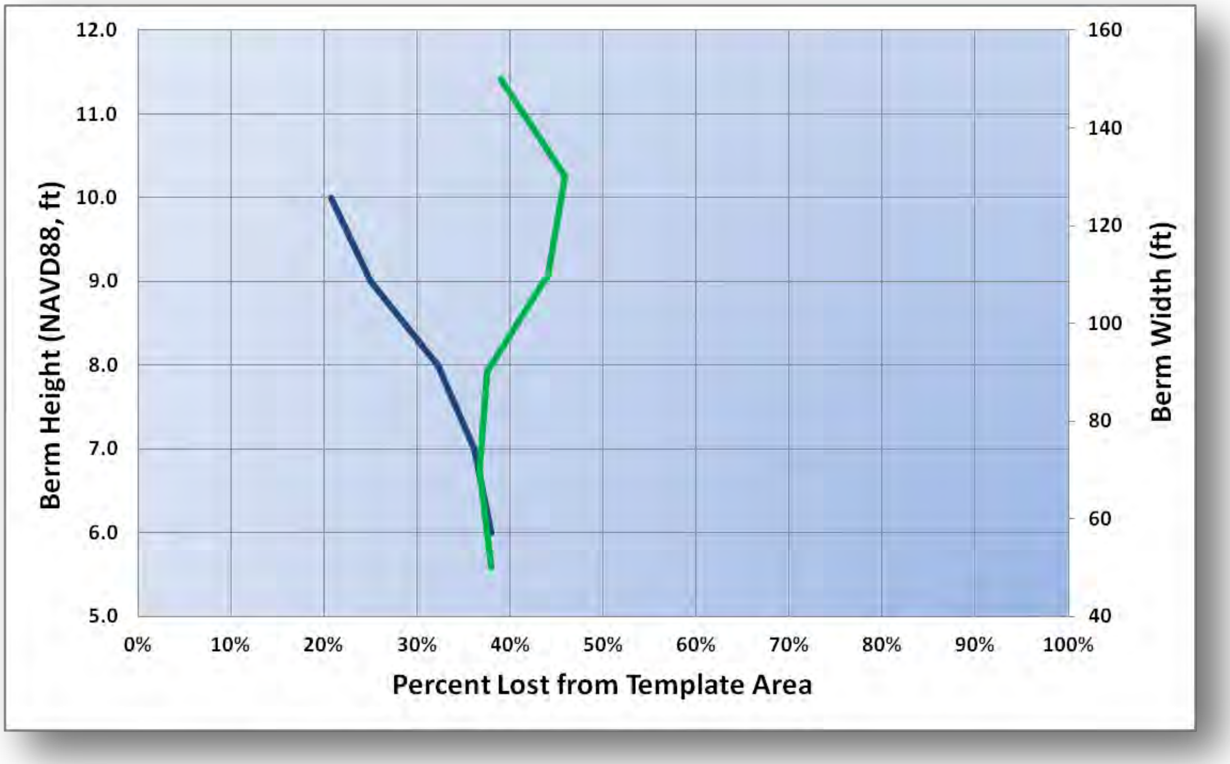


Figure 124. Eroded beach volume as a function of template berm height (blue line) and width (green line) for the Ludlam Island nourishment project in response to a 24-hour, 10-year return period storm event.

In addition to the cost savings estimated from the reduced sediment volume requirements for periodic nourishments, modification of the beach nourishment template may have other additional benefits as well. For example, the modified template may result in improved storm damage protection and reduced potential upland damage costs. Examples of other potential benefits included habitat enhancement, reduced ponding or upland flooding, and reduced environmental impacts offshore due to reduced offshore sediment needs.

Relative to the current authorization, the existing template defines the authorized project and the NED plan. Changing the template would imply that the authorized plan was no longer the NED plan and the project would have to be reanalyzed. To do so would require the use of the existing New Jersey shore study authority to determine the degree of federal interest, get the requisite environmental clearances, and recommend a change in the authorized plan. This would require the existing project authority to be modified by Congress. It would also likely require a new study cost sharing agreement to be signed, as well as a non-federal sponsor willing to contribute 50% of the study costs and agree to any changes in the construction and long-term cost sharing. Finally, new PCS conforming to the model agreement would have to be signed.

Potential constraints associated with modification of the beach nourishment template include environmental concerns (e.g., occupying a larger offshore footprint), political and local community concerns that would limit the ability to change the template (e.g., communities wouldn’t want an increased berm height), and logistical concerns associated with modification of the authority to construct the project.

Table 55 presents a summary of the criteria evaluated for the refined beach nourishment template strategy and ranks it as a low to intermediate priority and a Tier level of 2. Next steps for this strategy would be to conduct more detailed studies to assess if template modifications are warranted. The studies would focus on the cost benefit aspects of template modification.

Table 55. Beach Nourishment Template Refinement Strategy Summary.

Criteria	Summary
1. Authorization	Requires a change to the authorized plan and would include new study, permits, and cost-sharing agreements
2. Constraints	Logistic, political, local community, and environmental concerns
3. Cost Savings	Depends on template modification, $16 million for case evaluated
4. Service Life	Increased service life of beach nourishment expected
5. Other Benefits	Improved storm damage protection, habitat enhancement, reduced offshore environmental impacts
6. Priority	Low to Intermediate
7. Tier Level	Tier 2
8. Next Steps	USACE Philadelphia district decide if the strategy is warrants further study

G. *Dune Enhancement*

The dune enhancement strategy seeks to restore and enhance the existing coastal dunes in Sea Isle City. The intent of the strategy is to improve the function of the dunes against erosion, flooding and overwash that regularly occur along Landis Ave/Commonwealth Ave.

There is a history of nourishment along Whale Beach in Sea Isle City. The Whale Beach area is located at the narrowest part of the barrier island and supports only a single road, which is overtopped during major storm events, often rendering this important evacuation route impassable. The beach itself also experiences major erosion and protective dunes are nonexistent in this area (small dunes exist, but do not serve a protective function due to their low elevation). In 1976, an attempt to stabilize Whale Beach with the placement of 27,572 cy of sand was conducted. Another beach restoration project, sponsored by FEMA, was constructed in 1995 between 1st and 15th Streets. During this nourishment effort, 23,599 cy of sand and 15,247 cy of dune core were utilized. However, the result offered minimal protection, and the dunes between 3rd and 6th Streets were breached during a storm on January 8, 1996. In 1998, a 4,000 ft county sponsored geotextile project was completed. The geotextile tubes were placed between 1st and 13th Streets to provide protection during minor storms. However, by 2009, much of the sand covering the geotextile tubes had been eroded, leaving the tubes exposed.

In 2007, the Great Egg Harbor Inlet to Townsends Inlet Shore Protection Project was authorized and provided specifications for dune construction and enhancement for the entire oceanfront of Ludlam Island, including the communities of Strathmere and Sea Isle City. Following the 2007 federal project authorization, the only beach nourishment activity that has taken place is a 2009-2010 state-funded project. 216,630 cy of sand was dredged from Corson Inlet and placed between 1st and 15th Streets. The design plan for this project called for a 100 ft wide berm at elevation 7.0 ft NAVD, and a beachfill slope of 1V:30H, by utilizing 216,630 cy of sand. Although the 2009 nourishment was higher and wider than the federally authorized design, the plan did not include any dune enhancement or construction.

While the 2009-2010 project design incorporated some of the 2007 Great Egg Harbor Inlet to Townsends Inlet Shore Protection Project design recommendations, it failed to completely follow the recommended plans in terms of dune design, placement and size. Utilizing all specifications from the 2007 project authorization would be a first step in constructing a successful beach and dune nourishment project.

Although a small, narrow dune exists where the previous geotextile tube had been placed, it does not meet the specifications outlined in the 2007 project authorization plan, nor provide adequate overall protection from storm events. Discrete segments of the beach that are currently lower in elevation or more vulnerable, such as from 3rd to 6th Streets where the dunes have been breached in the past, may require a wider or higher dune and/or berm to reduce overtopping and damage from storms.

Once a sufficient dune is designed and constructed, it is necessary to ensure that the beach seaward of the dune is of sufficient size to prevent the dune from eroding away at the first storm. Additionally, appropriately stabilizing the newly constructed dune with suitable native vegetation, such as beach grass (*Ammophila*) is an important aspect of storm damage prevention. Beach grass has an extensive system of creeping underground stems or rhizomes, which not only allow them to thrive under conditions of shifting sands and high winds, but also help stabilize the dunes. Alternative core materials could also be explored, in addition to the geotextile tube used in the past. For example, coir logs, a flexible log of coconut fiber, covered by an exterior coir mesh netting, are also common in beach restoration projects, and help promote slope stabilization and vegetative regrowth.

Given improved design specifications and proper post-construction stabilization methods, dune enhancement along beaches in Sea Isle City, specifically Whale Beach, may be a viable strategy for reducing flooding and overtopping during storms and continued beach erosion, which are threatening Landis Ave/Commonwealth Ave.

Similar to template modification, the dune enhancement strategy would require some change in the authorized plan, although to a lesser degree since only a portion of the template would be changed and/or enhanced (e.g., dune core). There are minimal constraints associated with dune enhancement beyond some potential environmental aspects.

Table 56 presents a summary of the criteria evaluated for the dune enhancement strategy and ranks it as an intermediate priority and a Tier level of 2. Next steps for this strategy would be to conduct more detailed studies to assess functionality and performance of potential dune enhancements. The studies would focus on the dune design and response to storm events.

H. Coastal Structure Modification

This strategy involves the expansion of the existing groin field at Ludlam Island, and specifically in the Sea Isle City region. Groins, by design, inhibit the alongshore transport of sediment by retaining sediment on the updrift side of the structure. The regions downdrift of the structure will incur a reduced influx of sediment until sufficient bypassing is able to occur.

In 1980, the USACE released Miscellaneous Report 80-3 (Everts et al., 1980), a detailed study of historic shore position data, historic aerial photography, and ten years of survey data to determine trends in coastline change, and alongshore distribution of volumetric sediment change. Two sections of Ludlam

Island contained groins during the time frame of Everts' study (Figure 125): a section of generally good condition groins located at Sea Isle City and a section of generally poor condition groins located in Strathmere. The groin field at Strathmere is not investigated for this strategy.

Table 56. Dune Enhancement Strategy Summary.

Criteria	Summary
1. Authorization	May require a change to the authorized plan
2. Constraints	Some potential environmental concerns
3. Cost Savings	Potential reduction in road maintenance and upland flooding damage
4. Service Life	Potential increased dune performance at Whale Beach
5. Other Benefits	Improved storm damage protection
6. Priority	Intermediate
7. Tier Level	Tier 2
8. Next Steps	USACE Philadelphia district decide if the strategy is warrants further study

Everts et al. (1980) determined that the groin field shoreline at Sea Isle City exhibited lower than mean volume changes and increased in width over the time studied (Figure 126). The shoreline immediately updrift and downdrift of the Sea Isle City groins experienced erosion. Storm induced volume changes (Figure 127) at the Sea Isle City stations were also generally less severe than those experienced by the unprotected coastline (without groins).

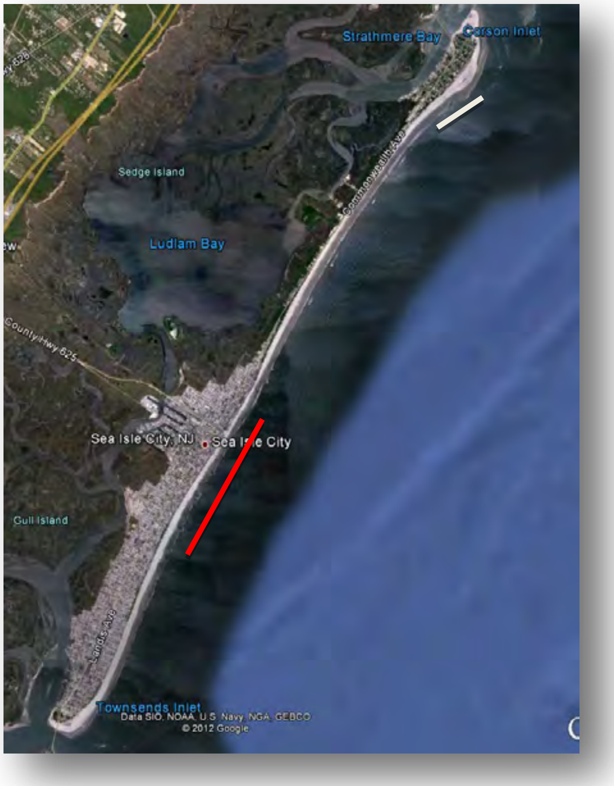


Figure 125. Approximate location of Sea Isle City (red) and Strathmere (white) groin fields.

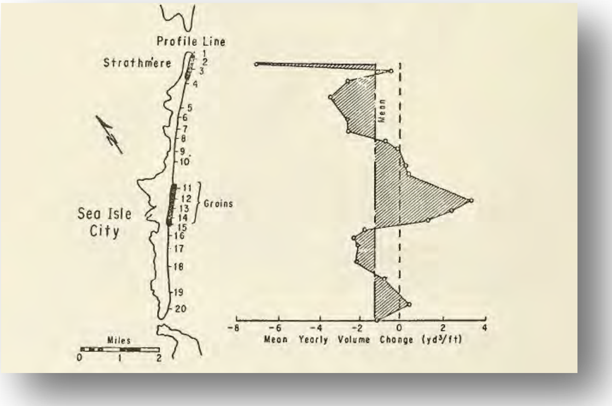


Figure 126. Mean Shoreline Change (dy/dt) for Ludlam Island (from Everts et al., 1980).

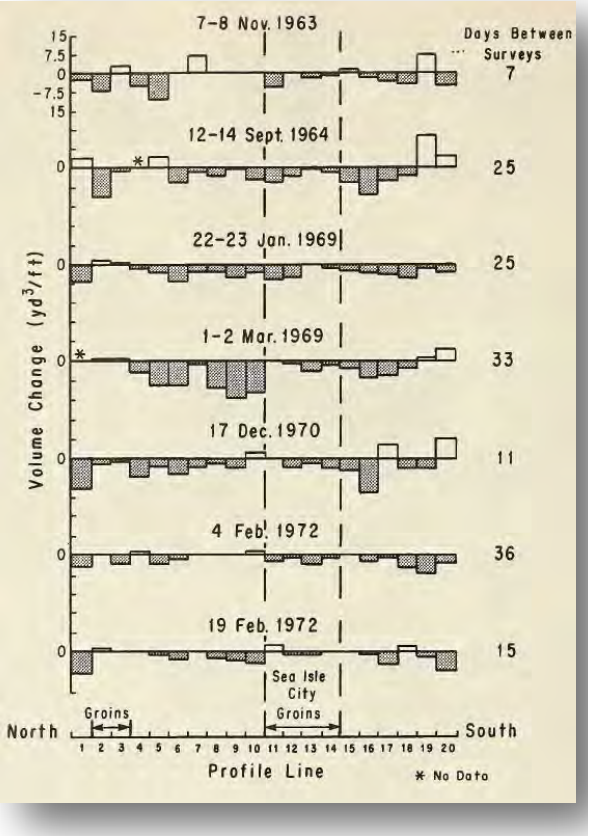


Figure 127. Beach volume changes resulting from seven storms between 1962 and 1972 (from Everts et al., 1980).

By expanding the groin field at Sea Isle City, especially in the areas where there are currently limited groins, the nourishment material would be better retained and the time between periodic nourishments would be extended or the volume of sediment required for periodic nourishments could be reduced. would be reduced. Using the results of Everts et al. (1980), a reduced shoreline loss rate of 2 cy/yr per linear foot of beach was applied to areas at Sea Isle City that do not currently contain groin fields.

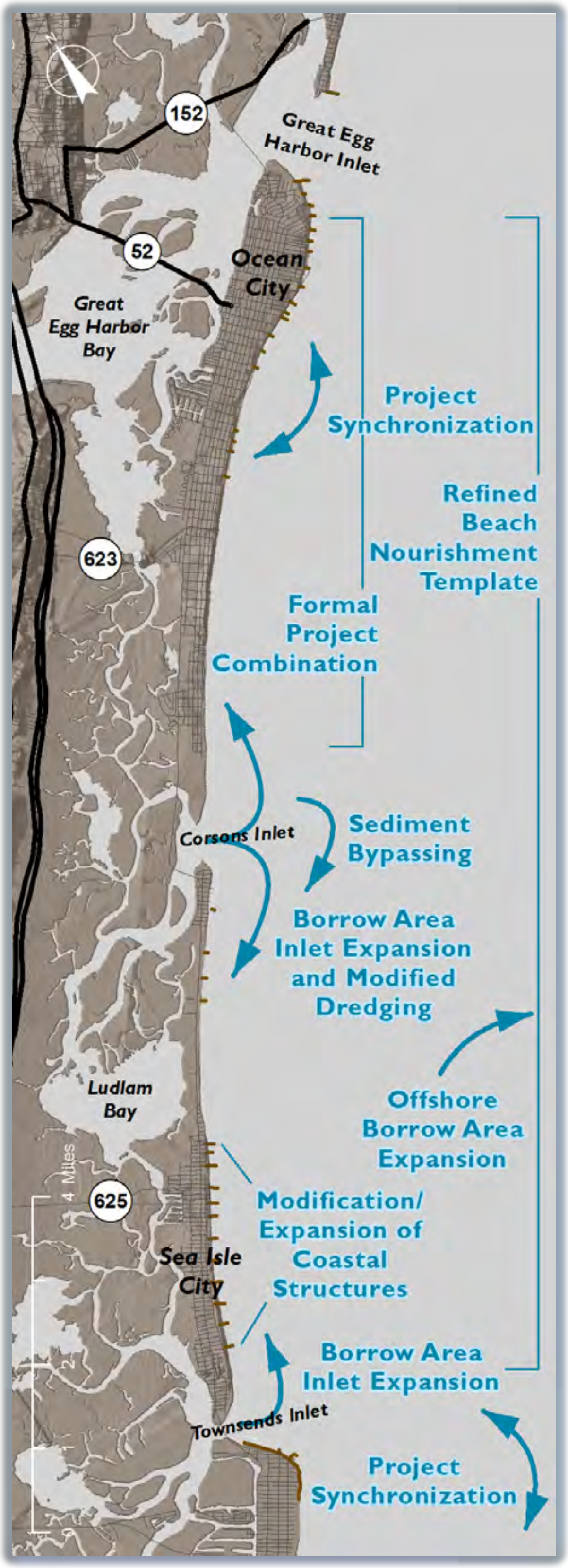
Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), it assumed adding approximately 6 groins to the Sea Isle City area and would reduce required periodic nourishment sediment and produce a savings of approximately $3 million over a 50 year time horizon.

These structural evaluations were partially analyzed in the development of the authorized plan. Therefore, prior to any further analysis on this potential strategy, reasons why this was not considered for inclusion in the recommended plan need to be revisited. The evaluation of these structures could be accomplished under the concept of value engineering.

Table 57 presents a summary of the criteria evaluated for the coastal structure modification and ranks this strategy as a low priority and a Tier level of 3. Next steps for this strategy would be to revisit the feasibility study and determine if additional groins at Sea Isle City may require additional assessment.

Table 57. Coastal Structure Modification Strategy Summary.

Criteria	Summary
1. Authorization	Could be conducted under a value engineering approach
2. Constraints	Environmental impacts need to be evaluated, coastal processes assessment to evaluate impact of structural modification
3. Cost Savings	$3 million
4. Service Life	Potential beach nourishment performance enhancement, structural service life expected to be 50 years
5. Other Benefits	Reduced environmental impacts to offshore resources
6. Priority	Low
7. Tier Level	Tier 3
8. Next Steps	Coastal processes and environmental studies to determine relative cost benefit of structural modifications



Summary

This section presents a brief summary of all the strategies presented for Ludlam Island and Peck Beach. The focus is on the potential cost savings and priority levels to assist in the identification and selection of strategies that could be implemented immediately and/or further pursued to more cost effectively manage sediment within the project area.

Figure 128 provides a summary of the estimated total cost savings (compared to current operations) over a 50-year time horizon for a number of the potential strategies (those that indicated a cost saving could be realized) for comparison purposes. Similarly, Additional analysis could be completed to evaluate the potential cost savings associated with combining various strategies as well.

Table 58 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies presented in Table 58 are listed in order of priority and estimated ease of implementation.

Table 58. Ludlam Island and Peck Beach Strategy Summary.

Strategy	Prioritization	Tier
A. Project Cycle Synchronization	High	1
C. Inlet Borrow Area Expansion at Townsends and Corson Inlets	High	2
B. Formal Project Combination	Intermediate to High	2
G. Dune Enhancement	Intermediate	2
D. Sediment Bypassing	Intermediate	2
E. Offshore Borrow Site Expansion	Low to Intermediate	1
E. Refined Beach Nourishment Template	Low to Intermediate	2
H. Coastal Structure Modification	Low	3

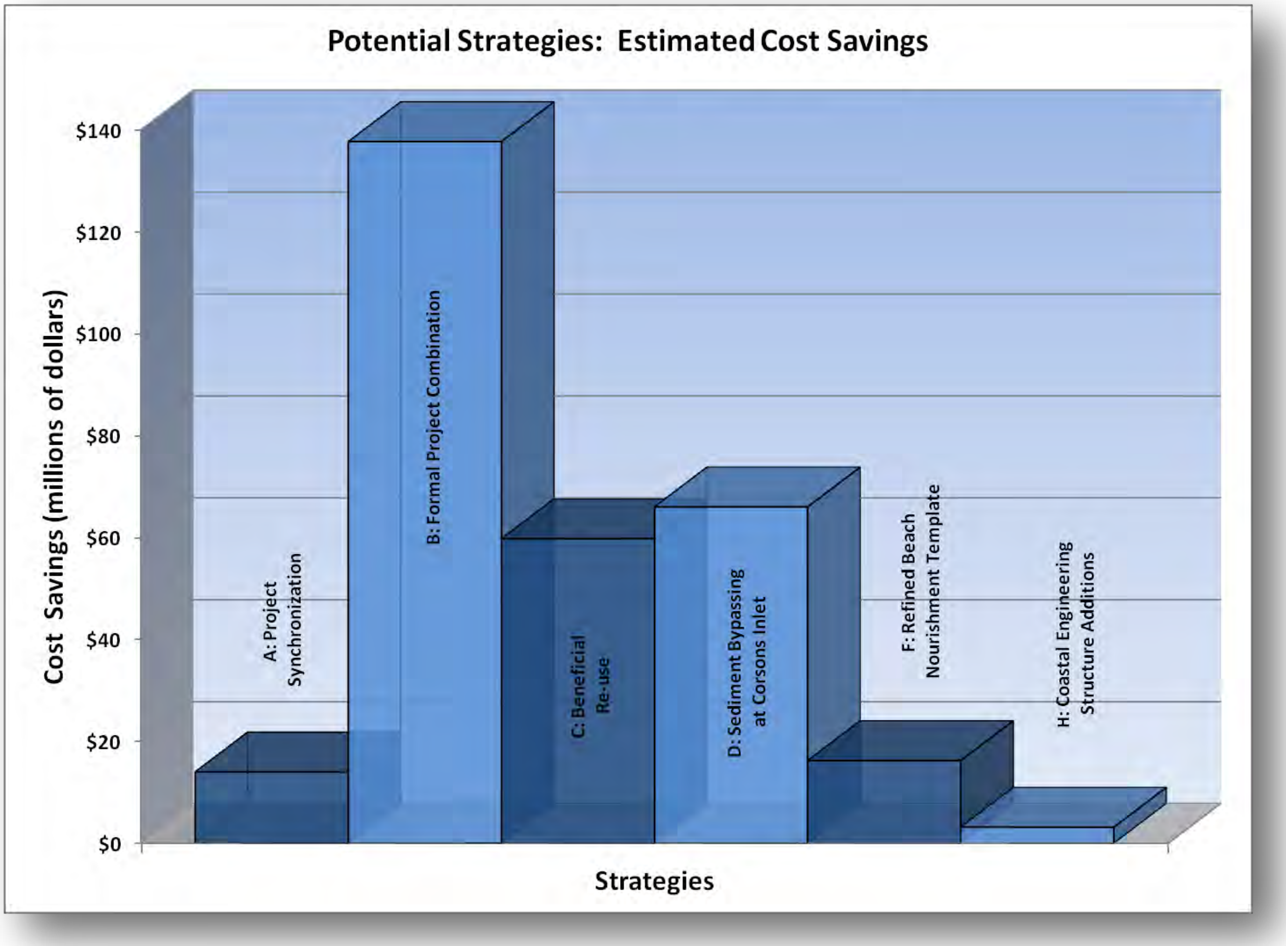


Figure 128. Estimate cost savings (compared to current operations) over a 50-year time horizon for select Ludlam Island and Peck Beach strategies.

OCEAN CITY

Project Description

The Great Egg Harbor and Peck Beach (Ocean City) Shore Protection Project was authorized for construction by the Water Resources Development Act of 1986. The project is located in Cape May County on the Peck Beach barrier island. Peck Beach is occupied in its entirety by the City of Ocean City, which extends 8 miles from Great Egg Harbor Inlet southwest to Corson Inlet. The authorized project includes beachfill, using sand dredged from Great Egg Harbor Inlet, to restore beaches along the northern end of the barrier island. Extension of 38 storm drain pipes is also included in the project.

The design berm is 100 ft wide at an elevation of 6.75 ft NAVD88. The total length of fill in northern Ocean City is approximately 21,500 linear ft, extending from Surf Road to 34th Street. The project overlaps the Great Egg Harbor Inlet to Townsends Inlet Shore Protection Project south of 34th Street where a 1,000 ft beachfill taper is authorized. Initial construction of the project requires placement of 6,200,000 cy of sand, with periodic nourishment of 1,100,000 cy every 3 years. The authorized borrow site for initial construction and periodic nourishment is the ebb shoal area of Great Egg Harbor Inlet located approximately 5,000 ft offshore of the inlet. Figure 129 shows the Ocean City Shore Protection Project.

Figure 129. Great Egg Harbor and Peck Beach (Ocean City) Authorized Shore Protection Project.

Project History

Peck Beach has a history of flooding and storm-induced shoreline erosion. Since 1992, the island has been declared a Federal Disaster Area on 7 occasions. Long-term erosion has caused a reduction in the height and width of the beach, which has increased the potential for storm damage. A great number of structures are at risk to storm damage in the densely developed northern Ocean City.

A variety of coastal engineering structures have been utilized over the years to mitigate erosion. The boardwalk, which runs 13,000 ft from St. James Place south to 23rd Street, is protected by a bulkhead. There are also 19 groins located along the beach between the northern end of Ocean City and 28th Street.

The Great Egg Harbor and Peck Beach Shore Protection Project was authorized to mitigate this ongoing erosion. Initial nourishment was performed in two phases, which were completed in October 1992 and March 1993. A total volume of 5,345,000 cy of sand was placed on the beach from Surf Road to 34th Street. Subsequent to the initial work, periodic nourishment has been performed 5 times and sand fill for storm rehabilitation has been performed once (Table 59). During the 1st and 3rd periodic nourishment projects, the City of Ocean City and NJDEP contracted for an additional volume of beachfill material to be placed south of the authorized project area. Approximately 360,000 cy was placed between 34th and 60th Streets as part of the 1st federal periodic nourishment, and 303,000 cy was placed in the area from 48th to 59th Streets during the 3rd federal periodic nourishment project. A total volume of 8,014,000 cy has been placed on the beach as part of this Federal project since initial construction. All beachfill material has been dredged from the ebb shoal offshore of Great Egg Harbor inlet.

Table 59. Ocean City Nourishment History.

Date	Volume (cy)	Source
Oct. 1992	2,618,000	Initial Const. Phase I
Mar. 1993	2,727,000	Initial Const. Phase II
Jul. 1993	846,000	Storm Rehabilitation
Dec. 1994	606,000	1st Periodic Nourishment Phase I
Aug. 1995	1,411,000	1st Periodic Nourishment Phase II
Oct. 1997	800,000	2nd Periodic Nourishment
Dec. 2000	1,351,000	3rd Periodic Nourishment
Feb. 2004	1,600,000	4th Periodic Nourishment
Mar. 2010	1,400,000	5th Periodic Nourishment

Project Observations

The following observations have been made regarding the Great Egg Harbor and Peck Beach Shore Protection Project:

- A high rate of erosion persists along the northern end of Ocean City, as much of the beachfill material placed over the past 10 years has been lost.
- Current projections show that the ebb shoal at Great Egg Harbor Inlet contains significant quantities of beach compatible sand to perform the authorized periodic renourishments. Consequently, new potential sources of borrow material may not be needed for continued maintenance of the Federal project.

Potential Strategies

This section presents the potential strategies for the Ocean City Shore Protection Project to provide improved project performance, cost savings, or other benefits. These strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. Some of the proposed strategies include a first-order technical analysis to evaluate their relative merit. These analyses are not intended to be detailed assessments and include some assumptions and simplifications. Rather, they are geared towards providing a preliminary estimate of the potential benefits each strategy may accrue. This analysis should be used as an initial screening tool to determine if a strategy warrants further consideration. Some strategies may require a more detailed analysis prior to formal pursuit.

A. Project Cycle Synchronization

This strategy informally theoretically synchronizes the construction of authorized shore protection projects that are in close proximity. The intent is to reduce mobilization and demobilization costs by combining re-nourishments. Peck Beach (south of Ocean City and Ocean City periodic nourishments were assumed to be already synchronized under the current authorizations since they both have the same periodic nourishment cycle (3 years), and could be nourished simultaneously going forward. Therefore, the criteria for this strategy are not specifically evaluated. Formal combination (Strategy B) was also considered to authorize simultaneous construction.

B. Formal Project Combination

This strategy involves formally aligning the federal authorizations of the Peck Beach (a component of the Great Egg Harbor to Townsends Inlet Shore Protection Project) and the Ocean City project such that periodic nourishment construction of these projects would always occur at the same time. The goal of this strategy is to not only reduce mobilization and demobilization costs, but also to provide increased project performance, thereby, reducing the number of periodic nourishments.

A brief analysis, which combines the conservation of sediment equation with the linearized transport equation, was conducted to determine the performance of the individual and combined beach nourishment projects. The *Pelnard-Considére* (1956) equation (Equation 13) is used to obtain theoretical results to establish design and performance standards for the Ocean City nourishment. A more detailed description of the derivation of the equations and their applications can be found in Dean (2002).

Equation 13:

$$M(t) = \frac{2\sqrt{Gt}}{l\sqrt{\pi}}\left(e^{-\left(\frac{l}{2\sqrt{Gt}}\right)^2 - 1} \right) + erf\left(\frac{l}{2\sqrt{Gt}}\right)$$

where *M(t)* is the proportion of sand remaining in the placed location, G is the alongshore diffusivity parameter, t is time, and l is the project (nourishment) length. The alongshore diffusivity (Equation 14) is presented by *Pelnard-Considére* (1956).

Equation 14:

$$G = \frac{K H_b^{5/2} \sqrt{g/\kappa}}{8(s-1)(1-p)(h_* + B)}$$

where K is the sediment transport coefficient, which is a function of sediment size, B is the berm elevation, H_b is the breaking wave height, h_* is the depth of closure, p is the *in-situ* sediment porosity (approximately 0.35 to 0.40), s is the sediment specific gravity (approximately 2.65), and κ is the ratio of wave height to water depth within the surf zone (approximately 0.78).

The *Pelnard-Considére* equation can be applied to evaluate the performance of a beach nourishment project. For this analysis, the Wave Information Study (WIS) time series of wave and wind data, developed by the United States Army Corps of Engineers, was used to describe the wave climate offshore of New Jersey. The WIS, performed by the USACE, is widely accepted for design purposes for United States shorelines by many coastal engineers and scientists (http:// wis.usace.army.mil/). WIS contains time series information of spectrally-based, significant wave height, peak period, peak direction, and wind speed and direction produced from a computer hindcast (prediction) model. The hindcast wave model, WISWAVE (Resio and Tracy, 1983) is simulated using wind information (speed and direction) at selected coastal locations around the United States. Wave measurements made by NOAA during the 1980s made verification of the WIS results possible by comparing the statistics and the distributions of wave heights and periods from different time periods (Hubertz et al., 1993). The availability of long-term records makes WIS data attractive when considering average or seasonal wave conditions. Twenty years of wave hindcast data from WIS station 63143 were used for analysis of the Ocean City nourishment.

In addition, since the offshore wave environment can be complex, calculation of the alongshore diffusivity was based on the wave energy distribution for average annual directional approach bins. Data were segregated by direction of approach. An energy distribution, as a function of frequency, was generated from all the waves in each directional bin. A representative two-dimensional spectrum was generated for each approach direction bin based on the sum of all the waves approaching from that mean direction. This was combined with the percentage of occurrence to create a 20 year evaluation of wave impacts at the shoreline. This energetic directional bin approach has been successfully utilized in transformation modeling (Byrnes et al., 2000) and identifies all potential approach directions, including those that may occur only a small percentage of time during a typical year, but potentially have significant impact on sediment transport. Values of alongshore diffusivity were computed for each directional bin and used for modeling beach nourishment performance.

Since the material spreads over time, it is possible to evaluate the longevity of the nourishment by looking at the amount of material left in the project area. Subsequently, nourishment alternatives can be compared to one another based on their longevity. The service life of the beach nourishment can be based upon the percent of the initial beach nourishment left within the boundary of the initial fill. The percentage remaining will decrease with time, but that material is not necessarily lost from the system, it has just spread to regions outside of the original nourishment template. For example, sediment may have been transported offshore or along the beach. Therefore, although the sediment no longer falls within the initial nourishment template, it has not completely disappeared from the system.

Figure 130 presents the performance of the authorized projects for Peck Beach (south of Ocean City), Ocean City, and a combined nourishment scenario that would nourish both projects simultaneously. The performance is expressed in terms of amount of material remaining in the initial template region, as a function of time, Peck Beach (black line), Ocean City (green line), and a combined nourishment (blue line). All results were adjusted to include a background erosion rate corresponding to the historical shoreline change. That is, in addition to the dispersion that is occurring, an additional amount is eroded due to the natural erosion of the beach. The percent of initial material remaining is presented along the y-axis, while the time in years is presented along the x-axis. For example, after 3 years, approximately 76% and 57% of the initial fill volume is remaining for Ocean City and Peck Beach, respectively. For a combined nourishment (blue line), approximately 83% of the initial fill volume remains after 3 years. This represents a significant improvement in project performance.

Since both the Peck Beach and Ocean City nourishments have a 3 year periodic nourishment cycle, it would be straightforward to construct the two projects jointly, and receive benefits from both project cycle synchronization (strategy A) and improved performance (strategy B) . The analysis indicates that through combining the projects, the periodic nourishment cycle for both Peck Beach and Ocean City could theoretically be extended to 6 years or longer, or the amount of sediment needed for each 3 year periodic nourishment would be reduced by approximately 575,000 cy.

Assuming a dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand, this strategy would result in a cost savings of approximately $138 million over a 50-year time horizon due to reduced volume requirements. This assumes periodic nourishment remains at a 3 year interval of approximately 900,000 cy (combined between Peck Beach and Ocean City) to return the nourishment to the original construction template. Cost benefits of this strategy are compared to current operations and other strategies in the summary section. Additional cost savings may be realized from reduced contracting and management requirements.

The reduced number of periodic nourishment episodes and reduced long-term volume requirements will also have an environmental benefit as there will be less frequent disturbance of the offshore borrow site areas, reduced disturbance on the beaches, reduced overall sediment needs (approximately 10 million cy less over 50 years) and reduced overall pollutions (e.g., noise, air, etc.).

This strategy may require a new construction authorization as the project being combined would be different in scale than the individual projects. A new feasibility study would be required to determine the extent of federal interest in a new plan and to address the environmental requirements of any new plan. The cost sharing may change as a result of the new plan as well as the timing and amount of non-federal funds required. Borrow areas would have to be revisited and sufficient borrow sites identified and evaluated as part of the reanalysis. The study itself could be accomplished under the existing New Jersey shore study authority and would likely require a feasibility study cost sharing arrangement. Finally, if a project is recommended and authorized for construction a new Project Cooperation Agreement (PCA) would have to be signed. If however, the project templates remain the same scale as the currently authorized projects, it may be more reasonable to implement this approach in an informal synchronization (Strategy A) and achieve the same benefits.

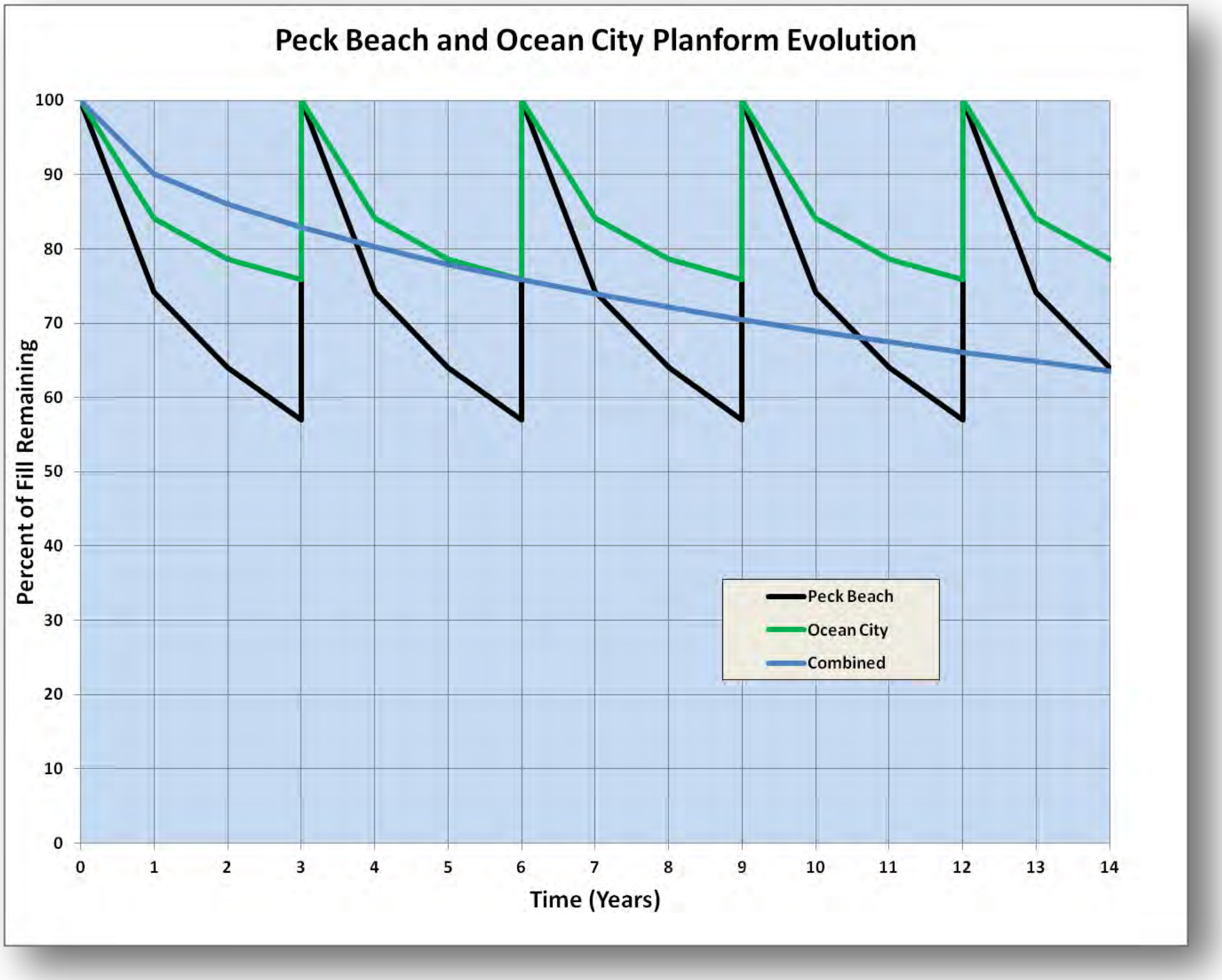


Figure 130. Estimated beach nourishment performance for the authorized projects at Peck Beach (black line), Ocean City (green line), and the combination (blue line) of the two projects.

The implementation of this strategy has minimal additional constraints, limited to availability of dredge equipment and borrows site quantities, which are also constraints of the current operations.

Table 60 presents a summary of the criteria evaluated for the project combination strategy and ranks this strategy as a intermediate to high priority with a Tier level of 2 (given the potential time constraints and requirements associated with changing authorizations). Because the strategy may be accomplished on an informal basis (Strategy A), there may be less urgency to implement it in the manner described (Strategy B).

Table 60. Project Combination Strategy Summary.

Criteria	Summary
1. Authorization	Depending on the exact nature of the combination or modification to the project scale, it is likely that a new construction authorization and other documents will be required
2. Constraints	No additional non-authorization requirement constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$138 million over 50-year time horizon
4. Service Life	Relatively significant increase in project longevity and service life
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale and reduced overall volumetric sand requirements in long-term
6. Priority	Intermediate to High Priority
7. Tier Level	Tier 2
8. Next Steps	If formal authorization is pursued, need more detailed studies

C. *Borrow Area Expansion at Great Egg Harbor Inlet*

The 1976 Phase I General Design Memorandum Great Egg Harbor Inlet and Peck Beach – Ocean City, New Jersey plan of improvement included dredging a navigation channel in Great Egg Harbor and using the material to nourish the Ocean City beachfront from the inlet south to 59th Street. The project was not constructed, as financial constraints forced the project to inactive status. In 1982, the NJ Shore Protection Master Plan renewed interest in the proposal. CENAP prepared a Beach Erosion Control-Navigation Study (1985) and a Plan Reevaluation and Scheme Selection (1987) for a scaled-back version of the project. The eventual federal project (Great Egg Harbor Inlet to Peck Beach – Ocean City, NJ), constructed in 1993 with 5,345,000 cy, included an even smaller nourishment area (Seaview Road to 36th Street) supplied by a 579 acre borrow area around the ebb shoal of Great Egg Harbor Inlet. Renourishments of northern Ocean City occurred periodically since construction and are expected over the 50 project cycle. To date, over 8,000,000 cy of Great Egg Harbor Inlet ebb shoal dredged material has nourished northern Ocean City, as discussed in the project description.

Therefore, the initial and periodic nourishments conducted to date have all used borrow areas within Great Egg Harbor Inlet. As such, this strategy is already being implemented by the USACE by utilizing material that is deposited in the inlet from local sources and replacing that material back on local eroding beaches.

The currently permitted borrow areas in Great Egg Harbor Inlet include a 580 acre area and a 180 acre area of the ebb shoal. The projected sand reserve for permitted borrow areas is estimated to be 16,000,000 cy. Based on survey and a thickness range of 10 to 15 ft, the estimated pre-project borrow quantity for the original (580 acre) Great Egg Harbor Inlet borrow area is between 9,344,966 and 14,017,449 cy. In 2009, USACE Public Notice CENAP-PL-E-09-04 proposed two new borrow areas at the ebb shoal of Great Egg Harbor Inlet. The NW Area is 745 acres and the SE area is 275 acres, however the Public Notice provides no volume estimates for these borrow areas. At an average thickness of 10 to 15 ft, the NW Area could yield between 12,019,000 and 18,029,000 cy. At an average thickness of 10 to 15 ft, the SE Area could yield between 4,437,000 and 6,655,000 cy.

Figure 131 shows these permitted borrow areas (gray) and the USACE potential borrow areas (blue) within Great Egg Harbor Inlet. The figure indicates that a majority of the Great Egg Harbor Inlet ebb tidal shoal and inlet itself has already been permitted or proposed as a borrow area, and this provides a significant amount of material for future periodic nourishments. Therefore, there is little need for expanded borrow areas in the Great Egg Harbor Inlet. However, the green outlined area in Figure 131 delineates a potential additional borrow site using the flood tidal shoal. The flood tidal shoal at Great Egg Harbor Inlet is approximately 23 acres. At an average thickness of 10 to 15 ft, the flood tidal shoal borrow area could yield between 371,000 and 557,000 cy.

Figure 131. USACE potential (blue) and permitted (gray) borrow areas at Great Egg Harbor Inlet. Also shown are potential expanded borrow areas (green) at the flood tidal shoal. Image courtesy of Google Earth©.

Although the need is minimal, expanded borrow areas within the inlet could be authorized by developing a beneficial reuse project using the coastal projects authorities to implement. Documentation would have to be developed to accomplish this as well as a new PCA reflecting today's model agreement would have to be negotiated and signed.

The primary constraints on expansion of the inlet borrow sites are environmental. Establishing borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave, tidal currents, and sediment transport processes also are needed, especially to determine the potential impact from removal of a significant portion of the ebb or flood tidal shoals. The physical and environmental delineation would add cost; however, once permitted, the construction costs associated with obtaining the nearshore material are significantly lower than for upland material, and also lower than offshore sources due to the close proximity of the inlet material to the beach nourishment project(s).

Table 61 presents a summary of the criteria evaluated for the expansion of the Great Egg Harbor Inlet borrow area and ranks this strategy as a high priority for beneficial reuse and a low priority for expansion (due to the adequate borrow site sediment supply) with a Tier level of 2. USACE potential borrow sites that have been previously delineated should continue to be pursued, but further expansion is likely not required. Next steps for this strategy would be to initialize any studies and surveys needed to expand the inlet borrow sites, if needed.

D. Site-Specific Coastal Processes Evaluation

This strategy involves developing a comprehensive, coastal processes based, understanding of the prominent erosion that occurs at the north end of Ocean City. A site-specific study, intended to focus on detailing the coastal processes (waves, tidal currents, wave-induced currents, sediment transport, etc.), would be recommended to identify potential alternatives or modifications that may improve the existing shore protection authorization.

The northern portion of Ocean City has a history of beach erosion and numerous attempts have been made to mitigate damage and maintain a recreational beach. Significant nourishment efforts (over 1,000,000 cy per periodic cycle) placed in this area have quickly eroded. Approximately 13.4 million cy of sand have been added to the beaches since 1992. This is a heightened need for local due to reduced federal funding for periodic nourishments. Borough and/or state funds have been solely used for maintenance, which is a difficult investment to support in the long-term.

Table 61. Borrow Area Expansion at Great Egg Harbor Inlet Strategy Summary.

Criteria	Summary
1. Authorization	May require modification of authority to include beneficial re-use of inlet material; however, since the existing borrow site is the inlet, this may be a simple expansion
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Some cost savings expected due to close proximity of borrow sites
4. Service Life	No change to shore protection service life
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Initiate studies and surveys.

Despite the federal project that continues to bring in sediment to the Ocean City area, the ocean facing beach at the north end of the barrier beach continues to erode, placing public and private infrastructure at risk. The quick dispersion of placed sediment has also become costly. Improving the performance of the nourishment may result in a significant reduction in the amount of periodic nourishments. A number of studies evaluated alternatives for shore protection in Ocean City, and monitoring documents the beach loss; however, a comprehensive study that defines the cause and effect relationship between the dominant coastal processes and shoreline erosion has not been performed. This proposed strategy addresses the knowledge gaps in the existing work.

This strategy will provide an improved understanding of the causes and nature of the significant erosion, including the short service life of the nourishment projects that are conducted. The study should be rooted strongly in applying scientific and engineering tools (i.e., data and models) to understand the erosional processes. This should include coupled hydrodynamic, wave, and sediment transport modeling, supported by field observations. Improved understanding of the system may suggest better approaches to mitigation

Table 62 presents a summary of the criteria evaluated for the site-specific coastal processes evaluation strategy (although many of the criteria are not applicable) and ranks it as an intermediate priority with a Tier level of 1. Although there is no immediate cost savings associated with implementation of this strategy, future financial savings could be significant for the given investment (estimated at $200,000).

Table 62. Site-Specific Coastal Processes Evaluation.

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings, potential future savings
4. Service Life	Not applicable
5. Other Benefits	An improved understanding of the coastal processes and potential mitigation options for Ocean City
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study

E. Sediment Backpassing to Ocean City

This strategy involves extracting sediment from a portion of the shoreline downdrift of the highest erosion areas at Ocean City (between 14th and 17th streets) and moving the material to the north end of Ocean City. This methodology, called sediment backpassing, is intended to work with the natural littoral drift within a system by recycling sand back updrift to the location where it initially resided. For example, nourishment material placed at Ocean City is transported to the south to an area that may be less erosional. This approach is shown conceptually in Figure 132. Currently, there is a limited opportunity for backpassing at Ocean City since there are limited accretional regions downdrift.

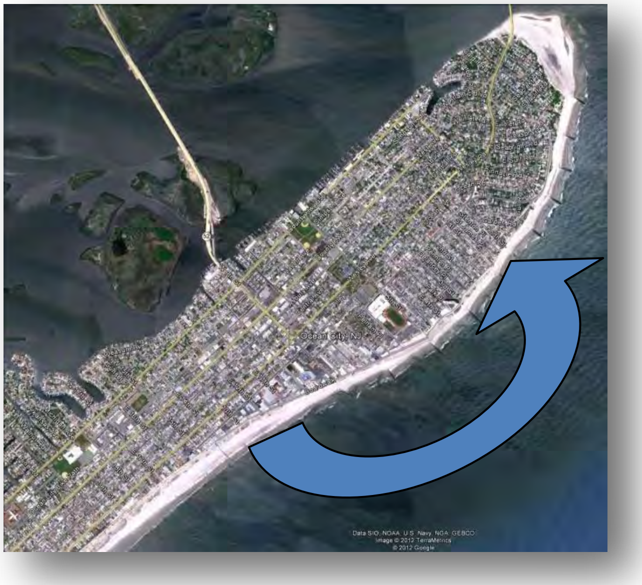


Figure 132. Sediment backpassing strategy for Ocean City.

As part of the Hereford Inlet to Cape May Inlet Feasibility Study, Clausner and Welp (2008) conducted a study to investigate the feasibility of mobile hydraulic back-passing for the Wildwood area. The study determined that in a time frame of two to four months, as much as 200,000 cy of sand could be back-passed distances of up to 15,000 ft using the mobile system they evaluated. Clausner and Welp (2008) also determined that the cost associated with the mobile system (a hydraulic pumping system mounted on a boom equipped crawler) would be approximately $10/cy. Using the results and costs developed by Clausner and

Welp (2008), and assuming compatible sediments along the Ocean City shoreline, a preliminary cost analysis was performed on the applicability of sand back-passing to compliment current nourishment efforts at Ocean City.

Historic shoreline change data indicates shoreline accretion occurs within 6,000 ft to the south of the most heavily eroded areas at Ocean City. In this region, there is an average rate of shoreline accretion of approximately 4.1 ft/yr (1.2 m/yr). To determine the potential volume available for backpassing, the existing profiles of the accretionary area were translated landward (a distance equivalent to the rate of advance) using equilibrium beach profile theory. To ensure shoreline stability, only sediment that was accreting was identified as available for backpassing. Using this approach, the volume of sediment accreting in the area south of Ocean City was calculated to be 26,000 cy annually, or approximately 78,000 cy every three years. However, not all of this excess material is available for extraction. Assuming the use of a 160 ft boom mounted pumping system, approximately 10,000 cy/yr of sand are available to be backpassed to Ocean City. More sediment could potentially be extracted using sheet piles and temporary earthworks, increasing the swath of the mobile dredging equipment.

The total amount of sediment available for backpassing is not enough to eliminate the need for periodic nourishment; however, utilizing this material reduces the amount of material needed for periodic nourishment.

Over a 50-year time horizon, there is a cost savings of $3 million if 10,000 cy/yr of sediment backpassing was implemented. This assumes that the mobile backpassing system is readily available and could be utilized at the Ocean City location. Additional cost savings may be realized from reduced contracting and management requirements. Reduced impacts to offshore or inlet borrow sites would be another benefit of this strategy. A comparison to current operations and to other strategies is presented in the summary section.

Constraints involve the potential impact on the beach where sand is extracted. This includes the ability of the beach to adequately serve the same function and level of protection as before the sediment removal.

The potential authorization for this project does not include specific authority to backpass sand. However, the Corps' value engineering authority could be used to determine the effectiveness of backpassing at reducing the long term nourishment costs compared to its implementation cost. The need to develop benefit numbers is also reduced by this approach; the benefits are simply the reduced nourishment costs. Appropriate environmental clearances would also be required.

Table 63 presents a summary of the criteria evaluated for the sediment backpassing strategy and ranks this strategy as High priority at this location and Tier Level 2.

F. Offshore Borrow Area Expansion or Establishment

As presented in Table 59, sediment sources for the initial construction of the Ocean City project, as well as the periodic nourishment, have been from inlet borrow areas at Great Egg Harbor. Currently, the permitted inlet borrow sites do not have enough material to complete future renourishments; however, the proposed additional sites in Great Egg Harbor Inlet would adequate provide sediment.

This strategy is not specifically geared towards providing a cost savings, but rather maintaining current operational costs since

Table 63. Sediment Backpassing at Ocean City Strategy Summary.

Criteria	Summary
1. Authorization	Use value engineering to determine the effectiveness of backpassing at reducing the long term nourishment costs compared to implementation cost
2. Constraints	Dredge equipment availability, potential impacts to source beach
3. Cost Savings	$3 million over 50-year time horizon
4. Service Life	No change to service life
5. Other Benefits	Reduced impacts to offshore and/or inlet borrow sites.
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Use value engineering to implement; assess environmental impacts on source beach.

upland sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., truck traffic, road repairs, time of construction, etc.).

Over a 50 year time horizon, the periodic nourishment sediment needs at Ocean City are approximately 17,000,000 cy. Initial construction of the Great Egg Harbor and Peck Beach shore protection project required 5,345,000 cy. Overall, the project requires approximately 22,945,000 cy over a 50-year time horizon.

The original inlet borrow sites (9A, 9B, Great Egg Harbor) for the Great Egg Harbor and Peck Beach authorized shore protection project had approximately 9,810,000 cy remaining after initial construction of Phase I and Phase II and an emergency storm rehabilitation. As such, there is a deficit of approximately 7 million cy for renourishment of the project.

Continued expansion of existing sites or searches for new borrow sites is needed for this region. For example, the proposed inlet borrow area should be considered (additional 29.2 million cy with a dredge cut of 15 ft). Potential searches in Federal waters also may be warranted through cooperation with the Bureau of Ocean Energy Management (BOEM).

This strategy can be accomplished under the existing project authorities as the provision of borrow areas for the life of the project is part of the authorization. It would require cost sharing likely at the same level as the project. Appropriate studies and environmental clearances would be needed.

The primary constraints with expansion or establishment of offshore borrow sites are environmental. Establishing offshore borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Studies of the impacts to wave and sediment transport processes also are needed. The physical and environmental delineation would add cost; however, once permitted, the construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 64 presents a summary of the criteria evaluated for the offshore borrow area expansion and establishment strategy and ranks this strategy as a High priority with a Tier level of 1. Priority should be placed on the previously identified potential borrow sites in Great Egg Harbor Inlet. Next steps for this strategy would be to initialize any studies and surveys needed to expand or establish new borrow sites for this region, which has a known deficit and coordinate with BOEM for any potential federal waters borrow sites.

Table 64. Offshore Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Initiate studies and surveys. Coordinate with BOEM

G. *Refined Beach Nourishment Template*

This strategy involves applying adjustments to the authorized beach nourishment template along Ocean City to determine if modifications may in increase performance or improve storm damage protection. A successful beach nourishment project consists of more than simply placing sediment on a beach. Beach nourishment projects are engineered. A beach nourishment template, which consists of numerous design parameters, is based on the characteristics of the site and the needs of a project. Every beach nourishment design is unique, since different beaches in different areas have different physical, geologic, environmental, and economic characteristics, as well as different levels of required protection. The design must consider climatology, the shape of the beach, type of native sand, volume and rates of sediment transport, erosion patterns and causes, waves and water levels, historical data and previous storms, probability of certain beach behaviors at the site, existing structures and infrastructure, and past engineering activities in the area.

The structure of a nourishment provides a protective barrier that also supplies material to the beach. A higher and wider beach berm is designed to absorb wave energy. Dunes may be constructed or existing dunes improved to reduce damage, including potential upland flooding, from storms. Figure 133 depicts a beach berm and dune on a typical beach profile. Nourishment length, berm height and width, dune height, and offshore slope are critical elements of a beach nourishment design. Periodic nourishment intervals are usually incorporated in the nourishment design. The renourishment interval will vary based on the initial design, wave climate, sand used, frequency of storms, and project age. In addition, beach nourishment is not an exact science; variables and uncertainties exist. Actual periodic nourishment intervals may differ from planned intervals based on conditions at the nourished beach and the frequency and intensity of storms.

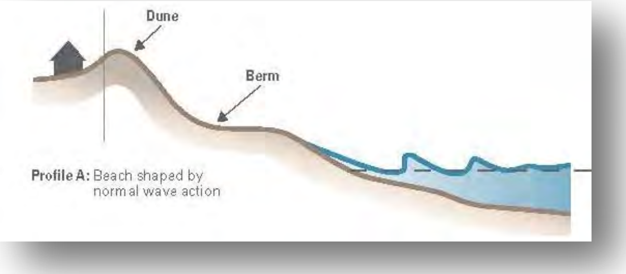


Figure 133. Typical beach profile and features (from Coastal Engineering Manual, 2003).

This proposed strategy evaluates potential improvements to project performance, storm damage protection, and subsequent cost savings that can be realized by modifications to the currently authorized beach nourishment template.

The feasibility studies for the authorized projects typically evaluate a range of proposed beach nourishment template designs using alongshore and cross-shore analysis and/or modeling efforts to assess performance and storm damage protection afforded by the proposed nourishment template. However, the USACE policy has been to not consider increases to the natural berm elevation for the design template. Additionally, the currently authorized design template has not been re-evaluated following monitoring of the performance of the system. Monitoring data may suggest potential modifications of the template. Therefore, this strategy assesses changes to the beach nourishment template that may yield cost savings over the long-term. An example of this type of analysis is presented here by evaluating change in berm width on the performance of the Ocean City project as a preliminary analysis of potential template modification. The influence on beach performance from modifying the berm height was not assessed for the Ocean City nourishment since an increase in berm height would result in significant amount of additional sediment requirements for this particular location. Due to the lack of natural dunes along portions of the Ocean City nourishment length (e.g., 6th Street), an increase in berm height would need to be extended landward all the way to the Ocean City broadwalk.

Similar analyses could be completed for a number of parameters that are components of beach nourishment design; including:

- Nourishment length – Expanding the nourishment length, specifically through combining or syncing projects could be evaluated (as in Strategy A and B).
- Berm Width – The width of the berm could be modified to see if there is a cost benefit that could be attained. This also may involve a spatially variable berm width modification
- Berm Height – The height of the berm could be modified to determine impact on storm damage protection.
- Offshore slope – The offshore slope of the nourishment can be changed.
- Grain size – The grain size of the source material for the nourishment may affect the performance of the projects. For example, coarser nourishment material may result in improved project performance (lower erodibility) and hence more protection.

To assess potential changes in berm width at Ocean City, the computer model SBEACH (Larson and Kraus 1989) was used to assess cross-shore evolution. SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and further developed and verified based on field measurements (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990). The model predicts the time-dependent evolution of existing or design beach and dune profiles for specified water levels and wave conditions. In addition to the proposed nourishment template, the model requires a time series of wave heights, wave periods and water levels as forcing inputs. The specific storm information required by SBEACH is a time history of total water level (tide plus surge) and wind wave height and period. The WIS hindcast information, FEMA FIS still water storm surge elevation, and extremal analysis were used to develop a simulated 10-year storm for this analysis.

Figure 134 presents results of varying the berm width (green line) of the Ocean City authorized beach nourishment template. The horizontal axis shows the percent of material lost from the nourishment template area caused by a 10-year, 24-hour storm for various berm widths. The left hand vertical axis shows berm width (feet). The variable width scenarios use a constant 6.75 ft NAVD88 berm height, which corresponds to the currently authorized berm height (authorized berm width is 100 ft). Increases in berm width show improved response to the 10 year storm. For example, the currently authorized project template loses approximately 85% of the periodic nourishment during the 10-year, 24-hour storm. However, increasing the berm width by twenty feet, to 120 ft wide, reduces the percentage of material lost to 46%. Increasing the berm width further results in decreased losses, but also requires additional nourishment volumes, sediment sources, and finances. As such, there is a point of diminishing returns on the amount of required sand needed to extend the berm width versus the increased performance gained. Adding more sand to the system may result in better performance, but also may not be worth the added cost of the additional sand. This type of analysis could be conducted to evaluate the sensitivity of various parameters in the beach nourishment design, their potential impacts on overall cost of the project, and identify the most cost-effective design template.

The 120 ft berm width modified design requires approximately 738,000 cy of additional sediment to gain the required berm width during the initial nourishment; however, the performance is improved over each 3 year cycle such that the amount of sediment required for each periodic nourishment is reduced.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this example of template modification would result in a cost savings of approximately $35 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments, or increased renourishment intervals. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

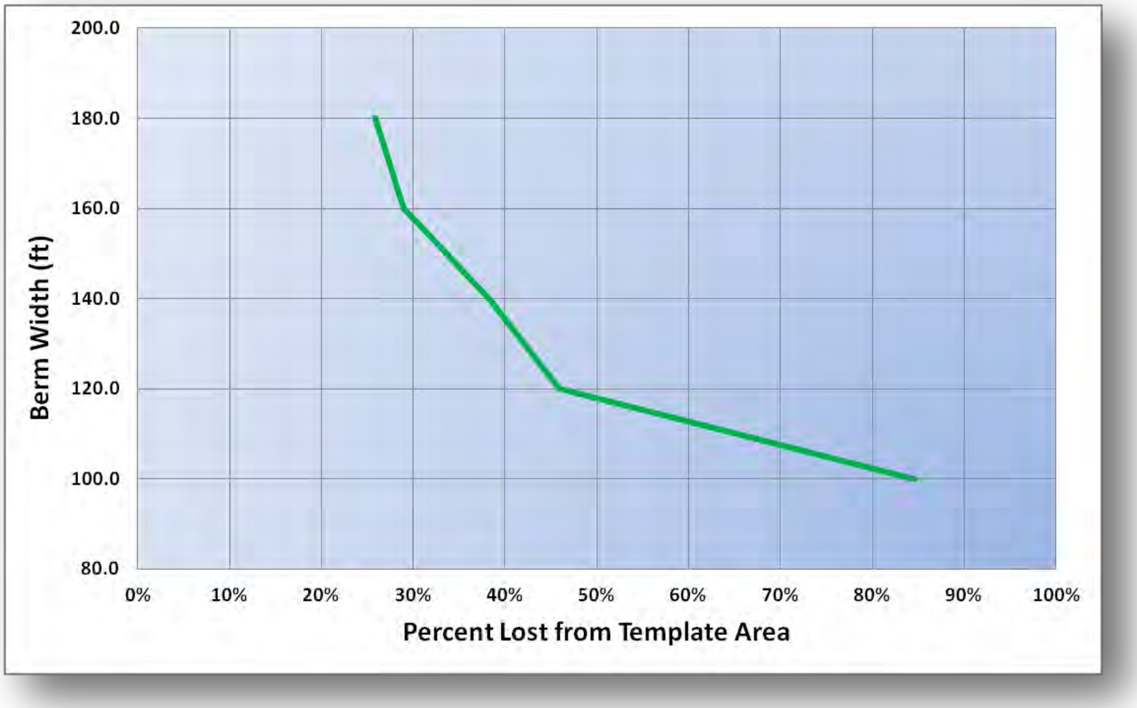


Figure 134. Eroded beach volume as a function of template berm width for the Ocean City nourishment project in response to a 24-hour, 10-year return period storm event.

In addition to the cost savings from reduced sediment volume requirements, modification of the beach nourishment template may have other benefitsl. For example, the modified template may result in improved storm damage protection and reduced potential upland damage costs. Examples of other potential benefits include habitat enhancement, reduced ponding or upland flooding, and reduced environmental impacts offshore due to reduced offshore sediment needs.

Relative to the current authorization, the existing template defines the authorized project and the NED plan. Changing the template would imply that the authorized plan was no longer the NED plan and the project would have to be reanalyzed. To do so would require the use of the existing New Jersey shore study authority to determine the degree of federal interest, get the requisite environmental clearances, and recommend a change in the authorized plan. This would require the existing project authority to be modified by the Congress. It would also likely require a new study cost sharing agreement to be signed, as well as a non-federal sponsor willing to contribute 50% of the study costs and agree to any changes in the construction and long-term cost sharing. A new PCS conforming to the model agreement would have to be signed.

Potential constraints associated with modification of the beach nourishment template include environmental concerns (e.g., occupying a larger offshore footprint), political and local community concerns that would limit the ability to change the template (e.g., communities may not want an increased berm height), and logistical concerns associated with modification of the authority to construct the project.

Table 65 presents a summary of the criteria evaluated for the refined beach nourishment template strategy and ranks it as a low to intermediate priority and a Tier level of 2. Next steps would be to conduct more detailed studies to assess the need for template modifications. The studies would focus on the cost benefit aspects of template modification.

Table 65. Beach Nourishment Template Refinement Strategy Summary.

Criteria	Summary
1. Authorization	Requires a change to the authorized plan and would include new study, permits, and cost-sharing agreements
2. Constraints	Logistic, political, local community, and environmental concerns
3. Cost Savings	Depends on template modification, $35 million for case evaluated.
4. Service Life	Increased service life of beach nourishment expected
5. Other Benefits	Improved storm damage protection, habitat enhancement, reduced offshore environmental impacts
6. Priority	Low to Intermediate
7. Tier Level	Tier 2
8. Next Steps	USACE Philadelphia district decide if the strategy is warrants further study

H. Adaptive Management Approach

This strategy considers the utilization of an adaptive management approach for the implementation of periodic nourishments. This would involve possible adaptation of the nourishment location, quantity, length, and template based on monitoring results and the behavior of previous nourishment events. The goal of the strategy would be to continually improve performance of the periodic nourishments by assessing the ongoing erosion at Ocean City. The authorized plan could be evaluated with the data in the Stockton College annual reports to identify possible benefits of more strategically placied sand. For example, a preliminary investigation of the temporal variability of the Ocean City profiles was completed using the Stockton College reports (2000 through 2008).

The area of authorized beach nourishment for Ocean City extends from Surf Road in the north down to 34th Street in the south. Four of the semiannual profile stations observed by Stockton College reside within this area. Another profile lies just to the south of the Ocean City nourishment area, at 56th Street. The four profiles, denoted by the street where they were observed, are Garden Road (Site 225), 6th (Site 125), 20th (Site 124) and 34th (Site 223) streets, as shown in Figure 135. The first two, Garden Road and 6th Street lie within the Ocean City groin field, the next two are south of final groin.

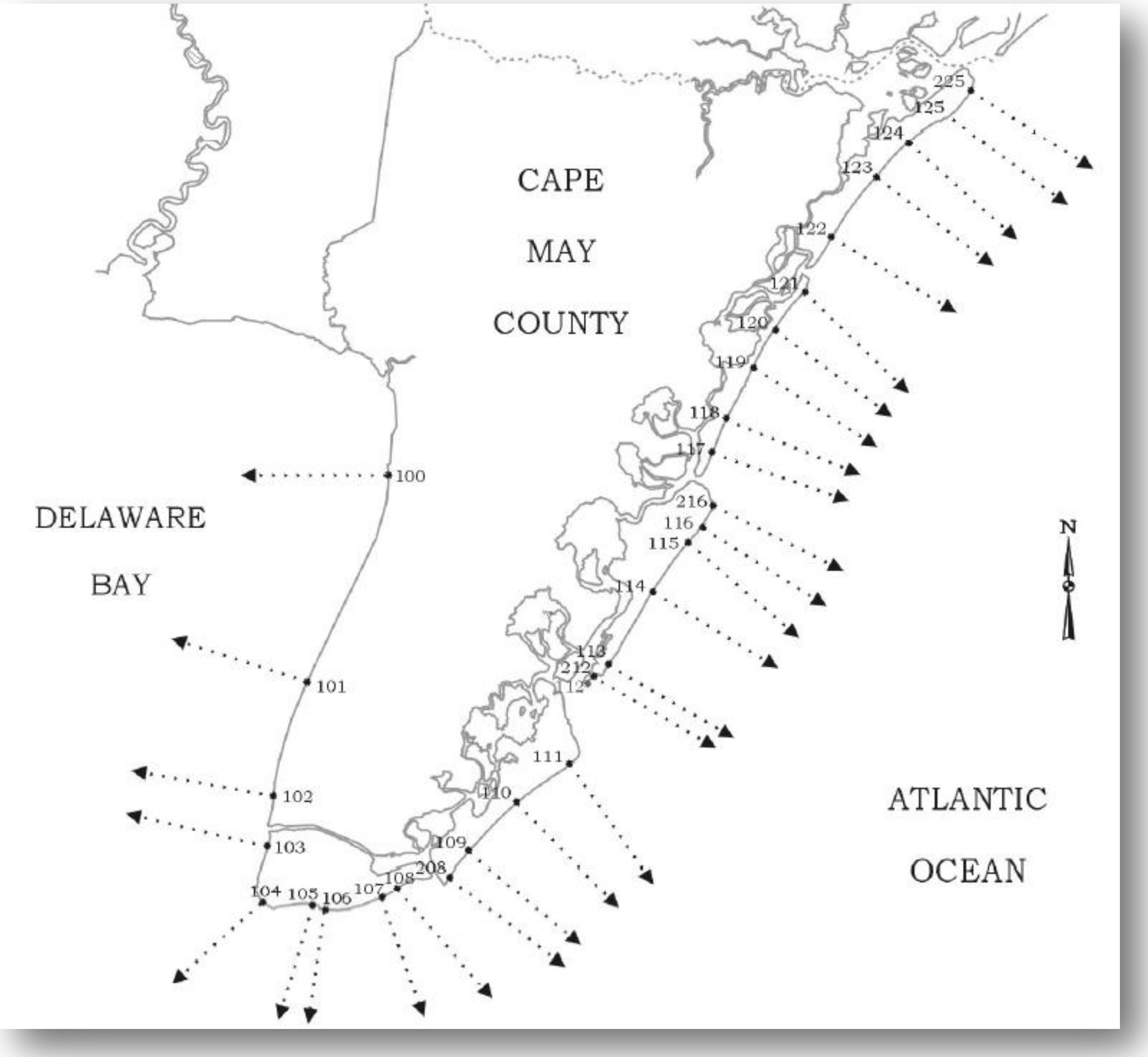


Figure 135. Location of beach profile monitoring stations in Cape May County (from Stockton College annual beach monitoring reports).

Preliminary examinations of profile evolution indicate that significant erosion and rapid nourishment loss occurs at Garden Road and 6th Street. Over the years this portion of beach is periodically nourished, only to quickly retreat landward. At 20th Street and 34th street, the beach profiles remain relatively stable with some seasonable variability. These two locations likely benefit from net southward littoral drift of sediment. As such, it may be beneficial to focus nourishment efforts north of 20th street, overfilling this portion of the beach and allowing sediment to naturally migrate south to nourish the downdrift beaches. This approach would be similar to the feeder beach implementation that is being conducted at Cape May City. This approach may reduce the frequency with which nourishment is needed in the higher erosional areas in Ocean City, especially if the berm width or elevation is increased (Strategy G).

This is only one potential approach that could result from the adaptive management strategy at Ocean City. Through closer evaluation of the monitoring results, especially relative to the performance of the placed sediment, future periodic nourishment efforts could be optimized for improved performance and cost savings.

Relative to the current authorization, this strategy could be accomplished under the existing project authority. Value engineering could be the vehicle to analyze the effectiveness of the potential approach and then validate the fiscal benefit.

Potential constraints associated with the adaptive management approach strategy include increased analysis and management requirements. There would also be some studies required to complete the value engineering and justify the approach. It is likely that environmental concerns would also need to be evaluated depending on the proposed change.

Table 66 presents a summary of the criteria evaluated for the adaptive management approach strategy and ranks this strategy as a high priority and a Tier level of 1. Next steps for this strategy would be to implement a program for more detailed assessment of profile monitoring data that would include some additional analysis techniques to determine beach profile response to nourishment efforts (e.g., principal component analysis).

Table 66. Adaptive Management Approach Strategy Summary.

Criteria	Summary
1. Authorization	Value engineering could be used to implement.
2. Constraints	Additional study and management, likely environmental concerns.
3. Cost Savings	Depends on adaptive management approach., but would not be a significant cost to implement the strategy
4. Service Life	Depends on the adaptive management approach
5. Other Benefits	Potential cost savings, lessons learned that may be applied in Ocean City and elsewhere
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Implement more detailed monitoring data assessment and analysis

I. Coastal Structure Modification

Groin fields are designed to inhibit and/or prevent the longshore transport of sediment by creating either an impermeable or a semi-permeable barrier (Kraus, Hanson and Blomgren, 1994). A traditional groin, however, only interrupts the longshore sediment transport and provides limited reduction in wave energy at the shoreline. By modifying the groin design to a T-head (or fish tail) shape, the groin not only continues to function as a barrier to littoral drift, but also reduces the amount of wave energy transferred to the shoreline through wave diffraction (Bodge, 2003). This shape also reduces the amount of sediment transported offshore due to cross-shore processes. The resulting shape is similar to a pocket, or embayed, beach with the equilibrium coastline geometry described with the parabolic bay shape equation (Hsu, et al., 2008).

Due to a limited amount of research available, predicting the shoreline position of a coastal cell protected by a T-head groin is uncertain. Bodge (2003) proposed the "γ shoreline" rule of thumb for preliminary design, where the initial design shoreline position is located a distance shoreward of the head of the groin approximately γ times the opening between adjacent groins ($0.35 < \gamma < 0.65$). Hsu et al., (2008) recommends the use of the parabolic bay equations. Although the use of bay shape equations was found to be accurate in predicting equilibrium positions, they cannot make dynamic shoreline predictions in their current form (Lausman, 2006). By tuning the initial design to existing wave parameters along Ocean City, modifying some or all of the existing groins will enhance the retention of sand, but this retention is not currently quantifiable.

As a preliminary analysis, the γ shoreline method was applied with the following assumptions:

- the groins will not be lengthened
- each arm of the t-head will be approximately the length of the emergent groin
- each arm will parallell the coatline at each existing groin

Using this approach, a rough estimate of future shoreline postion can be determined. The shoreline behind the T-head groins can be maintained at distances of 20 to 200 ft landward of the T-head structure. Approximatley 450,000 cy of sand may be retained by converting 8 of the groins at Ocean City into T-head designs. The conceptual layout of this strategy is shown in Figure 136.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), and an estimated cost of $5 million for each T-Head groin extension, this approach would result in a cost savings of approximately $23 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Figure 136. Ocean City conceptual layout of T-Head groin field. T-Head additions are shown in red.

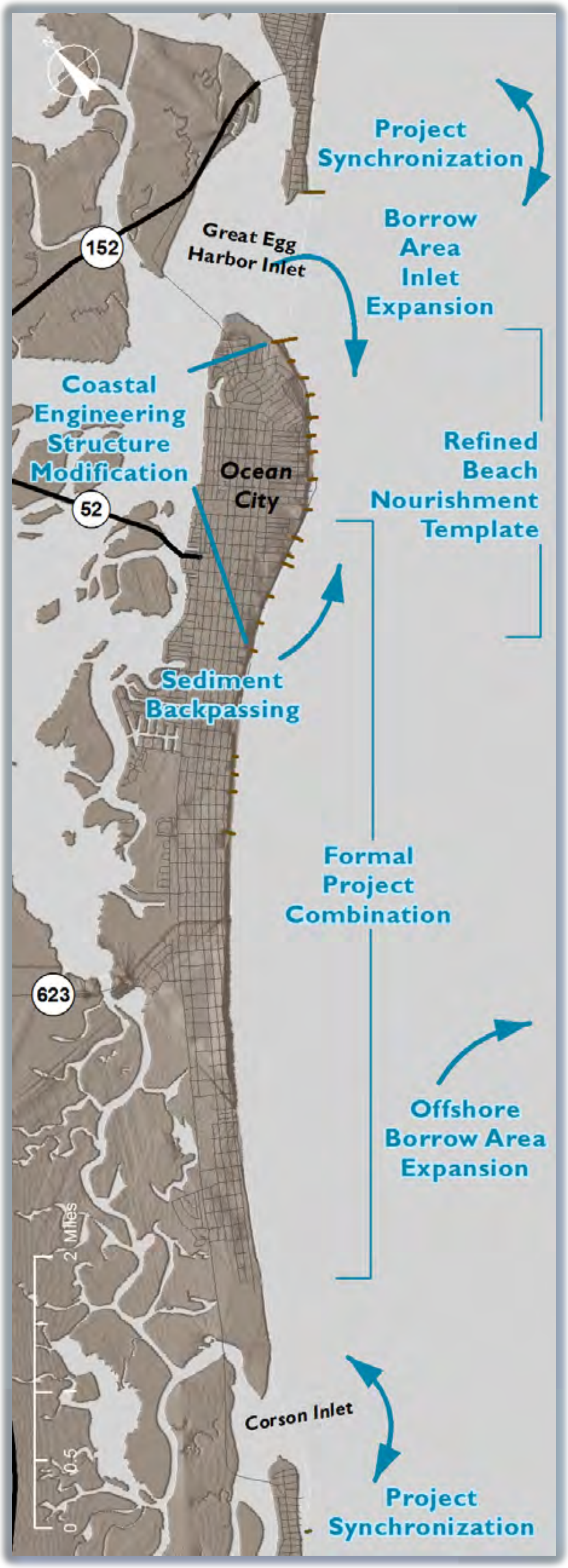
Structural modifications to Ocean City were previously rejected as a strategy during the development of the authorized project. Before any re-analysis is performed for this strategy, the reasons for initial rejection should be reviewed. If the conclusion of the review is that previous reasons for rejection are no longer applicable, then the evaluation of these structures could be accomplished under the concept of value engineering.

Constraints for this strategy include potential environmental impacts that need to be assessed and coastal processes evaluations that should evaluate the impact of proposed structural additions and/or modifications. Specifically, potential impacts of T-Head groins on the downdrift beaches needs to be thoroughly evaluated.

Table 67 presents a summary of the criteria evaluated for the structural modification strategy and ranks it as a low to intermediate priority with a Tier level of 3. Next steps would be to initialize more detailed studies to assess the physical and environmental impacts of proposed structural modifications. The studies would also focus on the cost benefit aspects of the structural modification proposal(s).

Table 67. Coastal Structure Modification Strategy Summary.

Criteria	Summary
1. Authorization	Need to revisit initial feasibility plan, could use value engineering to implement
2. Constraints	Environmental impacts need to be evaluated, coastal processes assessment to evaluate impact of structural modification
3. Cost Savings	$23 million for structural modification presented herein
4. Service Life	Enhanced beach nourishment performance, structural service life expected to be 50 years
5. Other Benefits	Reduced environmental impacts to offshore resources, increased shore protection level
6. Priority	Low to Intermediate
7. Tier Level	Tier 3
8. Next Steps	Coastal processes and environmental studies to determine relative cost benefit of structural modifications



Summary

This section presents a brief summary of all the strategies presented for Ocean City. The focus is on the potential cost savings and priority levels to assist in the identification and selection of strategies that could be implemented immediately and/or further pursued to more cost effectively manage sediment within the project area.

Figure 137 provides a summary of the estimated total cost savings (compared to current operations) over a 50-year time horizon for a number of the potential strategies (those that indicated a cost saving could be realized). Additional analysis could be completed to evaluate the potential cost savings associated with combining various strategies.

Table 68 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies presented in Table 68 are listed in order of priority and estimated ease of implementation.

Table 68. Ocean City Strategy Summary.

Strategy	Prioritization	Tier
C. Great Egg Harbor Inlet Borrow Area Expansion	High	2
H. Adaptive Management Approach	High	2
E. Sediment Backpassing	High	2
F. Offshore Borrow Site Expansion	High	1
B. Formal Project Combination	Intermediate to High	2
D. Site-specific Coastal Processes Evaluation	Intermediate	1
G. Refined Beach Nourishment Template	Low to Intermediate	2
I. Coastal Structure Modification	Low to Intermediate	3

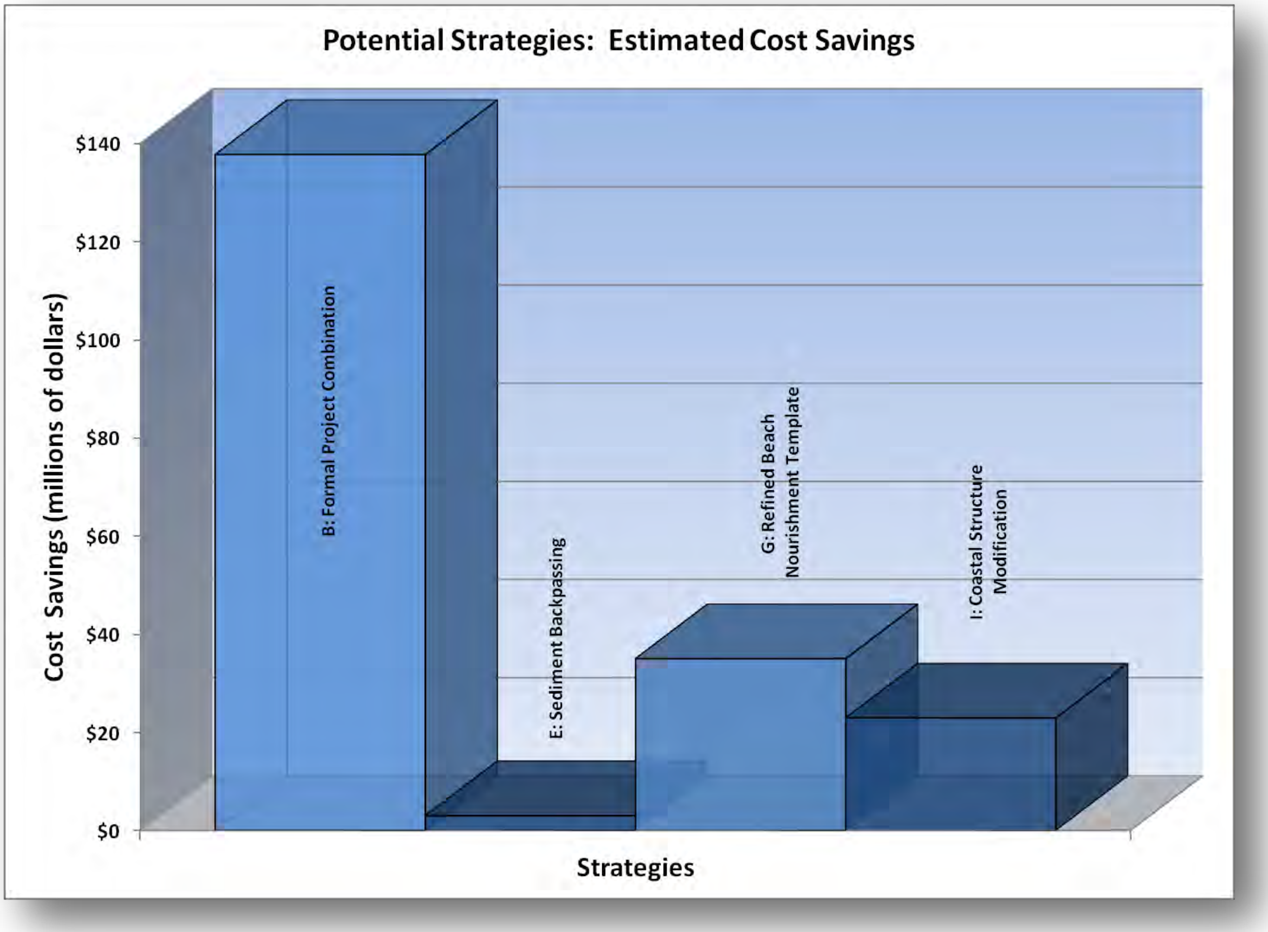


Figure 137. Estimate cost savings (compared to current operations) over a 50-year time horizon for select Ocean City strategies.

ABSECON ISLAND

Project Description

The Brigantine Inlet to Great Egg Harbor Inlet, Absecon Island Shore Protection Project was authorized for construction by the Water Resources Development Act of 1996. The project area extends for approximately 8.1 miles along Absecon Island on the central New Jersey coast, and is bound to the north by Absecon Inlet and to the south by Great Egg Harbor Inlet. The authorized project includes dune and berm restoration in the communities of Atlantic City, Ventnor, Margate, and Longport using sand dredged from Absecon Inlet. Periodic nourishment every 3 years is included to maintain the design template. Bulkhead construction along the Absecon Inlet frontage of Atlantic City is also authorized.

The design berm in Atlantic City is 200 ft wide at an elevation of 7.25 ft NAVD88. Further to the south in Ventnor, Margate, and Longport, the berm elevation remains the same but the width narrows to 100 ft. The berm extends seaward to meet the natural grade at a slope of 1V:30H. The dune crest is 25 ft wide with side slopes of 1V:5H. The elevation of the dune crest in Atlantic City is 14.75 ft NAVD88 and 12.75 ft NAVD88 in Ventnor, Margate, and Longport. The total length of fill along Absecon Island is 42,825 ft. Dune grass plantings over 91 acres and 63,675 ft of sand fencing are also included. The project authorizes an initial construction volume of 6,174,013 cy, with periodic nourishment of 1,666,000 cy every 3 years, using sand dredged from Absecon Inlet.

A bulkhead in Atlantic City is authorized for two sections of shoreline fronting Absecon Inlet; 1,050 ft from Oriental Avenue to Atlantic Avenue, and 550 ft from Madison Avenue to Melrose Avenue. The design elevation at the top of bulkhead is 14.0 ft NGVD29. Figure 138 shows the components of the authorized project.

Project History

Absecon Island has a history of shoreline erosion, inundation and wave attack during storms, and shoreline instability along the inlets. Since 1992 the area has been declared a National Disaster Area by the President of the United States on 13 separate occasions. Continued erosion has resulted in a reduction of the height and width of the beachfront, which has increased the potential for storm damage.

A variety of coastal engineering structures have been utilized over the years to mitigate erosion of Absecon Island. The entire oceanfront shoreline in the communities of Longport, Margate, and Ventnor is protected with a combination of bulkheads and/or seawalls. These structures were originally built between 1917 and 1964, with subsequent modifications and repairs between 1981 and 1993. The northern 1,000 ft of the Atlantic City shoreline is also protected with a bulkhead. A total of twenty-nine (29) groins are located on Absecon Island, most at the northern end in Atlantic City. Shore protection structures along the inlet frontage include a bulkhead with stone revetment built in 1993, as well as eight (8) groins installed between 1930 and 1958. The jetty on the south side of Absecon Inlet was constructed in 1948, extended in 1962, and repaired by the State in 1983.

Figure 138. Brigantine Inlet to Great Egg Harbor Inlet (Absecon Island) Authorized Shore Protection Project.

The Brigantine Inlet to Great Egg Harbor Inlet, Absecon Island Shore Protection Project was authorized to mitigate long-term erosion and to provide protection for heavily developed areas of the coastline. Initial nourishment and dune construction were completed in June 2004. Approximately 7,000,000 cy of sand from Absecon Inlet were placed in the communities of Atlantic City and Ventnor. Initial construction in Margate and Longport was delayed due to inadequate funding. Following severe storms in 2009, emergency repairs of the Atlantic City and Ventnor beaches were completed. Restoration to pre-storm conditions was completed in June 2011 by placing 1,100,000 cy of sand on the beach. The first periodic nourishment of Atlantic City and Ventnor was completed during the spring of 2012 (Table 69). As part of this project approximately 1,325,000 cy of sand were used to nourish the beach and rebuild dunes. Monitoring and design of the bulkheads authorized for the inlet frontage of Atlantic City are currently ongoing.

Table 69. Atlantic City and Ventnor Nourishment History.

Date	Volume (cy)	Project/Source
2004	7,000,000	Initial Const./Absecon Inlet
2011	1,100,000	Storm Rehabilitation/ Absecon Inlet
2012	1,325,000	1st Periodic Nourishment

Project Observations

Since initial construction of the Brigantine Inlet to Great Egg Harbor Inlet, Absecon Island Shore Protection Project a number of observations have been made:

- There continues to be a high rate of erosion along Absecon Island. Beach loss is greatest at the north end in Atlantic City and decreases towards the south.

- Beach nourishment material placed in Atlantic City and Ventnor has been transported to the south, reducing the rates of erosion in Margate and Longport.
- Although Absecon Inlet is the authorized borrow site for the Brigantine Inlet to Great Egg Harbor Inlet Shore Protection Project, dredging is not required on a routine basis to provide for safe navigation. As such, Absecon Inlet cannot be expected to supply adequate quantities of sand for future beach nourishment needs.
- Additional borrow sites are needed to maintain this Shore Protection Project.

Potential Strategies

This section presents the potential strategies for the Brigantine Inlet to Great Egg Harbor Inlet Shore Protection Project that are intended to provide improved project performance, cost savings, or other benefits. These strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. In addition, some of the strategies include a first-order technical analysis to evaluate the relative merit of the proposed strategy. These analyses are not intended to be detailed assessments and include some assumptions and simplifications. Rather, the analyses presented are geared towards providing a preliminary estimate of the potential benefits that may be realized if the strategy is implemented. The analysis presented herein can be used as an initial screening tool to determine if a strategy warrants further consideration. As such, for some strategies, a more detailed analysis may be required if the strategy is more formally pursued.

A. Project Cycle Synchronization

The project cycle synchronization strategy represents informally synchronizing the construction of authorized shore protection projects that are in close proximity. The intent is to reduce mobilization and demobilization costs by combining re-nourishments. In this case, coordination of the Absecon Island nourishment project would be synchronized with the Brigantine Island nourishment project. Synchronization with the Ocean City nourishment project was not considered, since it is expected that the primary future nourishment needs will be located along the northern portion of Absecon Island, which is closer in proximity to Brigantine Island.

A first-order analysis of potential cost savings realized by combining the periodic nourishment efforts at Absecon and Brigantine Islands was conducted. The analysis follows a similar approach as presented in Gebert (2010). In this particular case, it is assumed that the authorized three year periodic nourishment cycle at Absecon Island could theoretically be extended to a six year cycle and nourished jointly with the Brigantine Island authorized project.

Mobilization and demobilization costs constitute a significant portion of typical dredging contracts, and these costs do not necessarily get reduced with increased contract size (e.g., larger dredging projects). A number of factors contribute to the variations in dredging contract costs, including market conditions at the time, proximity of the borrow area to the nourishment site, and the limited number of capable dredging contractors. As such there can be large uncertainties when forecasting beach nourishment dredging and placement costs. Recent dredging contracts (2002-2009) for nourishment efforts in New Jersey and Delaware (Gebert, 2010) can account for 10% to 60% of the total winning bid, and average mobilization and demobilization costs are approximately $2 million per nourishment effort, regardless if it is an initial or periodic nourishment effort. The unit cost of sand over that same time period ranged from approximately $4 to $15/cy. Therefore, the preliminary analysis presented herein also assumes dredge mobilization and demobilization costs of $2 million, and a conservative unit price of $15/cy for sand.

Since many strategies may involve integration of projects with different remaining authorized lifetimes, a 50-year time horizon is used for comparison purposes irrespective of the remaining authorized project life. Use of a single standard time period also allows direct comparison between various strategies across projects and for those involving initial construction costs and maintenance (O&M) costs.

Over a 50-year time horizon, the volume of sediment placed on the beach remains the same, however, there is a cost savings of $16 million based solely on the reduced number of nourishment events. Additional cost savings may be realized from reduced contracting and management requirements. A comparison to current operations and to other strategies is presented in the summary section.

Fewer periodic nourishment episodes will also have an environmental benefit since there will be less frequent disturbance of the borrow site areas, reduced disturbance on the beaches, and reduced overall air and noise pollution.

Prior to implementing this strategy, evaluation of the storm damage protection impacts needs to be completed to ensure that protection of the Absecon Island region (specifically Atlantic City) is not compromised by extending the periodic nourishment interval from three to six years. However, this strategy may also have some performance benefits due to a regional increase in the recurrent volume added to the system (e.g., approximately 3.3 million cy every six years), perhaps resulting in improved project longevity and reduced periodic nourishment requirements.

This strategy can be implemented at any time since existing authorities do not preclude any re-nourishment from being done as part of a combined contract as long as the funds for each are available and are not comingled. Further, all requisite environmental clearances must be accomplished before award of such a contract. The implementation of this strategy has minimal constraints. These are limited to availability of dredging equipment and borrow site quantities, which are already constraints of current operations.

Table 70 presents a summary of the criteria evaluated for the improved project coordination strategy and ranks it as a high priority and easily implementable (Tier 1 level). This strategy should be pursued since the pathway to implementation is straightforward and there are no significant constraints.

B. Beneficial Reuse of Absecon Inlet Material

Over approximately the past 15 years, significant amounts of sediment have been dredged from Absecon Inlet and used for nourishment on Absecon Island. These dredge episodes removed enough sediment from the inlet that the federal navigation channel has not required maintenance dredging for at least the same time frame. Although recently the material dredged from Absecon Inlet has been used for nourishment of Absecon Island, historically the material from the inlet had not been beneficially reused. Therefore, this strategy encourages the continued beneficial use of sediment dredged from the Absecon Inlet for the Absecon Island authorized shore protection project. This approach is in direct concurrence with the Regional Sediment Management Initiative.

Table 70. Project Cycle Synchronization Strategy Summary.

Criteria	Summary
1. Authorization	No existing authorization limitations
2. Constraints	No constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$16 million over 50-year time horizon
4. Service Life	Potential increase in project longevity and service life
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Evaluate potential storm damage impacts, coordinate dredging, and implement

The potential benefit of this strategy is assessed through evaluation of the continued value of using the navigational material beneficially versus extracting all the required nourishment sediment from offshore. To determine the average annual amount of material dredged from Absecon Inlet, the USACE annual reports were used to calculate the cumulative maintenance dredging. As a conservative estimate of the sediment extracted from the navigational channel, only the routine federal maintenance dredging records were used to estimate the average annual volume available. Figure 139 presents the cumulative sediment volume dredged in Absecon Inlet from 1959 to 1976. Each black dot in the figure represens a dredging event, and shows the cumulative volume dredged as a function of time. The blue line in the figure represents a linear fit to the data and provides an average dredge quantity of approximately 140,400 cy per year.

The more recent dredging in Absecon Inlet (1986-2012) consists of a greater annual extraction volume (approximately 330,000 cy/yr) than historic dredging (Table 69). This is likely due to the larger borrow site areas and sediment removed.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this strategy would result in a cost savings of approximately $101 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments. This is likely an overestimate of potential savings since Absecon Inlet material is currently being beneficially reused and not removed from the system. As such, much of this cost reduction is already being realized. This assumes periodic nourishment is conducted every 3 years for Absecon Island. This analysis also assumes that:

- as a conservative estimate, the historic rate of 140,400 cy/yr of dredging would be required for the navigational channel at Absecon Inlet;
- the dredged material is beach compatible;
- the dredged material can be placed in the littoral zone or directly on the beach, such that adequate storm damage protection can be provided; and
- any incremental cost of placing the material on the beach is relatively insignificant, since periodic nourishment would also be required concurrently with the inlet dredging to supplement the needed quantity of material.

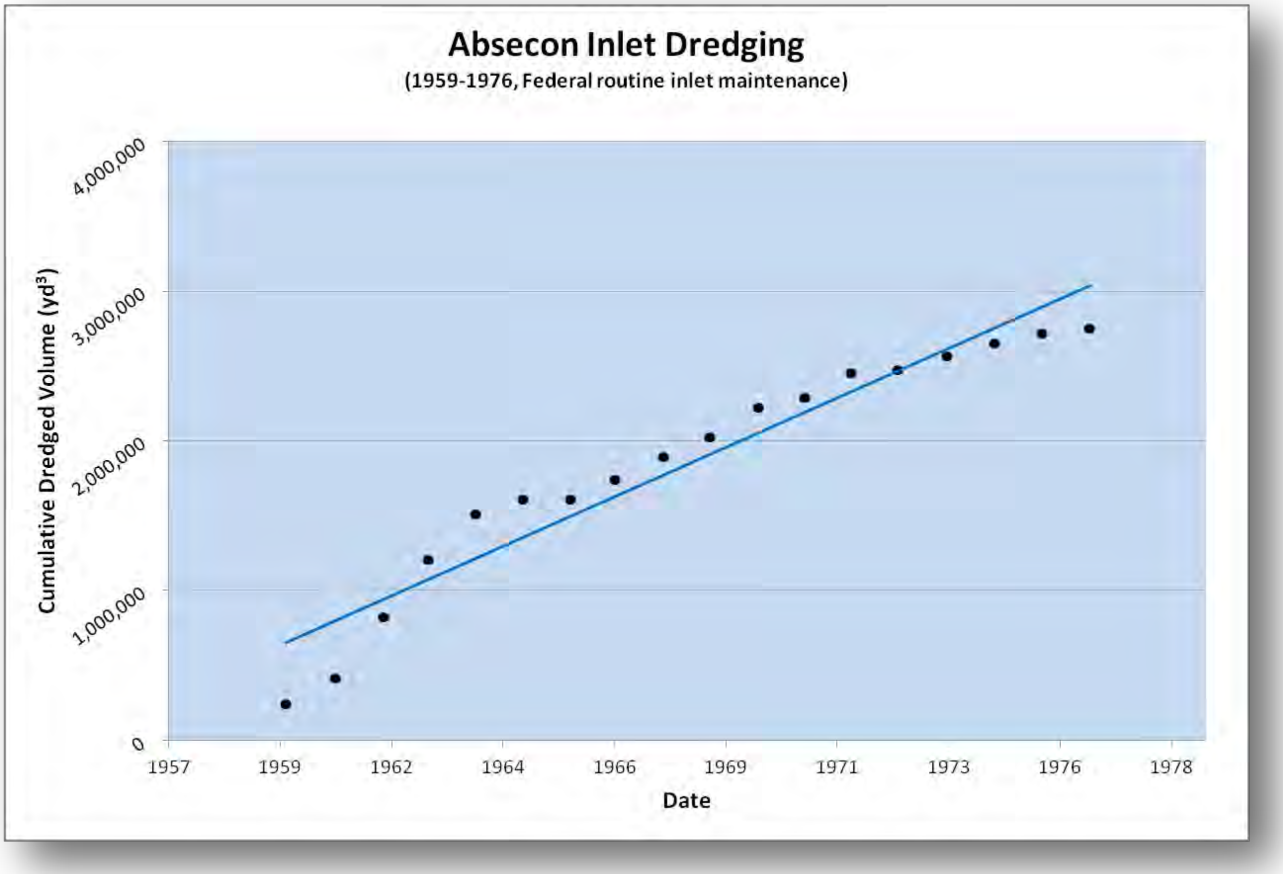


Figure 139. Cumulative dredge volume extracted from Absecon Inlet from 1959 to 1976.

Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Assuming the Absecon Island nourishment was completed entirely by offshore borrow site material, this strategy reduces the overall offshore borrow site sediment needs by approximately 5-6 million cy over 50 years.

Considering this strategy is already being implemented to a certain extent (Absecon Inlet is serving as a borrow site), authorization is not a limitation. Under the existing authorities, if the material is suitable, the federal government can continue to request that the material be placed directly on the beach. Permits are required to do so, but they can be obtained under the authorized navigation project. Implementation of this strategy has limited additional constraints. Table 71 presents a summary of the criteria evaluated for the beneficial reuse of Absecon Inlet strategy and ranks it as a high priority with a Tier level of 2. As long as the sediment dredged is compatible for beach nourishment or nearshore placement and the quantity of dredging remains approximately the same as historic levels, this strategy should continue to be pursued and implemented since it is directly in line with RSM strategies and initiatives.

C. *Sediment Backpassing to Atlantic City*

In 2008, Clausner and Welp conducted a study to investigate the feasibility of mobile hydraulic back-passing along the New Jersey coastline (Clausner & Whelp, 2008).

The study determined that in a time frame of two to four months, as much as 200,000 cy of sand could be back-passed distances of up to 15,000 ft. Clausner and Welp (2008) calculated a cost of $10/cy using a hydraulic pumping system mounted on a boom equipped crawler. Using the costs developed by Clausner and Welp (2008), and assuming compatible sediments on all reaches of Absecon Island, a preliminary cost analysis was performed on the applicability of sand backpassing to complement current nourishment efforts, specifically at Atlantic City. However, due to the fact that the majority of Absecon Island is erosional, this strategy has limited viability, at least currently.

Table 71. Beneficial Re-use Strategy Summary.

Criteria	Summary
1. Authorization	Currently conducted, no additional authorization needed
2. Constraints	Potential incremental cost increases for dredge material placement
3. Cost Savings	$101 million over 50-year time horizon
4. Service Life	No change to existing service life of shore protection project or navigational dredging
5. Other Benefits	Reduced offshore sediment source requirements
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Continue practice of using dredged material from Absecon Inlet for nourishment. This approach benefits both the navigation and shore protection projects

Investigation of historic shoreline position data indicates the shoreline of Absecon Island has an average retreat rate of 4.9 ft/yr (1.5 m/yr). The largest erosion rates occur at Atlantic City on the northern end of Absecon Island, while the southern reach of Absecon Island is eroding at only a third of the rate. This section investigates the economics of backpassing sand from the southern reaches of Absecon Island and applying that sediment to the higher erosion rate stations in the vicinity of Atlantic City as a means of normalizing the erosion rates along the length of the island. Figure 140 shows the sediment backpassing strategy concept for the Absecon Island area.

Figure 140. Sediment backpassing strategy for Atlantic City.

For this strategy, the mean shoreline change (average erosion rate of 1.5 ft/yr) on Absecon Island was used as the "normal" rate of coastline erosion for this area. Those sections of Absecon Island that had erosion rate less than the average, and were located within 15,000 ft of the highly erosional Atlantic City sections, were evaluated as potential donor locations. In the interest of not overly exacerbating the erosion rates at the potential donor locations, only enough sediment to result in a 1.5 ft/yr cumulative erosion rate was removed.

Assuming the use of a 160 ft boom mounted pumping system, approximately 15,600 cy/yr of sand are available to be backpassed to replenish the shoreline at Atlantic City at a cost of $10/cy (Clausner & Welp, 2008). Using sheet piles and temporary earthworks, the swath of the mobile dredging equipment can be increased to provide additional sand for back-passing, but at an additional, undetermined cost. There is a limited amount of sediment available at this location due to the historic erosion that exists along the majority of Absecon Island.

Over a 50-year time horizon, there is a cost savings of $4 million if 15,600 cy/yr of sediment backpassing was implemented. This assumes that the mobile backpassing system is readily available and could be utilized at the Absecon Island location. Additional cost savings may be realized from reduced contracting and management requirements. Reduced impacts to offshore borrow sites would be another benefit to this strategy. A comparison to current operations and to other strategies is presented in the summary section.

Potential constraints involve the potential impact on the beach where sand is extracted. This includes the ability of the beach to adequately serve the same function and level of protection as before the sediment removal. This strategy would also increase disturbance on the beaches, and overall air and noise pollution.

The current authorization for this project does not include specific authority to backpass sand. However, the Corps' value engineering authority could be used to determine the effectiveness of backpassing at reducing the long term nourishment costs compared to its implementation cost. The need to develop benefit numbers is also reduced by this approach; the benefits are just the reduced nourishment costs. Appropriate environmental clearances would also be required.

Table 72 presents a summary of the criteria evaluated for the improved project coordination strategy and ranks it as a low to intermediate priority (due to the limited sediment available at the donor location that is already erosional) and Tier Level 2.

Table 72. Sediment Backpassing to Atlantic City Strategy Summary.

Criteria	Summary
1. Authorization	Use value engineering to determine the effectiveness of backpassing at reducing the long term nourishment costs compared to implementation cost
2. Constraints	Dredge equipment availability, potential impacts to source beach; noise and pollution concerns
3. Cost Savings	$4 million over 50-year time horizon
4. Service Life	No change to service life
5. Other Benefits	Reduced impacts to offshore borrow sites
6. Priority	Low to Intermediate
7. Tier Level	Tier 2
8. Next Steps	Use value engineering to implement; assess environmental impacts on source beach

D. Borrow Area Expansion or Establishment

As presented in Table 69, sediment sources for the initial construction of the Atlantic City and Ventnor portions of the Absecon Island project, as well as the periodic nourishment, have been from Absecon Inlet. Currently, the permitted inlet borrow sites do not have enough material to complete initial construction and future renourishments of all parts of the Absecon Island Shore Protection Project. Therefore, unless the sediment needs of the shore protection project can be reduced (e.g., beach nourishment performance is enhanced), or alternative sediment sources are utilized (e.g., bypassing), additional offshore borrow locations will be required.

This strategy is not specifically geared towards providing a cost savings, but rather at maintaining current operations costs since upland sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., track traffic, road repairs, time of construction, etc.).

Over a 50 year time horizon, the periodic nourishment sediment needs at Absecon Island are approximately 26,660,000 cy, and initial construction at the southern portion of the project (Longport and Margate) will require an additional 1,570,000 cy. Overall, the Absecon Island projects require approximately 35,230,000 cy over a 50-year time horizon.

The original inlet borrow sites (A [ContractsA-E], B, C) for the Absecon Island authorized shore protection project have approximately 3,475,000 cy remaining after initial construction of Atlantic City and Ventor, storm rehabilitation, and the first periodic renourishment. As such, there is a deficit of approximately 22,330,000 cy for completion and renourishment of the project (exclusive of storm response).

Continued expansion of existing sites or searches for new borrow sites is needed for this region. For example, the proposed Area BA borrow area should be considered (as an additional 14.5 million cy with a dredge cut of 15 ft) as well as the proposed Area G1 borrow area (as an additional 22 million cy with a dredge cut of 15 ft). Potential searches in Federal waters also may be warranted through cooperation with the Bureau of Ocean Energy Management (BOEM).

This strategy can be accomplished under the existing project authorities as the provision of borrow areas for the life of the project is part of the authorization. It would likely require cost sharing at the same level as the current project. Appropriate studies and environmental clearances would be needed.

The primary constraints with expansion or establishment of offshore borrow sites are environmental. Establishing offshore borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave and sediment transport processes also are needed. The physical and environmental delineation would add cost. However, once permitted, the construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 73 presents a summary of the criteria evaluated for the offshore borrow area expansion and establishment strategy and ranks it as a high priority with a Tier level of 2. It is recommended that this strategy is pursued in advance of potential need, such that the borrow areas are established for future use.

Table 73. Offshore Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Initiate studies and surveys; Coordinate with BOEM

Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted offshore sites available if needed for storm events or unforeseen circumstances is good planning. Next steps for this strategy would be to initialize any studies and surveys needed to expand or establish new borrow sites for this region, which has a known deficit, and coordinate with BOEM for any potential federal waters borrow sites.

E. Refined Beach Nourishment Template

This strategy involves applying adjustments to the authorized beach nourishment template along Absecon Island to determine if modifications to the template may result in increased performance or improved storm damage protection. A successful beach nourishment project consists of more than simply placing sediment on a beach. Beach nourishment projects are engineered. A beach nourishment template, which consists of numerous design parameters, is based on the characteristics of the site and the needs of a project. Every beach nourishment design is unique, since different beaches in different areas have different physical, geologic, environmental, and economic characteristics, as well as different levels of required protection. The design must consider climatology, the shape of the beach, type of native sand, volume and rates of sediment transport, erosion patterns and causes, waves and water levels, historical data and previous storms, probability of certain beach behaviors at the site, existing structures and infrastructure, and past engineering activities in the area.

The structure of a nourishment template is designed to yield a protective barrier that also provides material to the beach. A higher and wider beach berm is designed to absorb wave energy. Dunes may need to be constructed or existing dunes improved to reduce damage, including potential upland flooding, from storms. Figure 141 depicts a beach berm and dune on a typical beach profile. Nourishment length, berm height and width, dune height, and offshore slope are critical elements of a beach nourishment design. Periodic nourishment intervals are also usually a part of the nourishment design. The renourishment interval will vary based on the initial design, wave climate, sand used, frequency of storms, and project age. However, beach nourishment is not an exact science; variables and uncertainties exist. Actual periodic nourishment intervals may differ from planned intervals based on conditions at the nourished beach and the frequency and intensity of storms.

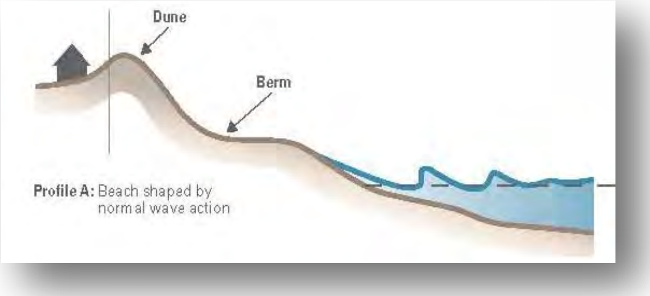


Figure 141. Typical beach profile and features (from Coastal Engineering Manual, 2003).

This proposed strategy evaluates potential improvements to project performance, storm damage protection, and subsequent cost savings that can be realized by modifications to the currently authorized beach nourishment template.

The feasibility studies for the authorized projects typically evaluate the a range of proposed beach nourishment template designs using alongshore and cross-shore analysis and/or modeling efforts to assess performance and storm damage protection afforded by the proposed nourishment template. However, the USACE policy has been to not consider increases to the natural berm elevation for the design template or to see if changes to the natural berm height result in performance gains or improved storm damage protection. Additionally, the currently authorized design template has not been re-evaluated following monitoring of the performance of the system. Monitoring data may reveal potential insight that could warrant modifications to the template. Therefore, this strategy involves assessing changes to the beach nourishment template that may yield cost savings over the long-term. An example of this type of analysis is presented herein by evaluating change in berm height and width on the performance of the Absecon Island project as a preliminary analysis of potential template modification.

Similar analyses could be completed for a number of parameters that are components of beach nourishment design; including:

- Nourishment length – Expanding the nourishment length, specifically through combining or syncing projects could be evaluated.
- Berm Width – The width of the berm could be modified to see if there is a cost benefit that could be attained. This also may involve a spatially variable berm width modification
- Berm Height – The height of the berm could be modified to determine impact on storm damage protection.
- Offshore slope – The offshore slope of the nourishment can be changed.
- Grain size – The grain size of the source material for the nourishment may affect the performance of the projects. For example, coarser nourishment material may result in improved project performance (lower erodibility) and hence more protection.

To assess potential changes in berm width and height at Atlantic City, the computer model SBEACH (Larson and Kraus 1989) was used to assess cross-shore evolution. SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and further developed and verified based on field measurements (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990). The model predicts the time-dependent evolution of existing or design beach and dune profiles for specified water levels and wave conditions. In addition to the proposed nourishment template, the model requires a time series of wave heights, wave periods and water levels as forcing inputs. The specific storm information required by SBEACH is a time history of total water level (tide plus surge) and wind wave height and period. The WIS hindcast information, FEMA FIS still water storm surge elevation, and extremal analysis were used to develop a simulated 10-year storm for this analysis.

Figure 142 presents results of varying the berm height (blue line) and width (green line) of the Atlantic City authorized beach nourishment template. The horizontal axis shows the percent of material lost from the nourishment template area caused by a 10-year, 24-hour storm for various berm heights and widths. The left hand vertical axis shows berm height (NAVD88, ft), while the right hand vertical axis shows berm width (ft). The variable width scenarios use a constant 7.2 ft NAVD88 berm height, while the variable height scenarios use a constant 200 ft berm width. This corresponds to the currently authorized template which consists of a berm height of approximately 7.2 ft NAVD88 and a berm width of 200 ft. Figure 142 shows the changes in expected sediment lost from the template area for increased berm height and width. Increases in both berm height and berm width indicate substantial improvement in protection from the 10-year storm. For example, the currently authorized project template loses approximately 98% of the periodic nourishment during the 10-year, 24-hour storm. However, increasing the berm height by a foot (8.2 ft NAVD88) reduces the percentage of material lost to approximately 44%. Increasing the berm width or height further results in decreased losses, but also requires additional nourishment volumes, additional sediment sources, and finances. As such, there is a point of diminishing returns on the amount of required sand needed to extend the berm height and the increased performance gained. Adding more sand to the system may result in better performance, but also may not be worth the added cost of the additional sand. This type of analysis could be conducted to evaluate the sensitivity of various parameters in the beach nourishment design, their potential impacts on overall cost of the project, and identify the most cost-effective design template.

The 8.2 ft NAVD88 berm height modified design requires approximately 1,823,000 cy of additional sediment to gain the required berm increase during the initial increased periodic nourishment. However, the performance is improved over each 3 year cycle, such that the amount of sediment required for each periodic nourishment is reduced.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this example of template modification would result in a cost savings of approximately $10 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments, or increased renourishment intervals. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

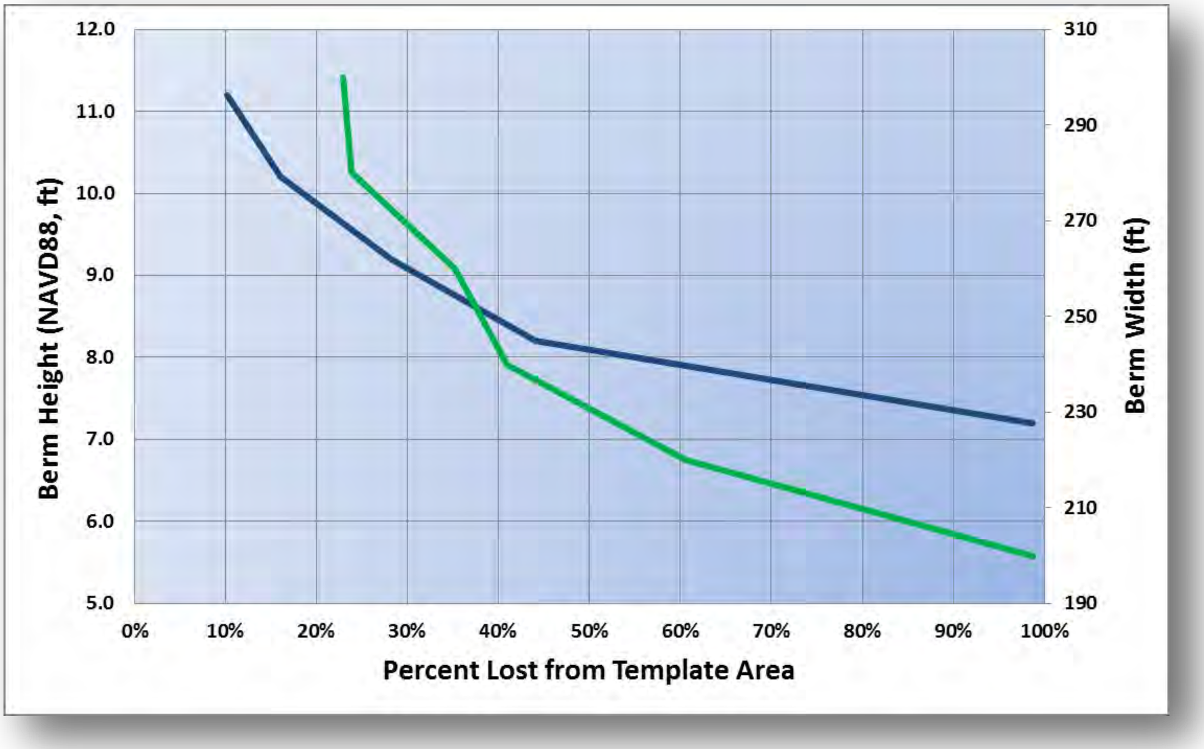


Figure 142. Eroded beach volume as a function of template berm height (blue line) and width (green line) for the Atlantic City nourishment project in response to a 24-hour, 10-year return period storm event.

In addition to the cost savings estimated from the reduced sediment volume requirements for periodic nourishments, modification of the beach nourishment template may have other benefits as well. For example, the modified template may result in improved storm damage protection and reduced potential upland damage costs. Examples of other potential benefits included habitat enhancement, reduced ponding or upland flooding, and reduced environmental impacts offshore due to reduced offshore sediment needs.

Relative to the current authorization, the existing template defines the authorized project and the NED plan. Changing the template would imply that the authorized plan was no longer the NED plan and the project would have to be reanalyzed. To do so would require the use of the existing New Jersey shore study authority to determine the degree of federal interest, get the requisite environmental clearances, and recommend a change in the authorized plan. This would require the existing project authority to be modified by Congress. It would also likely require a new study cost sharing agreement to be signed, as well as a non-federal sponsor willing to contribute 50% of the study costs and agree to any changes in the construction and long-term cost sharing. A new PCS conforming to the model agreement would have to be signed.

Potential constraints associated with modification of the beach nourishment template include environmental concerns (e.g., occupying a larger offshore footprint), political and local community concerns that would limit the ability to change the template (e.g., communities wouldn't want an increased berm height), and logistical concerns associated with modification of the authority to construct the project.

Table 74 presents a summary of the criteria evaluated for the refined beach nourishment template strategy and ranks it as a low to intermediate priority and a Tier level of 2. Next steps for this strategy would be to conduct more detailed studies to assess if template modifications are warranted. The studies would focus on the cost benefit aspects of template modification.

Table 74. Refined Beach Nourishment Template Strategy Summary.

Criteria	Summary
1. Authorization	Requires a change to the authorized plan and would include new study, permits, and cost-sharing agreements
2. Constraints	Logistic, political, local community, and environmental concerns
3. Cost Savings	Depends on template modification, $10 million for case evaluated
4. Service Life	Increased service life of beach nourishment expected
5. Other Benefits	Improved storm damage protection, habitat enhancement, reduced offshore environmental impacts
6. Priority	Low to Intermediate
7. Tier Level	Tier 2
8. Next Steps	USACE Philadelphia district decide if the strategy is warrants further study

F. Sediment Bypassing of Absecon Inlet

This strategy would involve implementation of sediment bypassing methodology to move sediment from the northerly updrift beaches of Absecon Inlet to nourish beaches downdrift of the inlet. A number of previous studies evaluated conceptual designs and methodologies for bypassing sediment around Cape May Inlet (USACE, EM 1110-2-1616, 1991; U.S. Army Engineer District, Philadelphia, 1987; USACE, 2004), and this information is used to conduct a similar assessment for Absecon Inlet bypassing.

Various bypassing alternatives have been considered at a conceptual design level and have been evaluated in preliminary analyses of bypassing of Cape May Inlet. (USACE, 2004; USACE, EM 1110-2-1616, 1991). For this preliminary analysis, it is assumed that a semi-mobile bypass system would be installed to bypass sand around Absecon

Inlet. Additional alternatives (e.g., a floating dredge plant) could also be considered in a more detailed analysis of potential bypassing approaches if this strategy is further pursued. However, in this preliminary analysis, a sediment bypassing plant (similar to the system operated at Indian River Inlet in Delaware – see Figure 143) is considered as a baseline approach to potential bypassing. The USACE Philadelphia District (2004) developed an initial cost estimate for a bypass system. The cost estimate included initial construction costs, Operation and Maintenance (O&M) costs for the sand bypassing plant, Engineering and Design (E&D) costs, Construction Management (S&A) costs, as well as a contingency factor. Detailed breakdown of the cost estimate can be found in the USACE (2004) document. These values were used in the current analysis as well. The following cost estimates were utilized and are intended to provide a first-order estimate of cost impacts:

- An initial construction cost of $6,345,000 for the bypass plant
- O&M costs of $613,000 annually. Bypassing efforts would take place from September to April, 5 days per week, 6 hours per day, bypassing approximately 140,400 cy/yr, as long as the sediment is available
- Replacement of the pump system every 12-13 years at a fixed cost of $600,000
- Refurbishing/replacement of the system at year 25 for $6,345,00

Figure 143. Indian River Inlet, Delaware fixed bypassing system (Photo courtesy of Tony Pratt, DNREC).

Based on the historical dredging of Absecon Inlet, it is expected that there would be approximately 140,400 cy/yr (as presented in Strategy B) of material deposited in Absecon Inlet. The analysis assumes that this material could be intercepted on the updrift shoreline prior to getting into the inlet. There is also a potential for additional sediment to be extracted since there are larger shoals that may be developing in the inlet.

This strategy would result in savings of approximately $62 million over a 50-year time horizon assuming that approximately 140,000 cy/yr was available for bypassing.

In addition, this strategy provides additional benefits, including, but not limited to:

- Reduced reliance on offshore borrow sites, of which currently permitted borrow sites are becoming depleted
- Minimizing environmental impacts to offshore borrow sites
- Promoting RSM approach through appropriate redistribution of sediment already in the littoral system

- Reduced sediment surplus at in updrift areas

This would not require additional authority if pursued under the concept of value engineering. If it is cost effective, then whatever environmental clearances were needed and the actual cost to construct it could be accomplished with construction funds. However, prior to implementation, significant environmental clearances would likely be required. Impacts and potential mitigation for this sensitive area would need to be evaluated in more detail prior to obtaining permits for project implementation.

Table 75 presents a summary of the criteria evaluated for the sediment bypassing strategy and ranks it as a high priority and a Tier level of 2. The strategy does have significant other benefits (e.g., reduce or eliminate dependence on offshore sediment sources, reduce sediment surplus on updrift beaches) and the approach takes advantage of beach compatible sediment already in the system. Next steps would involve a more detailed study of potential impacts caused by fillet extraction on adjacent beaches, finalization and design, and determining the right authorization approach and pathway to implement the bypassing project.

Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Table 75. Sediment Bypassing Strategy Summary.

Criteria	Summary
1. Authorization	Value engineering could be applied to implement
2. Constraints	Significant environmental questions may remain for impacts on extraction of updrift fillet
3. Cost Savings	$62 million over 50-year time horizon
4. Service Life	No change to existing service life of shore protection project
5. Other Benefits	Reduce offshore sediment source requirements and environmental impacts; Improved management of sediment in littoral system; Reduced sediment surplus updrift
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	More detailed study of potential impacts caused by fillet extraction.; Finalize and design project

G. *Coastal Structure Modification*

A number of potential coastal structure modifications and addition strategies were considered in the vicinity of Atlantic City intended to improve sediment retention in the region. Specifically, some of the following were considered:

- Raising or lengthening the southern jetty on Absecon Inlet. The purpose of this strategy was to attempt to limit sediment loss into Absecon Inlet from the Atlantic City shoreline during periods of non-dominant littoral drift reversals (sediment flux from southwest to northeast). However, currently there are approximately 300 ft from the shoreline position (at mean tide level) to the end of the existing jetty. Therefore, there is a significant area that would need to be filled prior to full bypassing from the shoreline into the inlet. For example, the average accretion rate for the coastline in the cell just southwest of the jetty is approximately 4.9 ft/yr. Assuming this rate of accretion, this area would not be filled to capacity for over 60 years. Therefore, this strategy was not further considered.

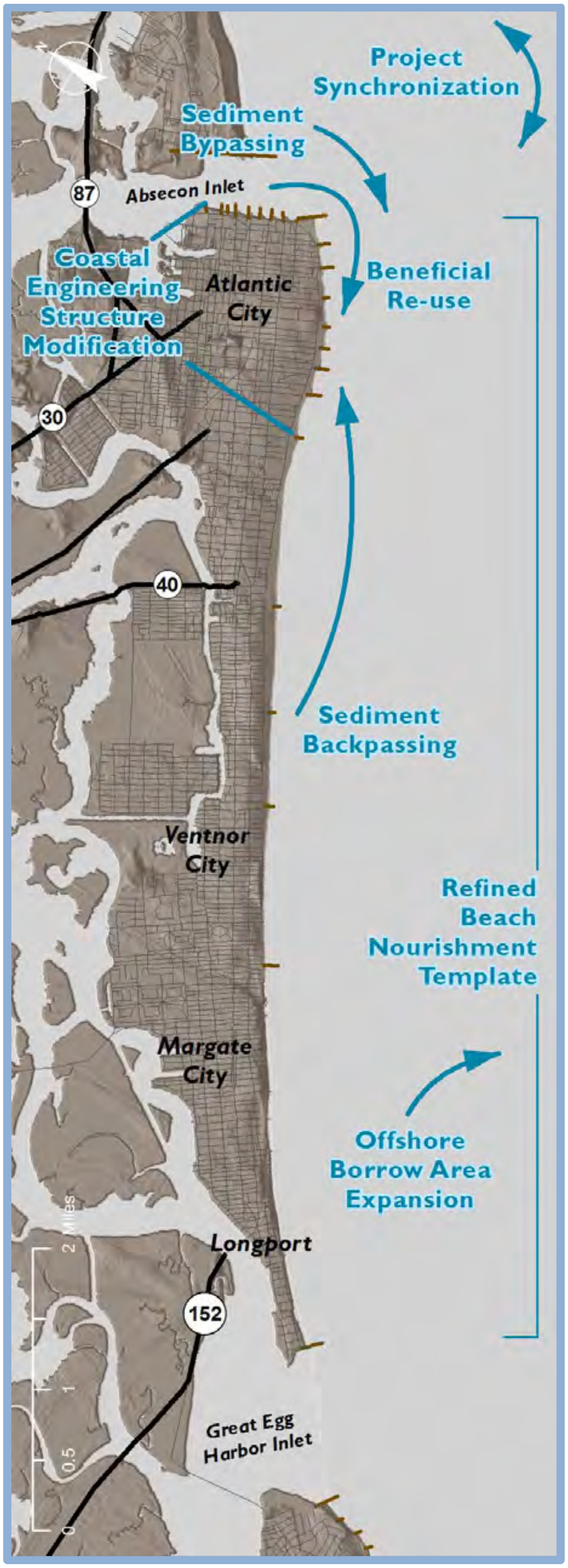
- Addition of low-profile or T-Head groins at Atlantic City spanning the highest erosion areas. Considering the highly developed nature of the shoreline (piers, outfall structures, etc.), there is little available space to construct the structures with the appropriate spacing.
- Potential improvements along the Absecon Inlet frontage of Atlantic City. This could include bulkhead improvements, groin additions, or other shoreline stabilization measures. A portion of this strategy is already authorized and therefore, no additional structural modifications are recommended at this time.

None of these structural modifications resulted in significant benefits, at least in this preliminary analysis. It may be feasible that a more detailed and site-specific evaluation of coastal processes and structural modifications may reveal benefits that could not be quantified by the preliminary analyses.

Table 76 presents a summary of the criteria evaluated for the coastal structure strategy and ranks it as a low priority and a Tier level of 3.

Table 76. Coastal Structure Strategy Summary.

Criteria	Summary
1. Authorization	Requires a reanalysis, environmental permitting, and identification of a non-Federal sponsor with the requisite cost-sharing and new project construction authorization
2. Constraints	Environmental impacts need to be evaluated, coastal processes assessment to evaluate impact of structural modification
3. Cost Savings	Not evaluated
4. Service Life	Minimal benefit
5. Other Benefits	Potential improved sediment retention
6. Priority	Low
7. Tier Level	Tier 3
8. Next Steps	More detailed study



Summary

This section presents a brief summary of all the strategies presented for Absecon Island. The focus is on the potential cost savings and priority levels to assist in the identification and selection of strategies that could be implemented immediately and/or further pursued to more cost effectively manage sediment within the project area.

Figure 144 provides a summary of the estimated total cost savings (compared to current operations) over a 50-year time horizon for a number of the potential strategies (those that indicated a cost saving could be realized) for comparison purposes. Similarly, additional analysis could be completed to evaluate the potential cost savings associated with combining various strategies.

Table 77 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies presented in Table 77 are listed in order of priority and estimated ease of implementation.

Table 77. Absecon Island Strategy Summary.

Strategy	Prioritization	Tier
A. Project Cycle Synchronization	High	1
B. Absecon Inlet Beneficial Re-use	High	2
D. Offshore Borrow Site Expansion	High	1
F. Sediment Bypassing	High	2
E. Refined Beach Nourishment Template	Low to Intermediate	2
C. Sediment Backpassing	Low to Intermediate	2
G. Coastal Structure Modification	Low	3

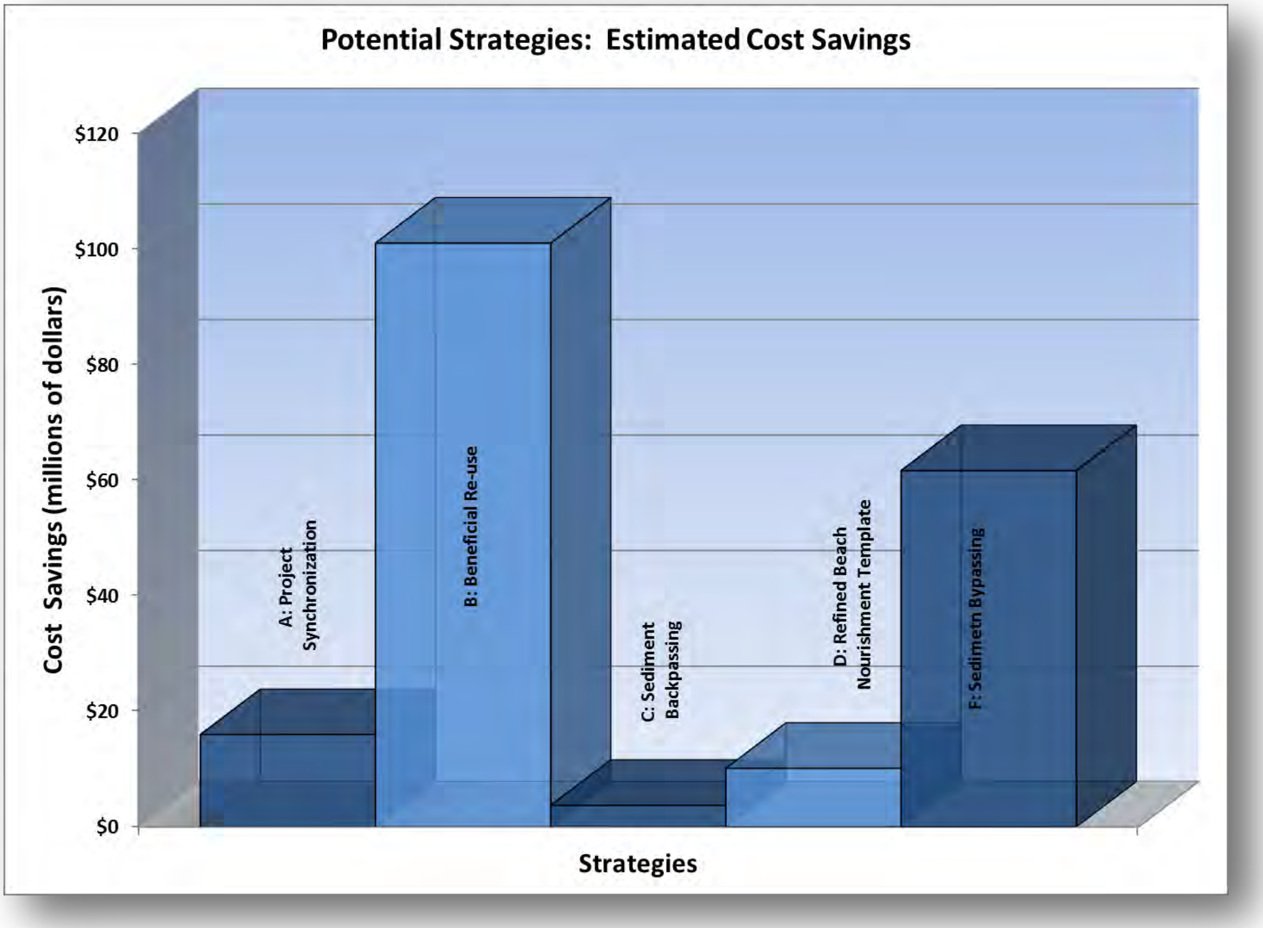


Figure 144. Estimate cost savings (compared to current operations) over a 50-year time horizon for select Absecon Island strategies.

BRIGANTINE ISLAND

Project Description

The Brigantine Inlet to Great Egg Harbor Inlet, Brigantine Island Shore Protection Project was authorized for construction by the Water Resources Development Act of 1999. The project area extends for approximately 6.5 miles along the central New Jersey coast, and is bound to the north by Brigantine Inlet and to the south by Absecon Inlet. The authorized project includes dune and berm restoration along the central portion of Brigantine Island using sand dredged from Brigantine Inlet located to the north. Periodic nourishment every 6 years is included to maintain the design template.

The design berm is 100 ft wide at an elevation of 6.0 ft NAVD. The berm extends seaward to meet the natural grade at a slope equal to the existing nearshore slope. The dune crest is 25 ft wide with side slopes of 1V:5H. The elevation of the dune crest is 10.0 ft NAVD. The total length of fill along Brigantine Island 7,400 ft; dunes are authorized for construction along 5,930 ft of the beach. Dune grass plantings over 10 acres and 12,000 ft of sand fencing are also included. The project authorizes an initial construction volume of 648,000 cy, with periodic nourishment of 312,000 cy every 6 years, using sand dredged from Brigantine Inlet. Figure 145 shows the components of the authorized project.

Figure 145. Brigantine Inlet to Great Egg Harbor Inlet (Brigantine Island) Authorized Shore Protection Project.

Project History

Brigantine Island has a history of beach and dune erosion that has left the island vulnerable to storm damage. Severe storms during the early 1990s caused a reduction in beach elevation and width, which along with the absence of significant dunes, exposed the community of Brigantine to costly damages from ocean flooding and wave attack. Since 1992 the area has been declared a National Disaster Area by the President of the United States on 13 separate occasions.

Coastal engineering structures were originally built in Brigantine during the 1960s, when five (5) groins were installed by the State of New Jersey. During this same time, two bulkheads were also built by the State to protect approximately 2,300 ft of shoreline. The larger bulkhead at the northern end of development between 15th Street North and 9th Street North was damaged during 1991-1992 storms, and subsequently reconstructed in 1994.

Two years after the bulkhead reconstruction, a beachfill project was constructed along 4,400 ft of shoreline from 9th Street North into the North Brigantine State Nature Area. This nourishment project was funded by the State of New Jersey and the City of Brigantine.

The Brigantine Inlet to Great Egg Harbor Inlet (Brigantine Island) Shore Protection Project was authorized to mitigate long-term erosion and to provide protection for developed areas at the northern end of the barrier. Initial nourishment and dune construction were completed in February 2006. Approximately 672,000 cy of sand from Brigantine Inlet was placed in the design template stretching 1,500 ft north of 15th Street North to 15th Street South.

The first periodic nourishment of Brigantine Island is scheduled for the end of 2012, when 350,000 cy of sand will be placed on eroding beaches at the northern end of development (Table 78).

Table 78. Brigantine Island Nourishment History.

Date	Volume (cy)	Project/Source
2006	672,000	Initial Const.
2012 (planned)	350,000	1st Periodic Nourishment

Project Observations

Since initial construction of the Brigantine Inlet to Great Egg Harbor Inlet, (Brigantine Island) Shore Protection Project, a number of observations have been made:

- There continues to be a high rate of erosion along Brigantine Island. Beach loss is greatest at the north end of the developed barrier island, and decreases towards the south.
- Beach nourishment material placed in the design template has been transported to the south, reducing the rates of erosion along the southern beaches.
- The wide and healthy dune system along the south end of the barrier is anchored by the north jetty at Absecon Inlet. This dune system provides significant protection for the more landward developed areas of Brigantine Island.
- The ebb shoals at Brigantine Inlet appear to supply adequate quantities of sand necessary to maintain the Authorized Shore Protection Project at Brigantine Island.

Potential Strategies

This section presents the potential strategies for the Brigantine Island Shore Protection Project that are intended to provide improved project performance, cost savings, or other benefits. These strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. In addition, some of the strategies include a first-order technical analysis to evaluate the relative merit of the proposed strategy. These analyses are not intended to be detailed assessments and include some assumptions and simplifications. Rather, the analyses presented are geared towards providing a preliminary estimate of the potential benefits that may be realized if the strategy is implemented. In other words, the analysis presented herein can be used as an initial screening tool to determine if a strategy warrants further consideration. For some strategies, a more detailed analysis may be required if the strategy is more formally pursued.

A. Project Cycle Synchronization

The project cycle synchronization strategy intends to informally synchronize the construction of authorized shore protection projects that are in close proximity. The intent is to reduce mobilization and demobilization costs by combining re-nourishments. For this project, coordination of the Brigantine Island nourishment project would be synchronized with the Absecon Island nourishment project.

A first-order analysis of potential cost savings realized by combining the periodic nourishment efforts at Absecon and Brigantine Islands was conducted. The analysis follows a similar approach as presented in Gebert (2010). In this particular case, it is assumed that the authorized three year periodic nourishment cycle at Absecon Island could be extended to a six year cycle and nourished jointly with the Brigantine Island authorized project.

Mobilization and demobilization costs constitute a significant portion of typical dredging contracts, and these costs do not necessary get reduced with increased contract size (e.g., larger dredging projects). A number of factors contribute to the variations in dredging contract costs, including market conditions at the time, proximity of the borrow area to the nourishment site, and the limited number of capable dredging contractors. As such there can be large uncertainties when forecasting beach nourishment dredging and placement costs. Recent dredging contracts (2002-2009) for nourishment efforts in New Jersey and Delaware (Gebert, 2010) can account for 10% to 60% of the total winning bid, and average mobilization and demobilization costs are approximately $2 million per nourishment effort, regardless if it is an initial or periodic nourishment effort. The unit cost of sand over that same time period ranged from approximately $4 to $15/cy. Therefore, the preliminary analysis presented herein also assumes dredge mobilization and demobilization costs of $2 million, and a conservative unit price of $15/cy for sand.

Since many strategies may involve integration of projects with different remaining authorized lifetimes, a 50-year time horizon is used for comparison purposes irrespective of the remaining authorized project life. Use of a single standard time period also allows direct comparison between various strategies across projects and for those involving initial construction costs and maintenance (O&M) costs.

Over a 50-year time horizon, the volume of sediment placed on the beach remains the same; however, there is a cost savings of $16 million based solely on the reduced number of nourishment events. Additional cost savings may be realized from reduced contracting and management requirements. A comparison to current operations and to other strategies is presented in the summary section.

Fewer periodic nourishment episodes will also have an environmental benefit since there will be less frequent disturbance of the borrow site areas, reduced disturbance on the beaches, and reduced overall air and noise pollution.

Prior to implementing this strategy, evaluation of the storm damage protection impacts needs to be completed to ensure that protection of the Absecon Island region (specifically Atlantic City) is not compromised by extending the periodic nourishment interval from three to six years.

This strategy can be implemented at any time since existing authorities do not preclude any re-nourishment from being done as part of a combined contract as long as the funds for each are available and are not comingled. Further, all requisite environmental clearances must be accomplished before award of such a contract. The implementation of this strategy has minimal constraints; limited to availability of dredging equipment and borrow site quantities, which are already constraints of current operations.

Table 79 presents a summary of the criteria evaluated for the improved project cycle synchronization strategy and ranks it as a high priority and easily implementable (Tier 1 level). This strategy should be pursued since the pathway to implementation is straightforward and there are no significant constraints.

Table 79. Project Cycle Synchronization Strategy Summary.

Criteria	Summary
1. Authorization	No existing authorization limitations
2. Constraints	No constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	$16 million over 50-year time horizon
4. Service Life	Potential increase in project longevity and service life
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Evaluate potential storm damage impacts, coordinate dredging, and implement

B. Borrow Are Expansion at Brigantine Inlet

The expansion of Brigantine Inlet borrow areas will assist in obtaining adequate material to use at nearby nourishment projects. The intent of the strategy is to identify and expand inlet based borrow areas that will help provide long-term sand sources for Brigantine Island nourishment. Recently, the city of Brigantine, the State of New Jersey, and the federal government have all extracted sand from Brigantine Inlet for beach nourishment purposes. The City of Brigantine and the State utilized 1.2 million cy of sand dredged from intertidal and shallow subtidal shoals near the main ebb tidal channel of Brigantine Inlet to nourish northern Brigantine beaches in 1997. The Brigantine Inlet to Great Egg Harbor Inlet (Brigantine Island) Shore Protection Project utilized 672,000 cy of sand dredged from the permitted Brigantine Inlet borrow area for initial construction in 2006 (Table 78).

This strategy encourages the continued use of sediment dredged from the Brigantine

Inlet for the Brigantine Island authorized shore protection project. This approach is in direct concurrence with the Regional Sediment Management Initiative.

The currently permitted borrow area in Brigantine Inlet is an 89 acre area at the mouth of the inlet containing an estimated 2,700,000 cy. Based on survey and a thickness range of 10 to 15 feet, the estimated pre-project borrow quantity for the original borrow area is between 5,214,124 and 7,821,186 cy. USACE noted three potential large new borrow areas in Federal waters offshore (G1, G2, G3). G1 is 2,660 acres, G2 is 3,160 acres and G3 is 2,480 acres. USACE provides no volume estimates for these borrow areas, so volumes are estimated here. At an average thickness of 10 to 15 ft, G1 could yield between 42,900,000 and 64,400,000 cy. At an average thickness of 10 to 15 ft, G2 could yield between 50,900,000 and 76,400,000 cy. At an average thickness of 10 to 15 ft, G3 could yield between 40,000,000 and 60,000,000 cy. Although these are large reserves of sand which could meet the needs of Brigantine Island as well as other regional projects (Strategy D), their distance from shore makes them potentially more costly sources.

For the current analysis, an investigation of historical aerial photography suggested that the shoals of Brigantine Inlet are substantial but migratory. Potential borrow areas are delineated based on the location of the ebb and flood tidal shoals in the latest available imagery (Google Earth, June 2011). Figure 146 delineates these potential borrow areas, along with the existing permitted borrow area at Brigantine Inlet.

The flood tidal shoal at Brigantine Inlet is approximately 24 acres. At an average thickness of 10 to 15 ft, the flood tidal shoal borrow area could yield between 380,000 and 570,000 cy. The ebb tidal shoal at Brigantine Inlet is approximately 71 acres. At an average thickness of 10 to 15 ft, the ebb tidal shoal borrow area could yield between 1,150,000 and 1,730,000 cy.

These expanded borrow areas within Brigantine Inlet could be authorized by developing a beneficial reuse project using the coastal projects authorities to implement. However since the authority to construct this project does not include beneficial reuse, it would have to be modified to include this and the project cost sharing adjusted to reflect a new purpose. Documentation would have to be developed to accomplish this as well as a new PCA reflecting today's model agreement would have to be negotiated and signed.

The primary constraints with expansion of the inlet borrow sites are environmental. Establishing borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave, tidal currents, and sediment transport processes also are needed, especially to determine the potential impact from removal of a significant portion of the ebb or flood tidal shoals. Although the physical and environmental delineation would add cost, once permitted, the construction costs associated with obtaining the nearshore material are significantly lower than for upland material, or offshore sources due to the close proximity of the inlet material to the beach nourishment project.

Figure 146. Potential borrow areas (green) at the ebb and flood tidal shoals of Brigantine Inlet. Permitted borrow areas shown as shaded gray areas. Image courtesy of Google Earth©.

Table 80 presents a summary of the criteria evaluated for the beneficial reuse of the Brigantine Inlet material and borrow area expansion strategy and ranks it as an intermediate priority for this region with a Tier level of 2. It is recommended that this strategy is pursued in advance of potential need, such that the borrow areas are established for future use. Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted sites with adequate volume to meet the shore protection needs in the future is beneficial. If storm events or unforeseen circumstances arise, having the sediment available would be critical. Next steps for this strategy would be to initialize any studies and surveys needed to expand the inlet borrow sites.

Table 80. Brigantine Inlet Borrow Area Expansion Strategy Summary.

Criteria	Summary
1. Authorization	Requires modification of authority to include beneficial re-use of inlet material
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Some cost savings expected due to close proximity of borrow sites
4. Service Life	No change to shore protection service life
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	Intermediate
7. Tier Level	Tier 2
8. Next Steps	Initiate studies and surveys

C. *Beneficial Reuse and Expanded Dredging in St. George's Thoroughfare*

The Beneficial reuse of material and/or expansion of dredging in Saint George's Thoroughfare strategy seeks to reduce the amount of offshore borrow material needed for nourishment of Brigantine Island. The USACE regularly maintains the navigational channel to Saint George's Thoroughfare Bay. Using this material, or expanding the area dredged could supplement sand from the authorized Brigantine Inlet borrow area for use along Brigantine Island. For the current analysis, an investigation of historical aerial photography suggested that the shoals at Saint George's Thoroughfare are small and surrounded by wetlands and recreational beach uses. The latest available imagery (Google Earth, June 2011) shows a small ebb shoal and sand spit extending into the channel that may be dredged without compromising wetland resources in the vicinity (Figure 147). However, this area is only half an acre and would only yield a maximum of 13,000 cy at an average thickness of 15 ft. It is likely not economically feasible to pursue such a small volume of sand for beneficial reuse on a large project such as Brigantine Island. In general, the amount of material dredged from this area, even if dredging was expanded is a small amount of material relative to the overall nourishment requirements. Therefore, this strategy is ranked as a low priority.

Table 81 presents a summary of the criteria evaluated for the beneficial reuse borrow area expansion and of St. George's Thorough fare material and ranks it as a low priority with a Tier level of 2. It is recommended that this strategy is not pursued due to the limited amount of material available.

Figure 147. Potential borrow areas (green) at the St. George's Thoroughfare. Image courtesy of Google Earth©.

Table 81. Beneficial Reuse and Expanded dredging of St. George's Thoroughfare Strategy Summary.

Criteria	Summary
1. Authorization	Requires modification of authority to include beneficial reuse of St. George's Thoroughfare material
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Minimal to no cost savings expected due to limited material
4. Service Life	N/A
5. Other Benefits	Minimal
6. Priority	Low
7. Tier Level	Tier 2
8. Next Steps	None recommended

D. Offshore Borrow Area Expansion or Establishment

As presented in Table 78, sediment sources for the initial construction of the Brigantine Island project, as well as the planned periodic nourishment, have been from the borrow area at Brigantine Inlet. Currently, the permitted inlet borrow site does not have enough material to complete future renourishments. Therefore, unless the sediment needs of the shore protection project can be reduced (e.g., beach nourishment performance is enhanced), or alternative sediment sources are utilized (e.g., bypassing), additional offshore borrow locations or expanded inlet dredging (Strategy B) will be required.

This strategy is not specifically geared towards providing a cost savings, but rather at maintaining current operations costs since upland sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., track traffic, road repairs, time of construction, etc.).

Over a 50 year time horizon, the periodic nourishment sediment needs at Brigantine Island are approximately 2,500,000 cy. The original inlet borrow site (BI 1) for the Brigantine Inlet to Great Egg Harbor Inlet (Brigantine Island) authorized shore protection project had approximately 2,030,000 cy remaining after initial construction. As such, there is a deficit of approximately 470,000 cy for renourishment of the project.

Therefore, continued expansion of existing sites, or searches for new borrow sites may be needed for this region. For example, the proposed borrow areas BI X (expanded Brigantine Inlet borrow area), G1, G2, and G3 should be considered. Potential searches in Federal waters also may be warranted through cooperation with the Bureau of Ocean Energy Management (BOEM).

This strategy can be accomplished under the existing project authorities as the provision of borrow areas for the life of the project is part of the authorization. It would likely require cost sharing at the same level as the project. Appropriate studies and environmental clearances would be needed.

The primary constraints with expansion or establishment of offshore borrow sites are environmental. Establishing offshore borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave and sediment transport processes also are needed. Although the physical and environmental delineation would add cost, once permitted, the construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 82 presents a summary of the criteria evaluated for the offshore borrow area expansion and establishment strategy and ranks it as an intermediate priority with a Tier level of 1. Similar to the inlet dredging expansion, it is recommended that this strategy is pursued in advance of potential need, such that the borrow areas are established for future use. These additional borrow sites may also be utilized in the greater regional nourishment needs (e.g., Long Beach Island). Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted offshore sites available if needed for storm events or unforeseen circumstances is good planning. Next steps for this strategy would be to initialize any studies and surveys needed to expand or establish new borrow sites for this region, which has a known deficit and coordinate

with BOEM for any potential federal waters borrow sites.

Table 82. Offshore Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Initiate studies and surveys; Coordinate with BOEM

E. *Refined Beach Nourishment Template*

This strategy involves applying adjustments to the authorized beach nourishment template along Brigantine Island to determine if modifications to the template may result in increased performance or improved storm damage protection. A successful beach nourishment project consists of more than simply placing sediment on a beach. Beach nourishment projects are engineered. A beach nourishment template, which consists of numerous design parameters, is based on the characteristics of the site and the needs of a project. Every beach nourishment design is unique, since different beaches in different areas have different physical, geologic, environmental, and economic characteristics, as well as different levels of required protection. The design must consider climatology, the shape of the beach, type of native sand, volume and rates of sediment transport, erosion patterns and causes, waves and water levels, historical data and previous storms, probability of certain beach behaviors at the site, existing structures and infrastructure, and past engineering activities in the area.

The structure of a nourishment template is designed to yield a protective barrier that also provides material to the beach. A higher and wider beach berm is designed to absorb wave energy. Dunes may need to be constructed or existing dunes improved to reduce damage, including potential upland flooding, from storms. Figure 148 depicts a beach berm and dune on a typical beach profile. Nourishment length, berm height and width, dune height, and offshore slope are critical elements of a beach nourishment design. Periodic nourishment intervals are also usually a part of the nourishment design. The renourishment interval will vary based on the initial design, wave climate, sand used, frequency of storms, and project age. However, beach nourishment is not an exact science, and variables and uncertainties exist. Actual periodic nourishment intervals may differ from planned intervals based on conditions at the nourished beach and the frequency and intensity of storms.

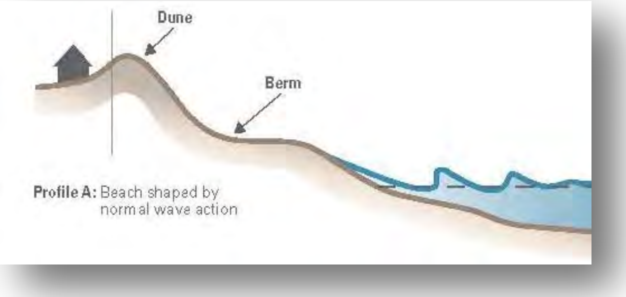


Figure 148. Typical beach profile and features (from Coastal Engineering Manual, 2003).

This strategy evaluates potential improvements to project performance, storm damage protection, and subsequent cost savings that can be realized through modifications to the currently authorized beach nourishment template.

The feasibility studies for the authorized projects typically evaluate a range of proposed beach nourishment template designs using alongshore and cross-shore analysis and/or modeling efforts to assess performance and storm damage protection afforded by the proposed nourishment template. However, the USACE policy has been to not consider increases to the natural berm elevation for the design template or to see if changes to the natural berm height result in performance gains or improved storm damage protection. Additionally, the currently authorized design template has not been re-evaluated following monitoring of the performance of the system. However, monitoring data may provide insight that could warrent modifications to the template. Therefore, this strategy involves assessing changes to the beach nourishment template that may yield cost savings over the long-term. An example of this type of analysis is presented herein by evaluating change in berm height and width on the performance of the Brigantine Island project as a preliminary analysis of potential template modification.

Similar analyses could be completed for a number of parameters that are components of beach nourishment design; including:

- Nourishment length – Expanding the nourishment length, specifically through combining or syncing projects could be evaluated.
- Offshore slope – The offshore slope of the nourishment can be changed.
- Grain size – The grain size of the source material for the nourishment may affect the performance of the projects. For example, coarser nourishment material may result in improved project performance (lower erodibility and hence more protection.

To assess potential changes in berm width and height at Brigantine Island, the computer model SBEACH (Larson and Kraus 1989) was used to assess cross-shore evolution. SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and further developed and verified based on field measurements (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990). The model predicts the time-dependent evolution of existing or design beach and dune profiles for specified water levels and wave conditions. In addition to the proposed nourishment template, the model requires a time series of wave heights, wave periods and water levels as forcing inputs. The specific storm information required by SBEACH is a time history of total water level (tide plus surge) and wind wave height and period. The WIS hindcast information, FEMA FIS still water storm surge elevation, and extremal analysis were used to develop a simulated 10-year storm for this analysis.

Figure 149 presents results of varying the berm height (blue line) and width (green line) of the Brigantine Island authorized beach nourishment template. The horizontal axis shows the percent of material lost from the nourishment template area caused by a 10-year, 24-hour storm for various berm heights and widths. The left hand vertical axis shows berm height (NAVD88, ft), while the right hand vertical axis shows berm width (ft). The variable width scenarios use a constant 6.0 ft NAVD88 berm height, while the variable height scenarios use a constant 100 ft berm width. This is consistent with the currently authorized template for a berm height of approximately 6.0 ft NAVD88 and a berm width of 100 ft. Figure 149 shows the changes in expected sediment lost from the template area for increased berm height and width. For example, the currently authorized project template loses approximately 52% of the periodic nourishment during the 10-year, 24-hour storm. However, by increasing the berm width to 140 ft the percentage of material lost is reduced to approximately 37%. Increasing the berm width further results in decreased losses, but also requires additional nourishment volumes, additional sediment sources, and finances. As such, there is a point of diminishing returns on the amount of required sand needed to extend the berm width and the increased performance gained. Adding more sand to the system may result in better performance, but also may not be worth the added cost of the additional sand. This type of analysis could be conducted to evaluate the sensitivity of various parameters in the beach nourishment design, their potential impacts on overall cost of the project, and identify the most cost-effective design template.

For example, the 140 ft berm width modified design requires approximately 173,000 cy of additional sediment to gain the required berm height during the initial increased periodic nourishment; however, the performance is improved over each 6 year cycle, such that the amount of sediment required for each periodic nourishment is reduced.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this example approach to template modification would actually result in a cost deficit of approximately $2 million over a 50-year time horizon. In this particular case, although the refined beach nourishment template offers improved performance, this improvement does not cover the added cost associated with the additional sediment requirements. Therefore, the added sediment needed for this specific modified template does not provide financial benefit. Although other template modifications may result in some cost benefits, the current authorized template appears to be fairly well optimized.

Modification of the beach nourishment template may have benefits that extend beyond improved performance. For example, the modified template may result in reduced potential upland damage costs, habitat enhancement, and reduced ponding or upland flooding.

Relative to the current authorization, the existing template defines the authorized project and the NED plan. Changing the template would imply that the authorized plan was no longer the NED plan and the project would have to be reanalyzed. To do so would require the use of the existing New Jersey shore study authority to determine the degree of federal interest, get the requisite environmental clearances, and recommend a change in the authorized plan. This would require the existing project authority to be modified by Congress. It would also likely require a new study cost sharing agreement to be signed, as well as a non-federal sponsor willing to contribute 50% of the study costs and agree to any changes in the construction and long-term cost sharing. Finally, a new PCS conforming to the model agreement would have to be signed.

Potential constraints associated with modification of the beach nourishment template include environmental concerns (e.g., occupying a larger offshore footprint), political and local community concerns that would limit the ability to change the template (e.g., communities wouldn’t want an increase berm height), and logistical concerns associated with modification of the authority to construct the project.

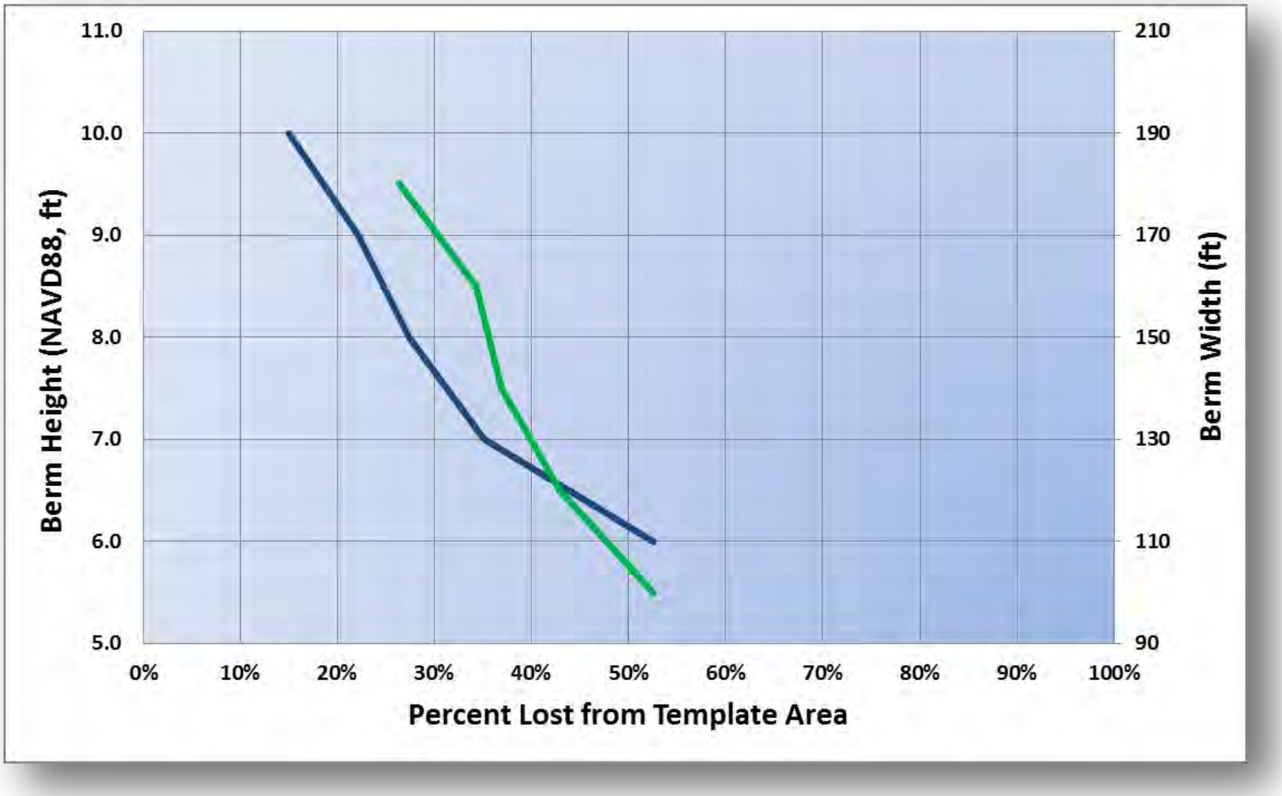


Figure 149. Eroded beach volume as a function of template berm height (blue one) and width (green line) for the Brigantine Island nourishment project in response to a 24-hour, 10-year return period storm event.

Table 83 presents a summary of the criteria evaluated for the refined beach nourishment template strategy and ranks it as a low priority, due to the lack of any cost savings for this project area, and a Tier level of 2. Next steps for this strategy would be to conduct more detailed studies to assess if template modifications are warranted. The studies would focus on the cost benefit aspects of template modification.

Table 83. Refined Beach Nourishment Template Strategy Summary.

Criteria	Summary
1. Authorization	Requires a change to the authorized plan and would include new study, permits, and cost-sharing agreements
2. Constraints	Logistic, political, local community, and environmental concerns
3. Cost Savings	Depends on template modification, No savings for case evaluated
4. Service Life	Increased service life of beach nourishment expected
5. Other Benefits	Improved storm damage protection, habitat enhancement, reduced offshore environmental impacts
6. Priority	Low
7. Tier Level	Tier 2
8. Next Steps	Strategy is not recommended

F. Sediment Backpassing

This strategy involves extracting sediment from a portion of the shoreline that is accreting and moving the material to an updrift location that is more erosional. This methodology, called sediment backpassing, is intended to work with the natural littoral drift within a system by recycling sand back updrift to the location where it had initially resided. For example, nourishment material placed in the Brigantine nourishment area is transported south, where an accretion area exists approximately 13,500 feet to the south. The sediment backpassing strategy would recycle a portion of this material back to the Brigantine nourishment area, as shown conceptually in Figure 150.

Figure 150. Sediment backpassing strategy for Brigantine Island.

As part of the Hereford Inlet to Cape May Inlet Feasibility Study, Clausner and Welp (2008) conducted a study to investigate the feasibility of mobile hydraulic back-passing for the Wildwood area. The study determined that in a time frame of two to four months, as much as 200,000 cy of sand could be back-passed distances of up to 15,000 ft using the mobile system they evaluated. Clausner and Welp (2008) also determined that the cost associated with the mobile system (a hydraulic pumping system mounted on a boom equipped crawler) would be approximately $10/cy. Using the costs developed by Clausner and Welp (2008), and assuming compatible sediments on all reaches of Brigantine Island, a preliminary cost analysis was performed on the applicability of sand backpassing to complement current nourishment efforts at Brigantine Island.

Using historic shoreline change data, shoreline accretion occurs within 13,500 ft to the south of the nourished areas, where the shoreline accretion occurrs at an average rate of 7.0 ft/yr (2.1 m/yr). In order to determine the potential volume available for backpassing, the existing profiles of the accretionary area were translated landward (a distance equivalent to the rate of advance) using equilibrium beach profile theory. Therefore, only sediment that was accreting was identified as available for backpassing, and the shoreline would remain stable and not turn into an erosional area. This profile translation method calculated the volume of sediment accreting to be almost 151,000 cy annually. However, not all of this excess material is available for extraction. Assuming the use of a 160 ft boom mounted pumping system, 31,000 cy/yr of sand are available to be backpassed to replenish the shoreline on Brigantine Island at a cost of $10/cy (Clausner & Welp, 2008). Using sheet piles and temporary earthworks, the swath of the mobile dredging equipment can be increased to provide additional sand for backpassing, but at an additional, undetermined cost.

The total amount of sediment available for backpassing is not enough to eliminate the need for periodic nourishment, but utilizing this material reduces the amount needed for periodic nourishment.

Over a 50-year time horizon, there is a cost savings of $25 million if 31,000 cy/yr of sediment backpassing was implemented. This assumes that the mobile backpassing system is readily available and could be utilized at the Brigantine Island location. Additional cost savings may be realized from reduced contracting and management requirements. Reduced impacts to offshore borrow sites would be another benefit to this strategy. A comparison to current operations and to other strategies is presented in the summary section.

Potential constraints involve the potential impact on the beach where sand is extracted. This includes the ability of the beach to adequately serve the same function and level of protection as before the sediment removal. This strategy would also increase disturbance on the beaches, and overall air and noise pollution.

The authorization for this project does not include specific authority to backpass sand. However, the Corps' value engineering authority could be used to determine the effectiveness of backpassing at reducing the long term nourishment costs compared to its implementation cost. The need to develop benefit numbers is also reduced by this approach; the benefits are just the reduced nourishment costs. Appropriate environmental clearances would also be required.

Table 84 presents a summary of the criteria evaluated for the sediment backpassing strategy and ranks it as a high priority and Tier Level 2.

Table 84. Sediment Backpassing Strategy Summary.

Criteria	Summary
1. Authorization	Use value engineering to determine the effectiveness of backpassing at reducing the long term nourishment costs compared to implementation cost
2. Constraints	Dredge equipment availability, potential impacts to source beach
3. Cost Savings	$25 million over 50-year time horizon
4. Service Life	No change to service life
5. Other Benefits	Reduced impacts to offshore borrow sites
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Use value engineering to implement; Assess environmental impacts on source beach

G. Coastal Structure Additions

One of the most vulnerable areas within the Brigantine Island nourishment template is at the northern end of the authorized nourishment project (in the vicinity of 14th and 15th Street N). For this strategy, the addition of low profile groins to stabilize the shoreline in this area was investigated.

To provide a preliminary evaluation of the terminal groins, the cross-shore distribution of the longshore transport was evaluated using relationships proposed by Longuet-Higgins (1970, 1970a). Using the cross-shore distribution, the effect of a shore-perpendicular structure on reducing or increasing the longshore sediment transport can be estimated.

The cross-shore distribution of longshore transport can be determined using a theoretical radiation stress approach (Longuet-Higgins and Stewart, 1962). This momentum based theory describes the energy imparted on the bottom of a nearshore breaking zone by shallow water waves.

When shallow water waves break at an angle that is not perpendicular to the coastline, the result is a net force that pushes a parcel of water in the direction of the oblique angle. In the case of a series of waves breaking at a similar angle, a net current results that continually forces water along the shore (or alongshore). The total volume flow rate, *Q*, is given as a function of velocity, v_o, as

Equation 15:

$$Q = \frac{1}{3s} h_B{}^2 v_0 = \frac{1}{3} h_B |x_B| v_0$$

where h_B is the depth of water at the breaker line, *s* is the slope of bottom, and x_B is the normalized distance to the breaker line.

Horizontal mixing is the result of waves breaking at different locations and wave-induced eddies varying the profile of the cross-shore velocity distribution. To account for this variability due to mixing, a quadratic equation is used to create a typical cross-shore flow profile. The shape of this new function is dependent on the known variability of the wave conditions and a horizontal eddy parameter. Figure 151 is a schematic representation of the long-shore velocity profile as a function the normalized offshore distance to the breaker line. The broken line represents the values without mixing. After applying a quadratic equation and its mixing coefficients, the longshore velocity profile looks like the solid line. The area under both lines equals to the volume flow rate, *Q*.

This distribution is calculated based on site-specific physical processes data (e.g., WIS hindcast information) for the Brigantine Island region, and is presented in Figure 152. The distribution can then be applied to assess different lengths (cross-shore direction) of structures by determining the amount of littoral transport that may be intercepted by the structures.

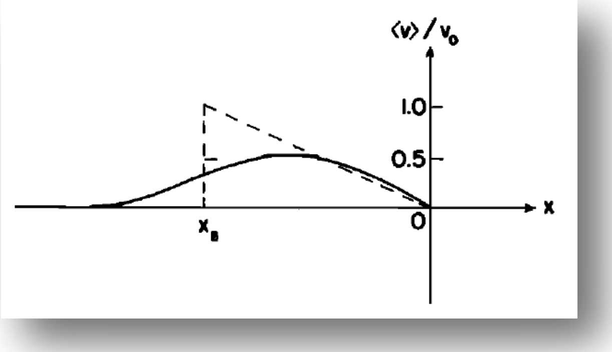


Figure 151. Example cross-shore distribution of alongshore velocities.

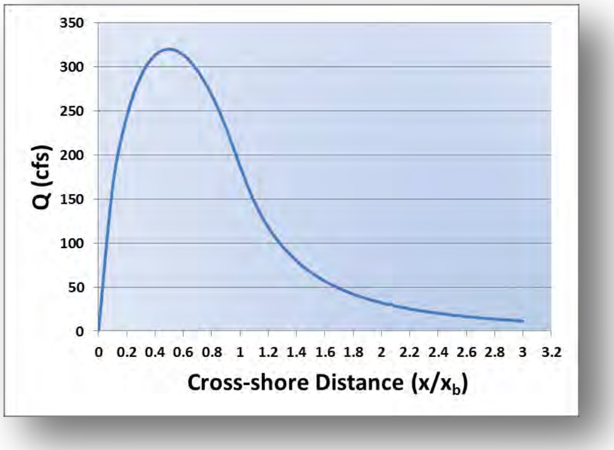


Figure 152. Cross-shore distribution of alongshore flux for Brigantine Island area.

The cross shore distribution of alongshore current was calculated and used as a proxy for sediment transport. The amount of longshore current impeded at each groin location is used to determine a minimum length to extend the groin. Placement of a low profile groin extending 75 ft beyond the mean water level will intercept approximately 20% of the sediment transport allowing the shoreline updrift of the groin to better retain the nourishment material. Figure 153 shows the locations of the low profile groins evaluated in this strategy.

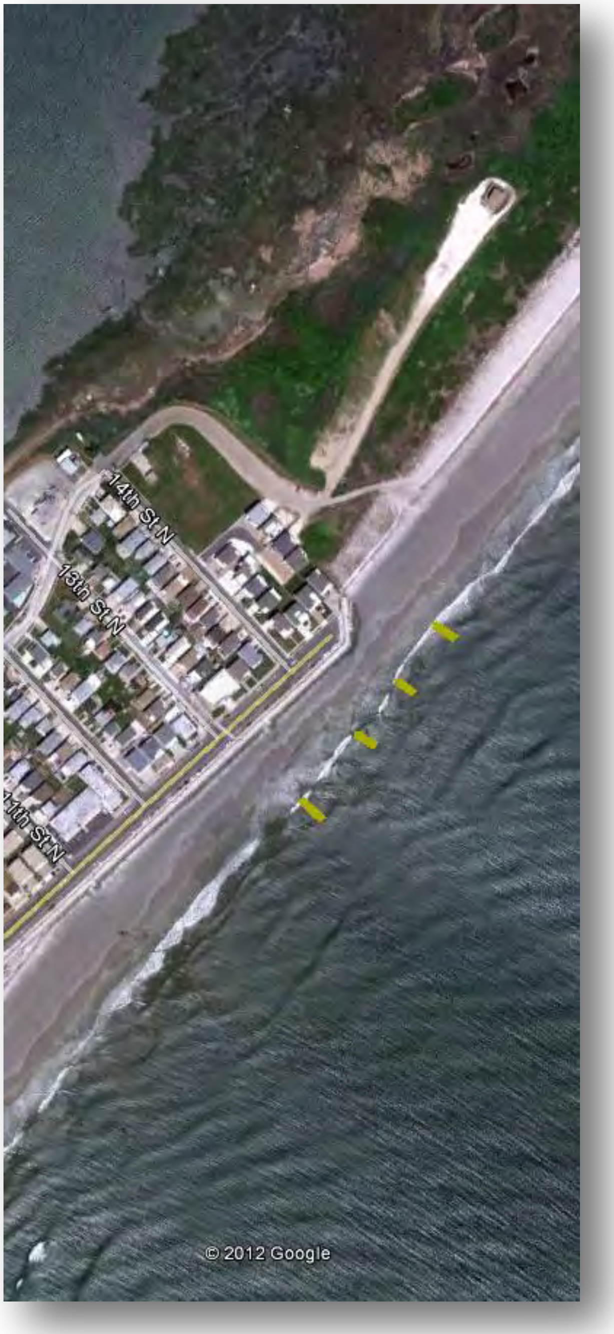


Figure 153. Approximate locations of low profile groins at Brigantine evaluated in this strategy.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this structural addition at Brigantine would result in a cost savings of approximately $3 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments. This preliminary analysis evaluated four (4) low profile groins at the northern end of the Brigantine Island nourishment. This basic cost analysis assumes:

- Groin construction costs of $1 million based on previous structural cost bids
- a net southward littoral drift rate of 200,000 cy/yr (USACE, 2006)
- periodic nourishment conducted as currently authorized (every 6 years)
- the structure maintains its same rate of effectiveness over the 50-year service life
- and that reduced sediment flow towards the southern portion of Brigantine Island does not significantly impact the stability of the shoreline. Given the historic shoreline advancement, this appears to be a reasonable assumption.

Extensions of other various lengths can also be evaluated in this manner. However, the structure should not be extended so far as it would negatively impact the downdrift shorelines by intercepting too much of the cross-shore distribution of alongshore sediment movement. Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Structural modifications could be evaluated under the existing New Jersey Shore authority. However, it would require study cost sharing, a non-federal sponsor and if it meets the criteria for implementing a new construction authorization.

Constraints for this strategy include potential environmental impacts that need to be assessed and more detailed coastal processes evaluations that should evaluate the impact of proposed structural additions and/or modifications.

Table 85 presents a summary of the criteria evaluated for the coastal structures additions strategy and ranks it as a low to intermediate priority with a Tier level of 3. Next steps for this strategy would be to initialize more detailed studies to assess the impact of proposed structural modifications from a physical and environmental impact basis. The studies would also focus on the cost benefit aspects of the structural modification proposal(s).

Table 85. Additional Coastal Engineering Structures Strategy Summary.

Criteria	Summary
1. Authorization	Requires study of cost sharing and a non-federal sponsor to implement construction authorization
2. Constraints	Environmental impacts need to be evaluated, coastal processes assessment to evaluate impact of structural modification
3. Cost Savings	$12 million for structural additions presented herein
4. Service Life	Potential beach nourishment performance enhancement, structural service life expected to be 50 years
5. Other Benefits	Reduced environmental impacts to offshore resources
6. Priority	Low to Intermediate
7. Tier Level	Tier 3
8. Next Steps	Coastal processes and environmental studies to determine relative cost benefit of structural modifications

H. Site-Specific Coastal Processes Evaluation

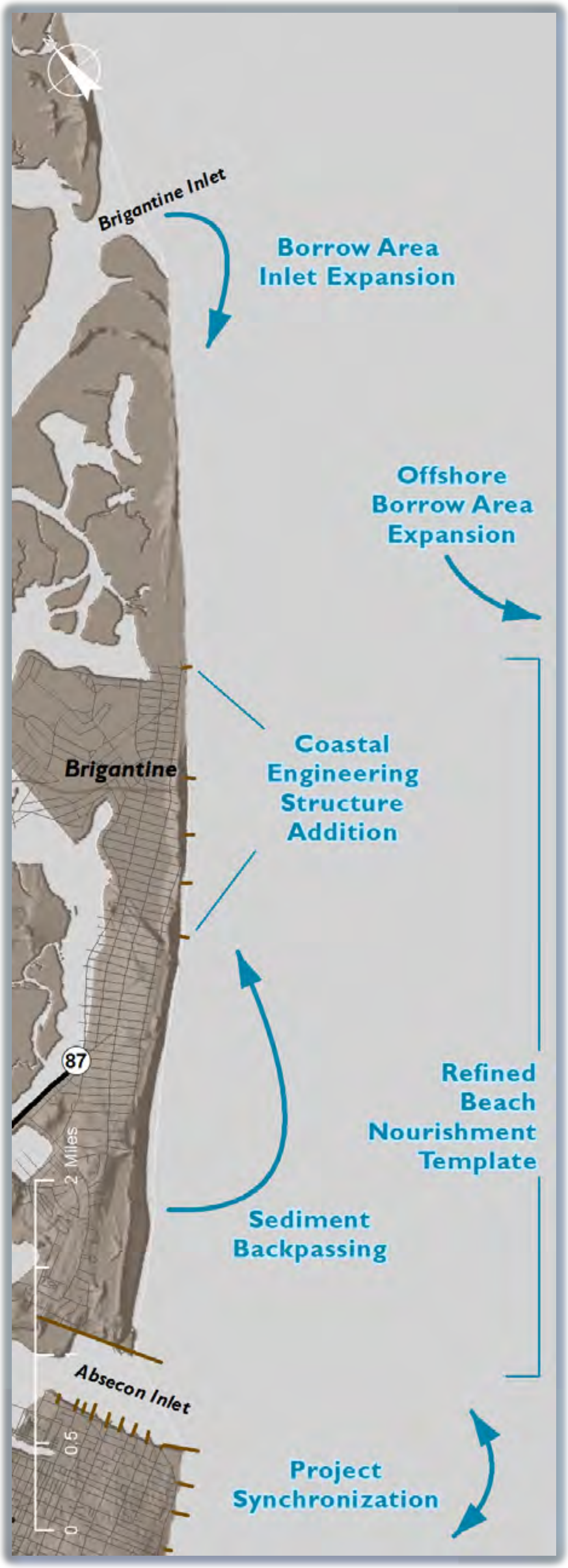
This strategy involves developing a comprehensive, coastal processes based, understanding of the prominent erosion that occurs at Brigantine Island. A site-specific study, intended to focus on detailing the coastal processes (waves, tidal currents, wave-induced currents, sediment transport, etc.), would be recommended to identify potential alternatives that may improve the existing shore protection authorization, or provide a better understanding of how to potentially modify the shore protection approach.

Brigantine has experienced accelerated erosion in recent years and the longevity of the authorized beach nourishment project has been short lived. In order to better understand the processes that may be causing this increased erosion, a more detailed study of the coastal processes at this location may be warranted. The intent of this strategy is to provide an improved understanding of the causes and nature of the significant erosion, including the short service life of the nourishment projects that are conducted. The study should be rooted strongly in applying scientific and engineering tools (i.e., data and models) to understand the erosional processes. This should include coupled hydrodynamic, wave, and sediment transport modeling, supported by field observations. Essentially if the coastal processes and causes of the elevated erosions are better understood, then perhaps a more advantageous mitigation approach could be implemented.

Table 86 presents a summary of the criteria evaluated for the site-specific coastal processes evaluation strategy (although any of the criteria are not applicable) and ranks it as an intermediate priority with a Tier level of 1. Although there is no immediate cost savings associated with implementation of this strategy, future financial savings could be significant for the given investment (expected to be approximately $200,000).

Table 86. Site-Specific Coastal Processes Evaluation Strategy Summary.

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings, potential future savings
4. Service Life	Not applicable
5. Other Benefits	An improved understanding of the coastal processes and potential mitigation options for Brigantine
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study



Summary

This section presents a brief summary of all the strategies presented for Brigantine Island. The focus is on the potential cost savings and priority levels to assist in the identification and selection of strategies that could be implemented immediately and/or further pursued to more cost effectively manage sediment within the project area.

Figure 154 provides a summary of the estimated total cost savings (compared to current operations) over a 50-year time horizon for a number of the potential strategies (those that indicated a cost saving could be realized) for comparison purposes. Additional analysis could be completed to evaluate the potential cost savings associated with combining various strategies as well.

Table 87 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies presented in Table 87 are listed in order of priority and estimated ease of implementation.

Table 87. Brigantine Island Strategy Summary.

Strategy	Prioritization	Tier
A. Project Cycle Synchronization	High	1
F. Sediment Backpassing	High	2
H. Site-specific Coastal Processes Evaluation	Intermediate	1
D. Offshore Borrow Site Expansion	Intermediate	1
B. Inlet Borrow Area Expansion at Brigantine Inlet	Intermediate	2
G. Additional Coastal Engineering Structure	Low to Intermediate	3
E. Refined Beach Nourishment Template	Low	2
C. Beneficial Reuse of St. George's Thoroughfare	Low	2

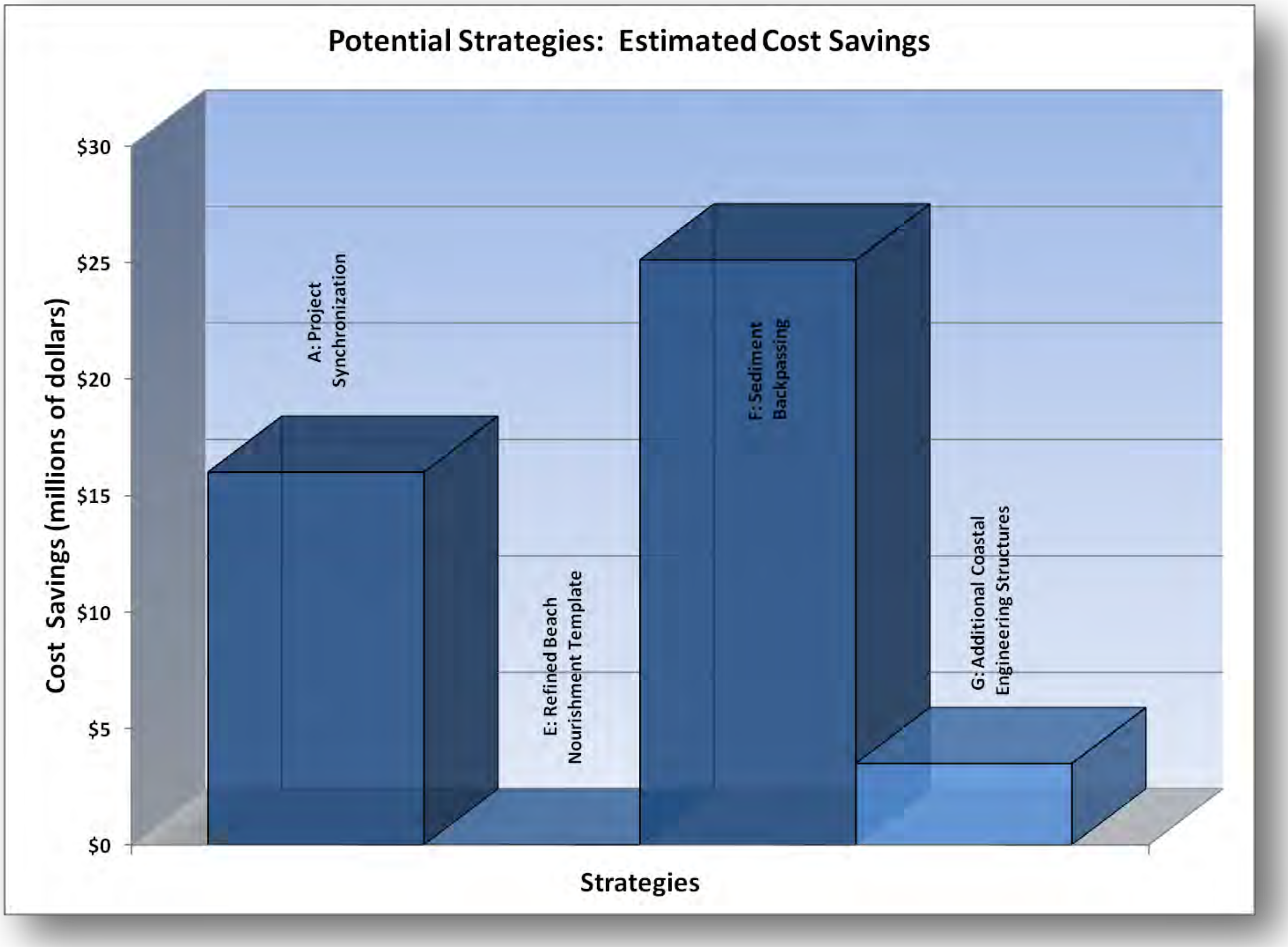


Figure 154. Estimate cost savings (compared to current operations) over a 50-year time horizon for select Brigantine Island strategies.

Long Beach Island

Project Description

The Barnegat Inlet to Little Egg Inlet Shore Protection Project was authorized for construction by the Water Resources Development Act of 2000. The project is located in Ocean County along the central New Jersey coast, and extends for approximately 20 miles along Long Beach Island between Barnegat Inlet and Little Egg Inlet. The authorized project provides a protective beach and dune system to reduce the potential for storm damage along the entire ocean coast of Long Beach Island. Sand dredged from offshore borrow sites provides the source of nourishment. Periodic nourishment every 7 years is included to maintain the design template.

The design berm is 125 ft wide at an elevation of 8.0 ft NAVD. The berm extends seaward to meet the natural grade at a slope equal to the existing nearshore slope. The dune crest is 30 ft wide with side slopes of 1V:5H. The elevation of the dune crest is 22.0 ft NAVD. The total length of fill along Long Beach Island is 89,000,000 ft. Dune grass plantings over 347 acres and 540,000 ft of sand fencing are also included. The project authorizes an initial construction volume of 7.4 million cy, with periodic nourishment of 1.9 million cy every 7 years, using sand dredged from offshore borrow sites. Figure 155 shows the components of the authorized project.

Figure 155. Barnegat Inlet to Little Egg Inlet (Long Beach Island) Authorized Shore Protection Project.

Project History

Long Beach Island has a history of beach and dune erosion. The area regularly suffers damages from coastal storms, hurricanes, and northeasters. The sections of Long Beach Island consistently affected the most by storm induced erosion are Harvey Cedars, Ship Bottom, Brant Beach, and Beach Haven. Since 1954, a number of beach restoration projects have been completed by State and local interests (Table 88). In response to erosion caused by the March 1962 storm, the Federal government placed approximately 3.1 million cy of sand in emergency dune restoration projects along most of the barrier beach.

Table 88. Long Beach Island Nourishment History.

Date	Volume (cy)	Community
1954	114,693	Harvey Cedars
1956	297,018	Ship Bottom Brant Beach
1958	224,000	Harvey Cedars
1961	190,498	Harvey Cedars Brant Beach
1962	1,289,521	Barnegat Light Harvey Cedars Loveladies Brant Beach Long Beach North Beach
1963	2,195,422	Ship Bottom North Beach Surf City Long Beach
1972	183,000	Loveladies
1978	1,000,000	Loveladies Harvey Cedars
1995	525,000	Harvey Cedars
1997	40,000	Brant Beach

Groins are the only type of fixed shore protection structure that exists along the oceanfront of Long Beach Island. The most recent condition survey of coastal structures performed in 1990 identified a total of 99 groins.

The Barnegat Inlet to Little Egg Inlet Shore Protection Project was authorized in 2000 to mitigate long-term erosion and to provide protection for developed areas of Long Beach Island. Initial nourishment and dune construction in Surf City and Ship Bottom were completed in 2007 when 900,000 cy of sand from an offshore borrow site was placed on the beach. Initial construction in Harvey Cedars was completed in June 2010 with the placement of 2,700,000 cy of sand. The Brant Beach portion of the barrier island is currently undergoing initial construction. A total volume of 1,200,000 cy is planned for placement (Table 89). Post-storm beach fill operations in Surf City and Ship Bottom were also performed in 2011, to restore the beaches to their conditions prior to the 2009 northeaster.

Table 89. History of Authorized Shore Protection Project Nourishment for Long Beach Island.

Date	Volume (cy)	Project/Source
2007	900,000 (Initial const.)	Surf City Ship Bottom
2010	2,700,000 (Initial const.)	Harvey Cedars
2011	224,000 (Storm rehab.)	Surf City Ship Bottom
2012	1,200,000 (Initial const.)	Brant Beach

Project Observations

- Until initial construction of the authorized shore protection project along the south end of Long Beach Island is complete, potential damages during storms will be a concern.
- Since military munitions were found on the beach following the first phase of construction in 2007, additional steps have been taken to screen the in-take and discharge ends of the pipeline. These measures will avoid this problem in the future.

- Beaches in Surf City that received sand as part of initial construction in 2007 have shown a gradual retreat of the shoreline and berm. However, the dunes provided critical protection to developed areas during the 2009 northeaster (Figure 156).
- Beaches in Ship Bottom that were nourished as part of initial construction in 2007 have remained relatively stable. Although, the 2009 northeaster caused a seaward migration of the nearshore bar; the material stored in the bar was still within the depth of closure and was available for transport back to the beach (Figure 157).

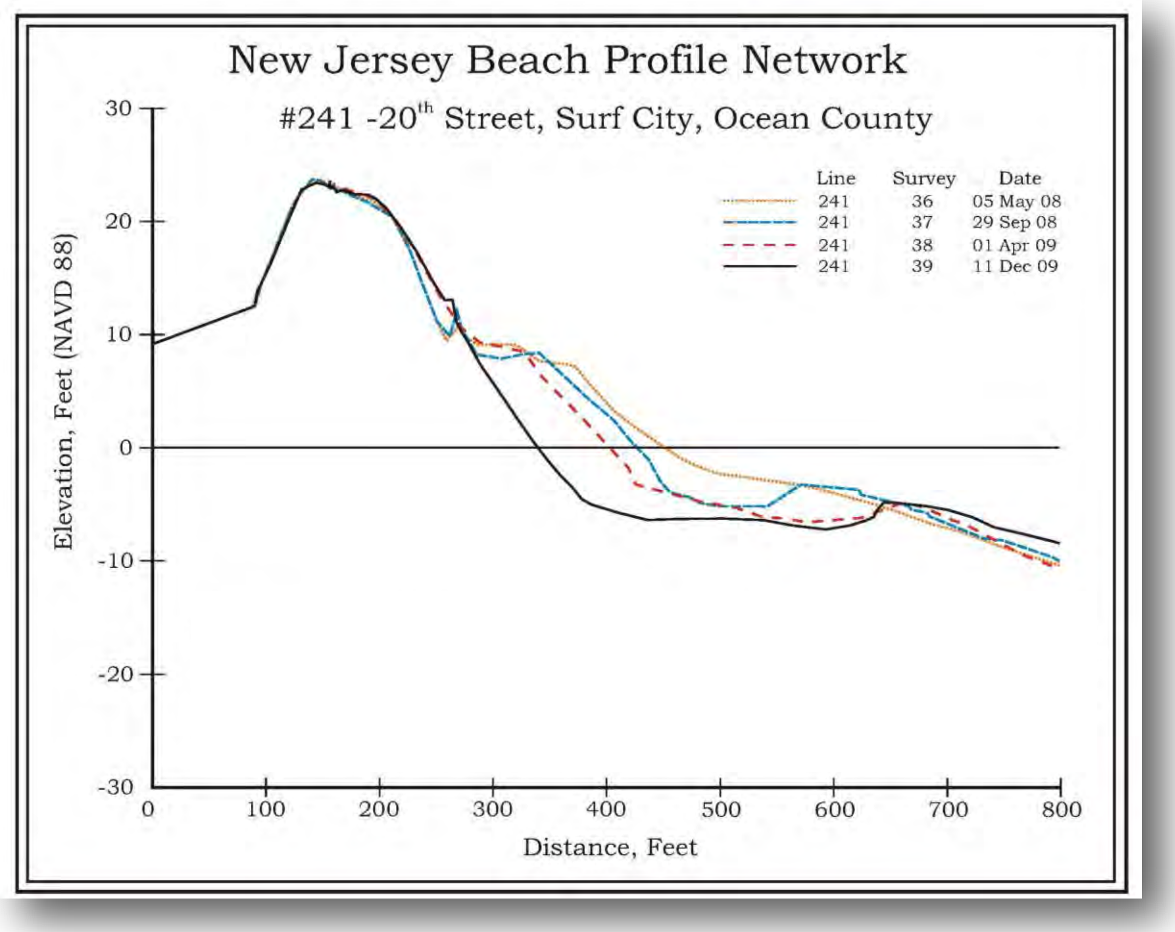


Figure 156. Stockton State College beach profile at Surf City showing performance of 2007 Federal Shore Protection Project (Stockton State College, 2009).

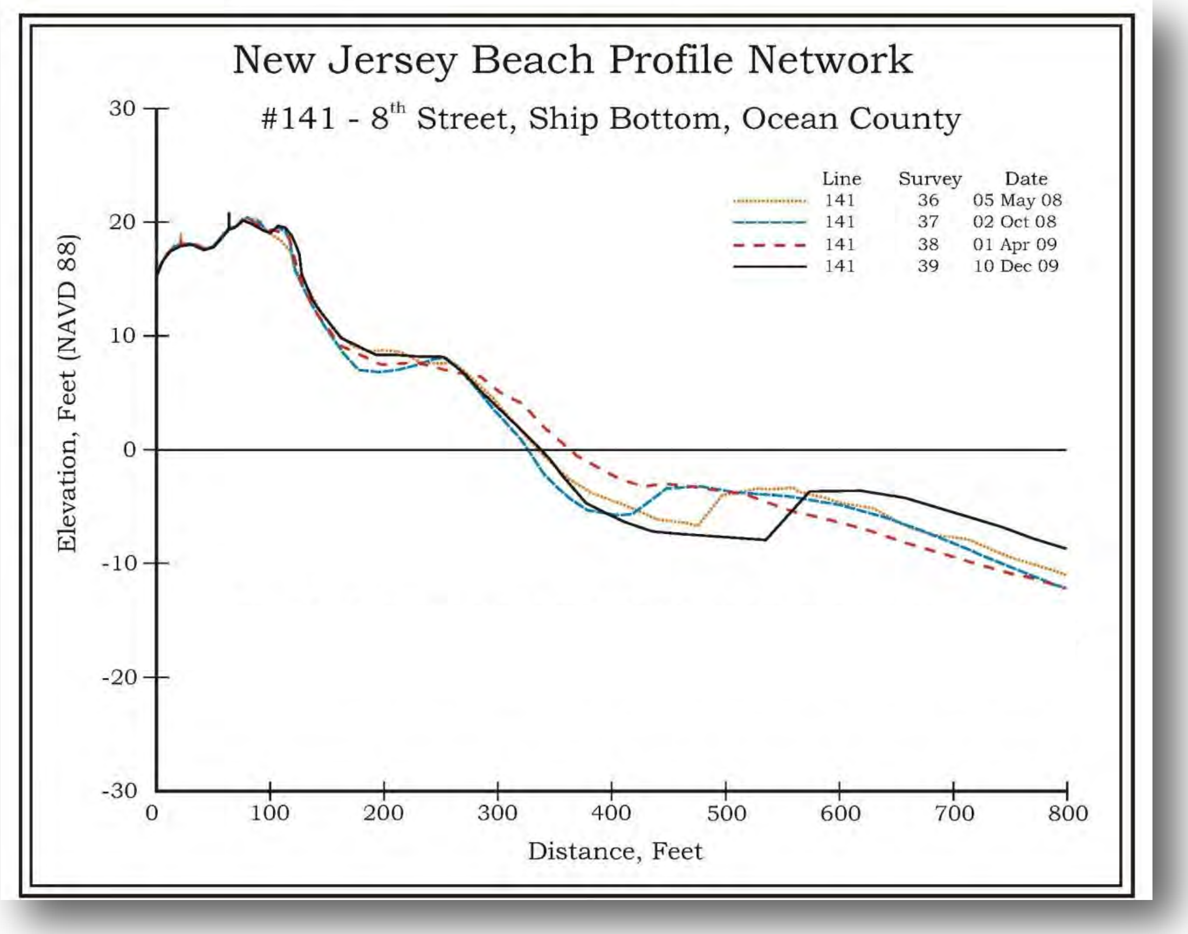


Figure 157. Stockton State College beach profile at Ship Bottom showing performance of 2007 Federal Shore Protection Project (Stockton State College, 2009).

Potential Strategies

This section presents the potential strategies for the Long Beach Island Shore Protection Project that are intended to provide improved project performance, cost savings, or other benefits. These strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. In addition, some of the strategies include a first-order technical analysis to evaluate the relative merit of the proposed strategy. These analyses are not intended to be detailed assessments and include some assumptions and simplifications. Rather, the analyses presented are geared towards providing a preliminary estimate of the potential benefits that may be realized if the strategy is implemented. In other words, the analysis presented herein can be used as an initial screening tool to determine if a strategy warrants further consideration. For some strategies, a more detailed analysis may be required if the strategy is more formally pursued.

A. Beneficial Reuse of Barnegat Inlet Dredging

This strategy intends to beneficially reuse sediment dredged from the Barnegat Inlet authorized navigation project for the Long Beach Island Shore Protection Project. This strategy is in direct concurrence with the Regional Sediment Management Initiative.

Maintenance dredging of the federally-authorized project at Barnegat Inlet is required approximately one to four times per year to maintain safe navigation. The cumulative volume of material removed from Barnegat Inlet since 1986 is shown in Figure 158. Each black dot in the figure represents a dredging event, and shows the cumulative volume dredged as a function of time. The blue line in the figure represents a linear fit to the data and provides an average dredge quantity of approximately 240,440 cy per year for the period 1986 to 2009.

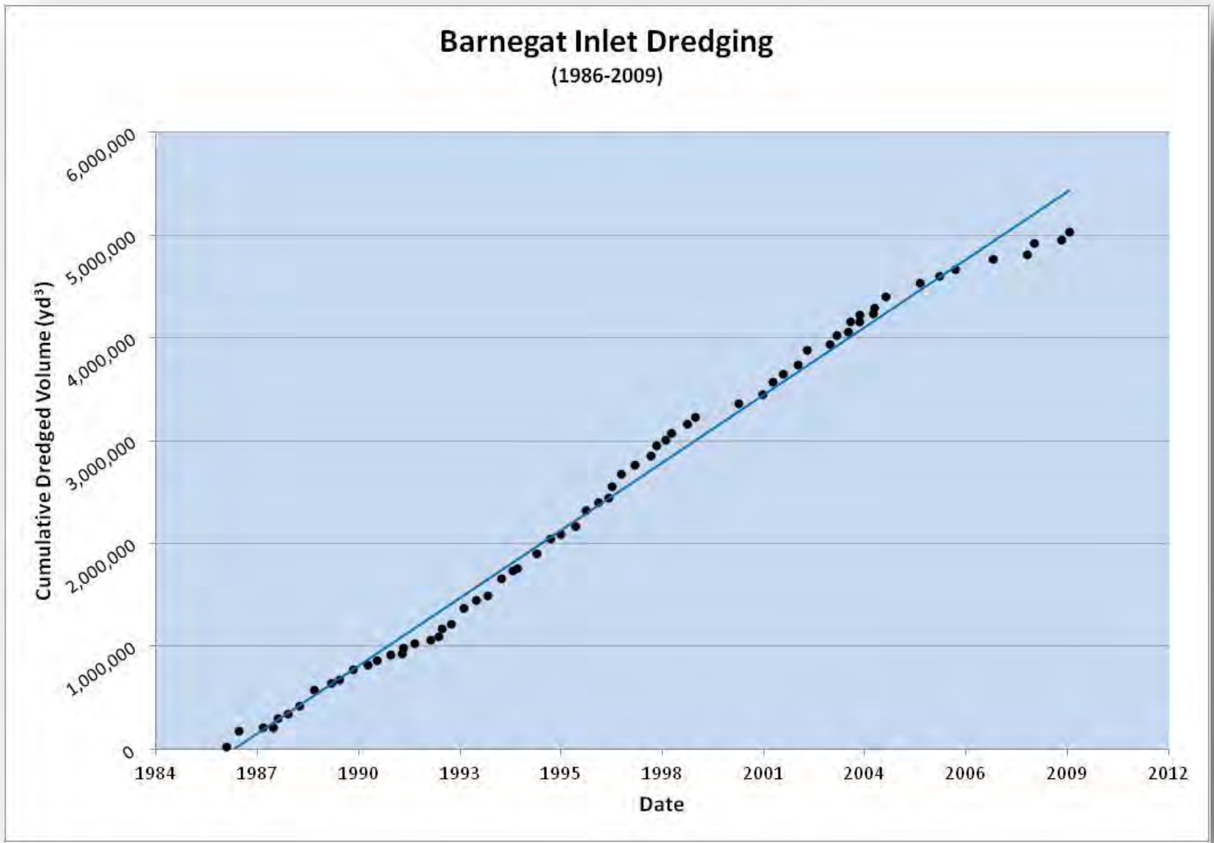


Figure 158. Cumulative dredge volume removed from Barnegat Inlet from 1986 to 2009.

Recent dredge requirements over the past seven years have been lower, averaging approximately 129,750 cy/yr. The reduction in dredging can be attributed to reconstruction of the south jetty which minimized sand transport into the channel. The inlet reconfiguration also altered the flow dynamics, which deflated the flood tidal delta and allowed incoming sediment to move further into Barnegat Bay. The change in transport patterns caused reduced infilling and less dredging.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this strategy would result in a cost savings of approximately $109 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments. This assumes periodic nourishment is conducted every 7 years for Long Beach Island. This analysis also assumes that:

- the more recent dredge rate of 129,750 cy/yr and frequency (averaging approximately 2 times a year) at Barnaget Inlet continues;
- the dredged material is beach compatible;
- the dredged material can be placed directly on the beach, such that adequate storm damage protection can be provided; and
- any incremental cost of placing the material on the beach is relatively insignificant, since periodic nourishment would also be required concurrently with the inlet dredging to supplement the needed quantity of material.

Maintenance dredging at Barnegat Inlet since 1992 has been conducted almost exclusively with the USACE hopper dredge, the Currituck. Dredged materials have been placed in the nearshore zone south of the inlet near the community of Barnegat Light. Although this approach helps to maintain navigational safety in the inlet, and potentially makes sand available for onshore transport to Long Beach Island, the beneficial reuse could be enhanced by directly placing the dredged material on beaches south of Barnegat Inlet. This strategy would require hydraulic dredge equipment to move sand from the channel to the beach nourishment site.

Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

This strategy reduces the overall offshore borrow site sediment needs (approximately 7 million cy less over 50 years) while supporting the overall RSM initiative.

There are two pathways to implement this strategy assuming the dredged material is suitable for direct placement on the beach. The first would involve developing a beneficial reuse project using the Long Beach Island authorities for implementation. However, the authority to construct the project does not include a provision for this type of beneficial reuse. As such, the project authorization would likely have to be modified to include this and the project cost sharing adjusted to reflect a new purpose. All the attendant documentation would have to be developed to accomplish this, as well as a new PCA reflecting today's model agreement would have to be negotiated and signed. The second way to implement this is to use the existing Barnegat Inlet navigation project authorities. Under the existing authorization, if the material is suitable, the federal government could request that the material be placed directly on the beach. Permits are required to do so, but they can be obtained under the authorized navigation project. If there is a cost differential to the navigation project, the State would likely have to pay the difference.

Although, implementation of this strategy has limited additional constraints, sediment compatibility of the Barnegat Inlet dredge material has to be determined.

Table 90 presents a summary of the criteria evaluated for the beneficial reuse of Barnegat Inlet strategy and ranks it as a high priority with a Tier level of 2. As long as the sediment dredged is compatible for beach nourishment or nearshore placement and the quantity of dredging remains approximately the same as historic levels, this strategy should be further pursued since it is directly in line with RSM strategies and initiatives. Additionally, every effort should be made to coordinate inlet dredging (navigation project) with the periodic nourishment (shore protection project) to minimize dredge mobilization costs.

In addition, further investigations should be performed to identify the optimum location along Long Beach Island for placement of the dredged material. Wave transformation and sediment transport modeling could be utilized to identify the migration area of the nodal zone, and beneficial reuse planned for beaches outside (south) of the migration area. This strategy would minimize transport of sediment back towards Barnegat Inlet, and would reduce demands on offshore borrow sites for shore protection at Long Beach Island.

Table 90. Beneficial Reuse of Barnegat Inlet Matirial Strategy Summary.

Criteria	Summary
1. Authorization	Implement under federally-authorized navigational project
2. Constraints	Incremental cost increases for dredge material placement
3. Cost Savings	$109 million over 50-year time horizon
4. Service Life	No change to existing service life of shore protection project or navigational dredging
5. Other Benefits	Reduced offshore sediment source requirements
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Evaluate sediment compatibility obtain permits for placement of dredged material on beaches; Evaluate best placement locations along Long Beach Island

B. *Borrow Area Expansion at Little Egg Inlet*

This strategy intends to expand the inlet borrow areas atLittle Egg Inlet to enhance shore protection capabilities at Long Beach Island. The intent of the strategy is to reduce operational costs of nourishment for the shore protection project, and reliance on offshore borrow sites by utilizing sediment that is already in the regional system.

There is a history of dredging along the Intracoastal Waterway in the vicinity of Little Egg Inlet, but no record of dredging the inlet itself. Sand used for beach replenishment along Long Beach Island has historically come from offshore borrow sites (and limited trucking). Historical records indicate that beneficial reuse of Little Egg Inlet material has not been considered in the past, possibly due to the distance between the inlet and the nearest nourishment site.

For the current analysis, an investigation of historical aerial photography suggested that the shoals of Little Egg Inlet are substantial but migratory. Therefore, potential borrow areas are delineated based on the location of the ebb and flood tidal shoals in the latest available imagery (Google Earth, June 2011). Figure 159 delineates these potential borrow areas.

The flood tidal shoal at Little Egg Inlet is approximately 95 acres. At an average thickness of 10 to 15 feet, the flood tidal shoal borrow area could yield between 1,540,000 and 2,310,000 cy. The ebb tidal shoal at Little Egg Inlet is approximately 363 acres. At an average thickness of 10 to 15 feet, the ebb tidal shoal borrow area could yield between 5,860,000 and 8,790,000 cy.

These expanded borrow areas within Little Egg Inlet could be authorized by collecting necessary data and obtaining necessary permits using the coastal projects authorities to implement.

Figure 159. Potential borrow areas (green) at the ebb and flood tidal shoals of Little Egg Harbor Inlet.

The primary constraints with the development of borrow sites in Little Egg Inlet are environmental. Establishing borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Analysis of the impacts to wave, tidal currents, and sediment transport processes also are needed, especially to determine the potential impact from removing of a significant portion of the ebb or flood tidal shoals. Although, the physical and environmental delineation would add cost, once permitted, the construction costs associated with obtaining the nearshore material are significantly lower than for upland material or offshore sources due to the close proximity of the inlet material to the beach nourishment project.

Table 91 presents a summary of the criteria evaluated for the beneficial reuse of Little Egg Inlet material and ranks it as a high priority for this region with a Tier level of 2 since material has not historically been removed from this inlet. Next steps for this strategy would be to initialize any studies and surveys needed to expand the inlet borrow sites.

Table 91. Borrow Area Expansion at Little Egg Inlet Strategy Summary.

Criteria	Summary
1. Authorization	Requires modification of authority to include beneficial re-use of inlet material
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Some cost savings expected due to close proximity of borrow sites
4. Service Life	No change to shore protection service life
5. Other Benefits	Reduced offshore borrow site reliance
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Initiate studies and surveys

C. *Offshore Borrow Area Establishment or Expansion*

This strategy intends to explore the potential benefits of expanding current offshore borrow areas or establishing new ones over a 50 year time horizon, the remaining sediment needs at Long Beach Island include approximately 2,600,000 cy to complete initial construction and 13,300,000 cy for periodic nourishment. To date sediment sources for construction and nourishments have been from offshore of Long Beach Island. Authorized projects have been completed in Surf City, Ship Bottom and Harvey Cedars; the authorized project in Brant Beach is under construction in 2012. Southern portions of the authorized project have not been constructed. Currently, the authorized and permitted borrow sites in the vicinity of Long Beach Island (offshore borrow sites A, D1, and D2) provide adequate material to construct the initial and periodic nourishments. Therefore, there is not an immediate need for additional sediment sources. However, additional sources may be needed in the long-term or for storm response, and additional borrow areas could be identified offshore.

This strategy is not specifically geared towards providing a cost savings, but rather at maintaining current operations costs since upland sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., track traffic, road repairs, time of construction, etc.).

Potential additional sediment sources in the vicinity of Long Beach Island include:

1. Unquantified reserves at borrow area MMS-C1,
2. Approximately 3,640,000 cy at borrow area B, and
3. Approximately 9,350,000 cy at borrow area E.

This strategy can be accomplished under the existing project authorities as the provision of borrow areas for the life of the project is part of the authorization. It would likely require cost sharing at the same level as the project, and appropriate studies and environmental clearances would be needed. Construction funds can be used to accomplish this as it is a part of the process of continuing construction.

The primary constraints with expansion or establishment of offshore borrow sites are environmental. Establishing expanded borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave and sediment transport processes also are needed. The physical and environmental delineation would add cost; however, once permitted, the construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 92 presents a summary of the criteria evaluated for the offshore borrow area expansion and establishment strategy and ranks it as a high priority for this region with a Tier level of 1. Next steps for this strategy would be to initialize any studies and surveys needed to expand or establish new borrow sites for this region, and coordinate with BOEM for any potential federal waters borrow sites.

Table 92. Offshore Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Initiate studies and surveys; Coordinate with BOEM

D. Sediment Bypassing of Barnegat Inlet

This strategy would involve implementation of sediment bypassing methodology to move sediment from the northerly updrift beaches of Barnegat Inlet to nourish beaches downdrift of the inlet. A number of previous studies evaluated conceptual designs and methodologies for bypassing sediment around Cape May Inlet (USACE, EM 1110-2-1616, 1991; U.S. Army Engineer District, Philadelphia, 1987; USACE, 2004), and this information is used to conduct a similar assessment for Barnegat Inlet bypassing.

For this preliminary analysis, it is assumed that a semi-mobile bypass system would be installed to bypass sand around Barnegat Inlet. Additional alternatives (e.g., a floating dredge plant) could also be considered in a more detailed analysis of potential bypassing approaches if this strategy is further pursued. However, in this preliminary analysis, a sediment bypassing plant (similar to the system operated at Indian River Inlet in Delaware – see Figure 160) is considered as a baseline approach to potential bypassing. The USACE Philadelphia District (2004) developed an initial cost estimate for a bypass system. The cost estimate included initial construction costs, Operation and Maintenance (O&M) costs for the sand bypassing plant, Engineering and Design (E&D) costs, Construction Management (S&A) costs, as well as a contingency factor. Detailed breakdown of the cost estimate can be found in the USACE (2004) document. These values were used in the current analysis as well. The following cost estimates were utilized and are intended to provide a first-order estimate of cost impacts:

- An initial construction cost of $6,345,000 for the bypass plant
- O&M costs of $613,000 annually. Bypassing efforts would take place from September to April, 5 days per week, 6 hours per day, bypassing approximately 130,000 to 240,000 cy/yr, as long as the sediment is available.
- Replacement of the pump system every 12-13 years at a fixed cost of $600,000
- Refurbishing/replacement of the system at year 25 for $6,345,000

Based on the historical dredging of Barnegat Inlet, it is expected that there would be approximately 130,000 to 240,000 cy/yr (as presented in Strategy A) of material deposited in Barnegat Inlet. The analysis assumes that this material could be intercepted on the updrift shoreline prior to getting into the inlet. There is also a potential for additional sediment to be extracted since there are larger shoals that may be developing in the inlet and areas along the shoreline that have extensive sedimentation (updrift fillet).

Figure 160. Indian River Inlet, Delaware fixed bypassing system (Photo courtesy of Tony Pratt, DNREC).

This strategy would result in approximately $64 million in savings over a 50-year time horizon assuming that approximately 130,000 cy/yr was available for bypassing.

In addition, this strategy provides additional benefits, including, but not limited to:

- Reduced reliance on offshore borrow sites, of which currently permitted borrow sites are becoming depleted
- Minimizing environmental impacts to offshore borrow sites
- Promoting RSM approach through appropriate redistribution of sediment already in the littoral system
- Reduced sediment surplus at in updrift areas

This would not require additional authority if pursued under the concept of value engineering. If it is cost effective, then whatever environmental clearances are needed and the actual cost to construct it could be accomplished with construction funds. Prior to implementation, however, significant environmental clearances would likely be required. Impacts and potential mitigation for this sensitive area would need to be evaluated in more detail prior to obtaining permits for project implementation.

Table 93 presents a summary of the criteria evaluated for the sediment bypassing strategy and ranks it as an intermediate to high priority and a Tier level of 2. The strategy does have significant other benefits (e.g., reduce or eliminate dependence on offshore sediment sources, reduce sediment surplus on updrift beaches) and the approach takes advantage of beach compatible sediment already in the system. Next steps would involve a more detailed study of potential impacts caused by fillet extraction on adjacent beaches, finalization and design, and determining the right authorization approach and pathway to implement the bypassing project.

Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Table 93. Sediment Bypassing Strategy Summary.

Criteria	Summary
1. Authorization	Value engineering could be applied to implement
2. Constraints	Significant environmental questions may remain for impacts on extraction
3. Cost Savings	$64 million over 50-year time horizon
4. Service Life	No change to existing service life of shore protection project
5. Other Benefits	Reduce offshore sediment source requirements and environmental impacts; Improved management of sediment in littoral system; Reduced sediment surplus updrift
6. Priority	Intermediate to High
7. Tier Level	Tier 2
8. Next Steps	More detailed study of potential impacts caused by fillet extraction; Finalize and design project.

E. Develop Nourishment Priorities with Strategic Coastal Structure Modifications

This strategy intends to prioritize projects to focus on the most vulnerable developed areas. On average, Long Beach Island is eroding at 1.6 ft/yr (0.5 m/yr), except for select accreting areas immediately north of Little Egg Inlet and from Barnegat Light to Barnegat Inlet in the North. This rate is based on 30 years of recent data and therefore reflects the anthropogenic influence (nourishment) on the shoreline. Despite nourishment efforts, the project area still has erosional hotspots. There are areas within the authorized project that are experiencing higher than average shoreline retreat (Figure 161), with recession rates up to 6.1 ft/yr (1.9 m/yr). These erosionial hot spots are not uncommon, and have been known to exist along Long Beach Island, with documented occurrences in the 1999 Barnagat Inlet to Little Egg Inlet Final Feasibility Report (USACE, 1999) at Surf City, Brant Beach, Ship Bottom, and Beach Haven.

Due to the large scale of this nourishment project (7.4 million cy), it is expected that funding for the full authorized projects, as well as the subsequent periodic nourishments may be difficult to consistently acquire. Therefore, this strategy includes prioritizing nourishment efforts to vulnerable developed areas that have shown the highest erosion rates. Completing these smaller priority based nourishments may be more manageable from both an operation and fiscal basis. As such, rather than wait for adequate funding to become available for the entire authorized project, critical erosional areas could be addressed more readily as funding becomes available.

Figure 161. Erosional hotspots areas (shown in red) along Long Beach Island.

These identified priority areas have to be sufficient in magnitude and length such that the smaller nourishment projects would still provide a reasonable service life and protection ability. For example, the long term performance of a beach nourishment project depends on the local wave climate, storm frequency and intensity, the characteristics of native and fill sediments, and the physical shoreline length of the project. Longer projects have a longer longevity as the nourishment functions more effectively. Utilizing the local wave climate information (WIS hindcast data) and some preliminary analysis of beach nourishment performance and sediment dispersion, a minimum length of 1.5 miles was the determined as a reasonable length for an adequately performing nourishment project.

Using the 1.5 mile criterion, historical shoreline change rates by station were investigated and five high priority locations located within the currently authorized project area were identified for potential priority nourishment projects. Therefore, the northern (Barnegat Light) and the southern terminus of Long Beach Island were excluded from this assessment. While ultimately a number of social, political, economic, and environmental factors may contribute to a final decision on potential nourishment projects. For this preliminary assessment, only historical erosion rate was used.

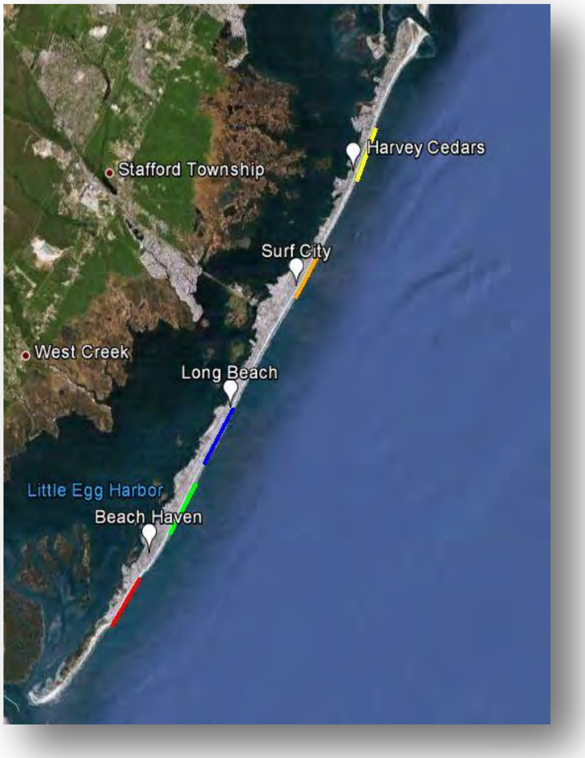


Figure 162. Identified priority areas within the Long Beach Island authorized project extent.

Five high priority locations were identified as potential priority nourishment areas within the authorized project extent, as shown in Figure 162. The sections south of Beach Haven (red) and at Surf City (orange) are retreating at an average rate of approximately 3.8 ft/yr and were selected as the highest priority areas for nourishment. The shoreline at Harvey Cedars (yellow) has a shoreline erosion rate of approximately 3.1 ft/yr and the shoreline just south of Long Beach (blue) has an erosion rate of 2.9 ft/yr. The shoreline north of Beach Haven (green) is retreating at an average rate of 2.4 ft/yr. Assuming that a beach nourishment template similar to the authorized template would be applied at each priority nourishment area, an average volume of 83 cy per linear foot of beach was assumed. Estimated project costs were calculated using $15/cy for sediment and $2,000,000 for combined mobilization/demobilization costs of dredging operations per project. Table 94 provides the estimated cost for each priority project, and also includes the historic erosion rate and project length.

Table 94. Priority nourishment areas on Long Beach Island.

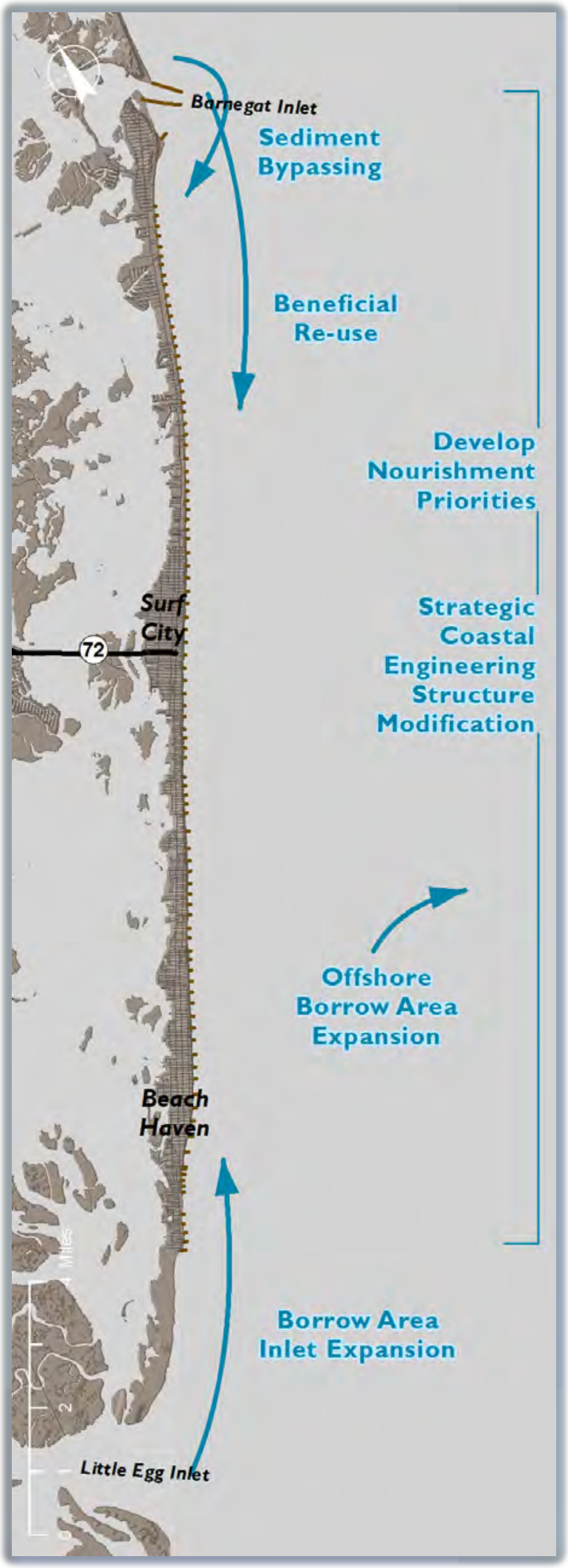
Location	Erosion Rate (ft/yr)	Length (mi)	Estimated Cost (Millions)
Beach Haven (South)	-3.8	1.55	$12.2
Surf City	-3.8	1.49	$11.8
Harvey Cedars	-3.1	1.52	$12.0
Long Beach (South)	-2.9	1.77	$13.6
Beach Haven (North)	-2.4	1.55	$12.2

This strategy further recommends consideration of using groins to prolong the life of the proposed strategic nourishments in certain areas. This would require additional study and engineering assessments to evaluate utility, function, and value of potential structures to help retain sediment at strategic locations.

Table 95 presents a summary of the criteria evaluated for the development nourishment priorities strategy and ranks it as a high priority and a Tier level of 1. A Tier level of 1 was assigned since the USACE currently does some segmented nourishments in areas along Long Beach Island currently (i.e., the full authorized initial nourishment has never been constructed).

Table 95. Nourishment Prioritization Strategy Summary.

Criteria	Summary
1. Authorization	Use existing authorization to implement via value engineering
2. Constraints	Minimal
3. Cost Savings	Not specifically evaluated.
4. Service Life	Reduced overall service life compared to full project
5. Other Benefits	More continual sediment supply to beaches versus waiting for full funding
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Could be implemented as needed, more study required for potential use of strategic structures



Summary

This section presents a brief summary of all the strategies presented for Long Beach Island. The focus is on the potential cost savings and priority levels to assist in the identification and selection of strategies that could be implemented immediately and/or further pursued to more cost effectively manage sediment within the project area.

Table 96 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies presented in Table 96 are listed in order of priority and estimated ease of implementation.

Table 96. Long Beach Island Strategy Summary.

Strategy	Prioritization	Tier
A. Beneficial Reuse: Barnegat Inlet	High	2
E. Nourishment Prioritization	High	1
B. Inlet Borrow Area Expansion at Little Egg Inlet	High	2
C. Offshore Borrow Site Expansion	High	1
D. Sediment Bypassing at Barnegat Inlet	Intermediate to High	2

ISLAND BEACH

Project Description

The Manasquan Inlet to Barnegat Inlet Shore Protection Project was authorized for construction by the Water Resources Development Act of 2007. The project is located on the Atlantic coast of Ocean County, extending approximately 14 miles from Point Pleasant Beach to Island Beach State Park. The authorized project provides a protective beach and dune system to reduce impacts from coastal erosion and storms. Sand dredged from offshore borrow sites provides the source of nourishment. Periodic nourishment every 4 years is included to maintain the design template.

The design berm is 100 ft wide at Seaside Heights and northern Point Pleasant Beach, narrowing to 75 ft wide at all other locations. The berm elevation is 11.5 ft NAVD at northern Point Pleasant Beach and 8.5 ft NAVD at all other beaches. The berm extends seaward at a slope of 1V:10H to meet the existing nearshore profile. The dune crest is 25 ft wide with side slopes of 1V:5H. The elevation of the dune crest is 18 ft NAVD at Seaside Heights and northern Point Pleasant Beach, and 22 ft NAVD at the other beaches. The total length of fill is 13.7 miles. The project authorizes an initial construction volume of 10,689,000 cy of sand with periodic nourishment of 961,000 cy every 4 years, using sand dredged from offshore borrow sites (Areas A and B). Dune grass plantings over 175 acres and 206,000 ft of sand fencing are also included. Figure 163 shows the components of the authorized project.

Figure 163. Manasquan Inlet to Barnegat Inlet Authorized Shore Protection Project.

Project History

The project area between Manasquan and Barnegat Inlets is vulnerable to storm and wave-induced erosion, as well as inundation during hurricanes and northeasters. Severe storms in recent years have caused a reduction in overall beach height and width. This has increased the potential for catastrophic damages to beach front communities during storms.

Despite vulnerability of the project area, beach and/or dune restoration has not historically been performed by Federal or State stakeholders. Local municipalities have placed sand at various times to mitigate for beach and dune loss after storms, and to maintain a minimum level of protection. Although these actions have provided temporary protection to individual communities, they have not addressed the ongoing problems of coastal erosion and storm damage vulnerability.

Shore protection structures between Manasquan and Barnegat Inlets include bulkheads, seawalls, and multiple groins. Seaside Park is protected by a 1,350 ft long bulkhead and Bay Head has a 4,300 ft long seawall. A total of sixteen (16) groins, constructed of timber and stone are also located along the beach. Dunes extend for most of the length of the shoreline with varying heights, the exceptions being at Seaside Heights and Point Pleasant Beach, which have no dunes.

The Manasquan Inlet to Barnegat Inlet Shore Protection Project was authorized in 2007 to mitigate long-term erosion and to provide protection for developed areas of the barrier beach. Initial construction is dependent upon future funding. The next steps toward initial construction include completion of the Limited Reevaluation Report, execution of a Project Partnership Agreement, acquisition of necessary real estate, completion of plans and specifications, and contractor solicitation and award.

Project Observations

Until initial construction of the Manasquan Inlet to Barnegat Inlet Shore Protection Project is complete, potential damages during storms will be a concern.

Potential Strategies

This section presents the potential strategies for the Island Beach Shore Protection Project that are intended to provide improved project performance, cost savings, or other benefits. These strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. In addition, some of the strategies include a first-order technical analysis to evaluate the relative merit of the proposed strategy. These analyses are not intended to be detailed assessments and include some assumptions and simplifications. Rather, the analyses presented are geared towards providing a preliminary estimate of the potential benefits that may be realized if the strategy is implemented. In other words, the analysis presented herein can be used as an initial screening tool to determine if a strategy warrants further consideration. For some strategies, a more detailed analysis may be required if the strategy is more formally pursued.

A. Beneficial Reuse of Manasquan Inlet Material

This strategy intends to beneficially reuse sediment dredged from the Manasquan Inlet authorized navigation project for the Island Beach shore protection project. This strategy is in direct concurrence with the Regional Sediment Management Initiative. Manasquan Inlet material is also viable for use in the Sea Bright to Manasquan shore protection project, and due to the prevailing alongshore sediment transport in this area, would likely be a priority for the beneficial re-use material (as presented in the Sea Bright to Manasquan section). However, if priorities or conditions change in the future, the Island Beach area may also benefit from placement of Manasquan Inlet dredge material.

Maintenance dredging of the federally-authorized project at Manasquan Inlet is required approximately 1 to 1.5 times per year to maintain safe navigation. The cumulative volume of material removed from Manasquan Inlet since 1998 is shown in Figure 164. Each black dot in the figure represents a dredging event, and shows the cumulative volume dredged as a function of time. The blue line in the figure represents a linear fit to the data and provides an average dredge quantity of approximately 40,400 cy per year for the period 1989 to 2009.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this strategy would result in a cost savings of approximately $32 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments. This assumes periodic nourishment is conducted as every 4 years for Island Beach. This analysis also assumes that:

- the dredge rate of 40,400 cy/yr and frequency (averaging approximately every 1-2 years) at Manasquan Inlet continues;
- the dredged material is beach compatible;
- the dredged material can be placed directly on the beach, such that adequate storm damage protection can be provided; and
- any incremental cost of placing the material on the beach is relatively insignificant.

Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

This strategy reduces the overall offshore borrow site sediment needs (approximately 2 million cy less over 50 years) while supporting the overall RSM initiative.

There are two pathways to implement this strategy assuming the dredged material is suitable for direct placement on the beach. The first would involve developing a beneficial reuse project using the Island Beach authorization for implementation. However, the authority to construct the project does not include a provision for this type of beneficial reuse. As such, it would likely have to be modified to include this and the project cost sharing adjusted to reflect a new purpose. All the attendant documentation would have to be developed to accomplish this, as well as a new PCA reflecting today's model agreement would have to be negotiated and signed. The second way to implement this is to use the existing Manasquan Inlet navigation project authorities. Under the existing authorities, if the material is suitable, the federal government could request that the material be placed directly on the beach. Permits are required to do so, but they can be obtained under the authorized navigation project. If there is a cost differential to the navigation project, the State would likely have to pay the difference.

Although implementation of this strategy has limited additional constraints, sediment compatibility of the Manasquan Inlet dredge material has to be determined.

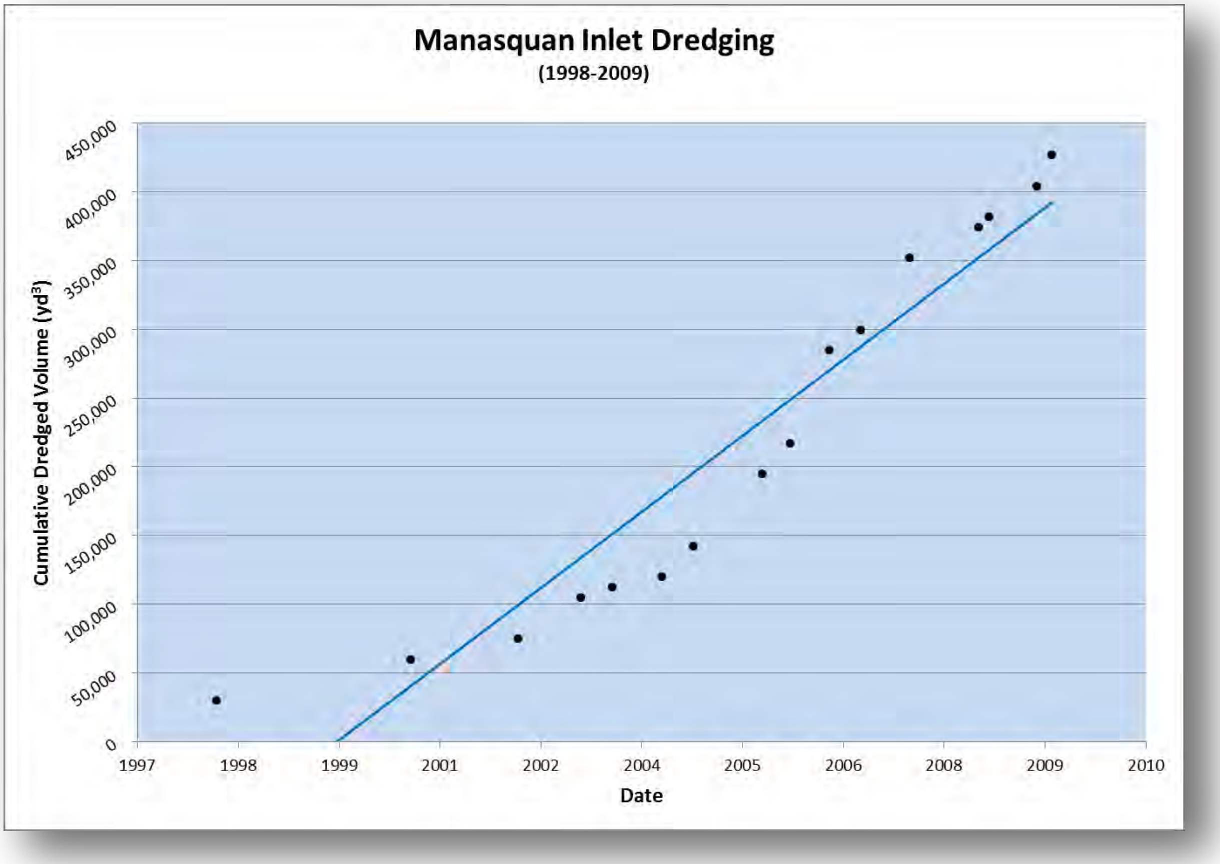


Figure 164. Cumulative dredge volume removed from Manasquan Inlet from 1998 to 2009.

Table 97 presents a summary of the criteria evaluated for the Manasquan Inlet beneficial reuse strategy and ranks it as a high priority with a Tier level of 2. As long as the sediment dredged is compatible for beach nourishment or nearshore placement and the quantity of dredging remains approximately the same as historic levels, this strategy should be further pursued since it is directly in line with RSM strategies and initiatives. Additionally, every effort should be made to coordinate inlet dredging (navigation project) with the periodic nourishment (shore protection project) to minimize dredge mobilization costs.

Table 97. Manasquan Inlet Beneficial Reuse Strategy Summary.

Criteria	Summary
1. Authorization	Implement under federally-authorized navigational project
2. Constraints	Incremental cost increases for dredge material placement
3. Cost Savings	$32 million over 50-year time horizon
4. Service Life	No change to existing service life of shore protection project or navigational dredging
5. Other Benefits	Reduced offshore sediment source requirements.
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Evaluate sediment compatibility obtain permits for placement of dredged material on beaches

B. Offshore Borrow Area Establishment or Expansion

Initial construction of the shore protection project will require approximately 10,690,000 cy. Over a 50 year time horizon, the periodic nourishment sediment needs at Island Beach are approximately 11,530,000 cy. Overall, the Island Beach project requires approximately 22,220,000 cy over a 50-year time horizon (including both the initial construction and periodic nourishments).

This strategy is not specifically geared towards providing a cost savings, but rather at maintaining current operations costs since upland sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., track traffic, road repairs, time of construction, etc.).

The original offshore borrow sites (A,B) for the Island Beach authorized shore protection project have approximately 17,500,000 cy of material. As such, there is a deficit of approximately 4,720,000 cy for completion and renourishment of the project.

Continued expansion of existing sites or searches for new borrow sites is needed for this region. For example, potential sources have been proposed at Manasquan Inlet, and at offshore sites F1 and F2. Potential searches in Federal waters also may be warranted through cooperation with the Bureau of Ocean Energy Management, (BOEM). USACE estimates that sand resources in Federal waters near the project are 6,000,000 cy.

This strategy can be accomplished under the existing project authorities as the provision of borrow areas for the life of the project is part of the authorization. It would likely require cost sharing at the same level as the project. Appropriate studies and environmental clearances would be needed.

The primary constraints with expansion or establishment of offshore borrow sites are environmental. Establishing offshore borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave and sediment transport processes also are needed. The physical and environmental delineation would add cost; however, once permitted, the construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 98 presents a summary of the criteria evaluated for the offshore borrow area expansion and establishment strategy and ranks it as an intermediate to high priority with a Tier level of 1. It is recommended that this strategy is pursued in advance of potential need, such that the borrow areas are established for future use. Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted offshore sites available if needed for storm events or unforeseen circumstances is good planning. Next steps for this strategy would be to initialize any studies and surveys needed to expand or establish new borrow sites for this region, which has a known deficit and coordinate with BOEM for any potential federal waters borrow sites.

C. Develop Nourishment Priorities with Strategic Coastal Structure Modifications

On average, the Island Beach shoreline within the authorized project area is eroding at a rate of 2.0 ft per year. Erosion in some areas (Figure 165) can be as great as 6.2 ft per year.

Table 98. Offshore Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	Intermediate to High
7. Tier Level	Tier 1
8. Next Steps	Initiate studies and surveys. Coordinate with BOEM

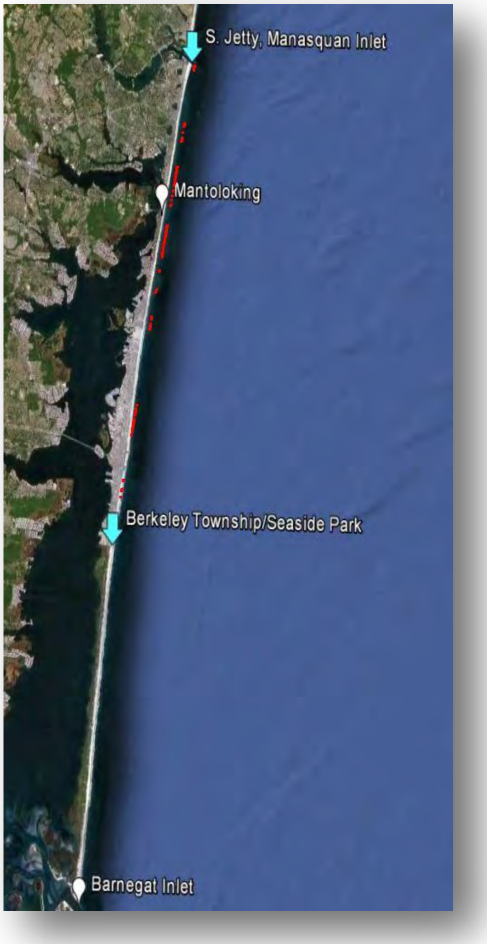


Figure 165. Erosional hotspots (red areas) in Island Beach authorized shore protection project area.

Due to the large scale of this nourishment project (10.7 million cy), it is expected that funding for the full authorized project, as well as the subsequent periodic nourishments may be difficult to consistently acquire. Therefore, this strategy includes prioritizing nourishment efforts to vulnerable developed areas that have shown the highest erosion. Completing these smaller priority based nourishments may be more manageable from both an operation and fiscal basis. As such, rather than wait for adequate funding to become available for the entire authorized project, critical erosional areas could be addressed more readily as funding becomes available.

These identified priority areas have to be sufficient in magnitude and length such that the smaller nourishment projects would still provide a reasonable service life and protection ability. For example, the long term performance of a beach nourishment project depends on the local wave climate, storm frequency and intensity, the characteristics of native and fill sediments, and the physical shoreline length of the project. Longer projects have a longer longevity as the nourishment functions more effectively. Utilizing the local wave climate information (WIS hindcast data) and some preliminary analysis of beach nourishment performance and sediment dispersion, a minimum length of 1.5 miles was determined as a reasonable length for an adequately performing nourishment project.

Using the 1.5 mile criterion, historical shoreline change rates by station were investigated and five high priority locations located within the currently authorized project area were identified for potential priority nourishment projects. While ultimately a number of social, political, economic, and environmental factors may contribute to a final decision on potential nourishment projects. For this preliminary assessment, only historical erosion rate was used.

Two critically eroding shoreline segments (excluding undeveloped areas south of Berkeley Township) were identified within the Island Beach project area: at Seaside Heights and in the vicinity of Mantoloking (Figure 166).

Figure 166. The two identified critically eroding areas within the Island Beach authorized project areas. The higher priority area is marked in red.

Assuming that a beach nourishment template similar to the authorized template would be applied at each priority nourishment area, an average volume of 140 cy per linear foot of beach was estimated. Estimated project costs were calculated using $15/cy for sediment and combined mobilization/demobilization costs of dredging operations of $2,000,000 per project. Table 99 provides the estimated cost for each priority project, and also includes the historic erosion rate and project length.

Table 99. Priority nourishment areas on Island Beach.

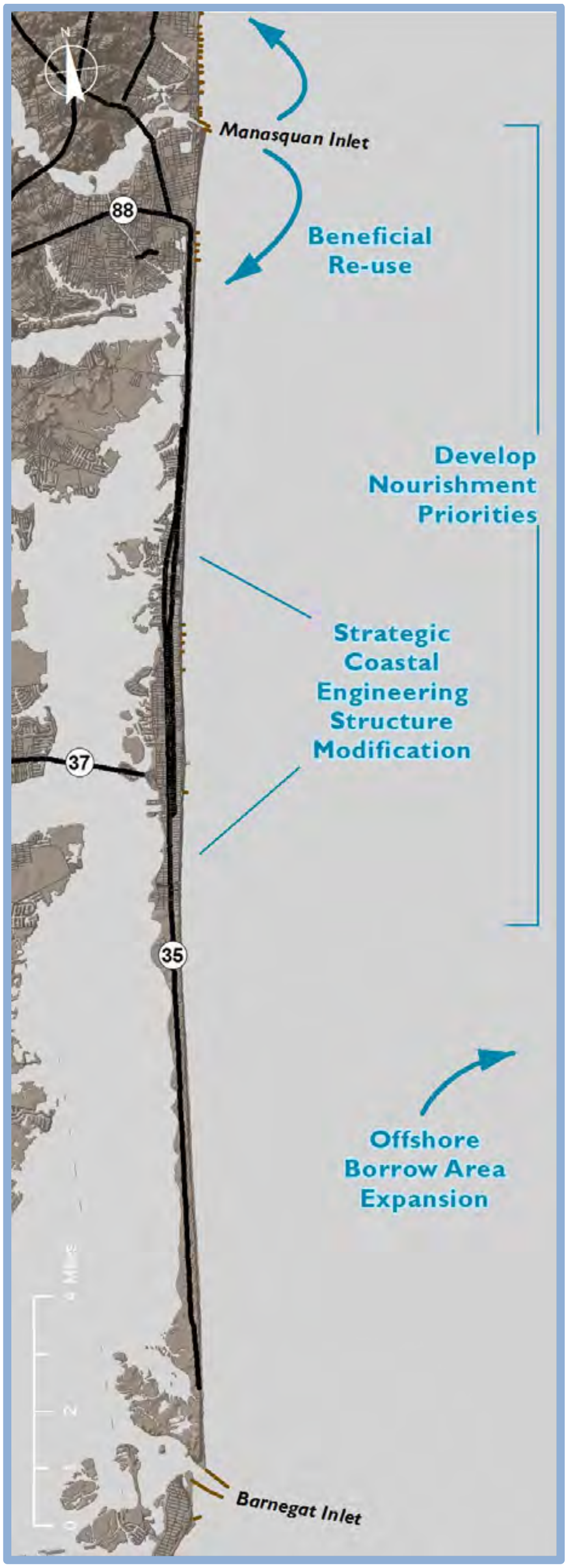
Location	Erosion Rate (ft/yr)	Length (mi)	Estimated Cost (Millions)
Mantoloking (Lyndhurst to Curtis Point)	-3.2	3.9	$47.4
Seaside Heights	-2.9	1.4	$19.0

This strategy also recommends using groins to prolong the life of the proposed strategic nourishments in certain areas. This would require additional study and engineering assessments to evaluate utility, function, and value of potential structures to help retain sediment at strategic locations.

Table 100 presents a summary of the criteria evaluated for the developing nourishment priorities strategy and ranks it as an intermediate priority with a Tier level of 1. A Tier level of 1 was assigned since the USACE currently does some segmented nourishments in other areas of the coastline.

Table 100. Developing Nourishment Priorities Strategy Summary.

Criteria	Summary
1. Authorization	Use existing authorization via value engineering
2. Constraints	Minimal
3. Cost Savings	Not specifically evaluated
4. Service Life	Reduced overall service life compared to full project
5. Other Benefits	Continual sediment supply to beaches
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Could be implemented as needed, more study required for potential use of strategic structures



Summary

This section presents a brief summary of all the strategies presented for Island Beach. The focus is on the potential cost savings and priority levels to assist in the identification and selection of strategies that could be implemented immediately and/or further pursued to more cost effectively manage sediment within the project area.

Table 101 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies presented in Table 101 are listed in order of priority and estimated ease of implementation.

Table 101. Island Beach Strategy Summary.

Strategy	Prioritization	Tier
A. Beneficial Reuse: Manasquan Inlet	High	2
B. Offshore Borrow Site Expansion	Intermediate to High	1
C. Nourishment Prioritization	Intermediate	1

SEA BRIGHT TO MANASQUAN

Project Description

The Sandy Hook to Barnegat Inlet, Sections I and II – Sea Bright to Manasquan Shore Protection Project was authorized for construction by the Water Resources Development Act of 1992. The project consists of 21 miles of shoreline from the Township of Sea Bright to Manasquan Inlet in Monmouth County. The project provides beach restoration and storm damage protection to the highly populated communities and infrastructure along the northern New Jersey coastline. Section I extends for 12 miles from Sea Bright to Ocean Township, and Section II extends for 9 miles from Asbury Park south to Manasquan Inlet.

The northern portion of this project area (Section I) is comprised of a barrier spit complex where the shoreline is on a narrow strip of unconsolidated sand, which forms a peninsula between the ocean and bay environments. In contrast, the southern portion of the study area (Section II), including southern Monmouth Beach, Long Branch, Deal and Allenhurst, is classified as headlands, where the beaches are attached to the mainland. The entire coastal zone within this study area is heavily developed, and the peninsula area is fronted by a seawall with elevations ranging from 14 to 22 ft above MLW.

Periodic nourishment on a 6 year cycle is authorized to maintain the design template. The project also includes notching of existing stone groins and outfall pipe extensions. The design berm in Sections I and II is 100 ft wide at an elevation of 10 ft MLW. The onshore portion of the berm template has a slope of 1V:10H; the offshore slopes at 1V:35H to meet the natural grade of the profile. The design also calls for a 2 ft storm berm cap to be placed on top of the berm. The total length of fill in Section I is 11.83 miles, extending from Sea Bright to Deal Lake, with a total volume of 17,882,000 cy of sand authorized for initial construction of Section I. The total length of fill in Section II is 9.17 miles from Ashbury Park to Manasquan Inlet. Initial construction in Section II required 7,200,000 cy of sand.

Erosion and storm recession have drastically reduced the width of most beaches in the study area, which has increased exposure of the shore to storm damage. This has resulted in most of the shorefront property in Sea Bright and Monmouth Beach having no dry beach. With the exception of sand fillets south of groins, very little beach width remains in the southern section of the study area either. As erosion increases, public roads and utilities have become more susceptible to storm damage.

Project History

The project area consists of a heavily developed and a rapidly eroding shoreline. By 1988, virtually all of the protective coastal structures, including the massive sea walls and 103 groins, had deteriorated and became increasingly susceptible to storm damage as the beach continued to erode. A study comparing 1953 and 1985 hydrographic survey data indicated a loss of over 10 million cy of sediment between Sea Bright and Ocean Township (Atlantic Coastal of New Jersey Sandy Hook to Barnegat Inlet Beach Erosion Control Project Section I – Draft General Design Memorandum, 1988).

A number of beach nourishment projects were performed prior to authorization of Sandy Hook to Barnegat Inlet Shore Protection Project. First, between April 1962 and January 1963, an emergency beach restoration project involving approximately 1,443,000 cy of sand was constructed at Sea Bright and Monmouth Beach. The fill provided a beach slope of 1:20, but most of the fill was lost by 1988 due to fill incompatibility and long term erosion. Another beach nourishment project was undertaken in 1982-1983 by the New York District Corps of Engineers for the National Park Service at Sandy Hook. Approximately 2,385,000 cy of fill was dredged from the navigation channels and placed at the "critical zone" located at the southern end of Sandy Hook (Atlantic Coastal of New Jersey Sandy Hook to Barnegat Inlet Beach Erosion Control Project Section I – Draft General Design Memorandum, 1988).

Due to its length, when the Sandy Hook to Barnegat Inlet Shore Protection Project was authorized, the project area was divided into constructable reaches. Section I of the Sea Bright to Manasquan Shore Protection Project is separated into four construction contracts. Contracts 1A and 1B (Figure 167) were completed in November 1995 and December 1996, respectively. The Contract 1A project was 3.1 miles long and required 4.5 million cy, while the Contract 1B project was 2.4 miles long and required 3.8 million cy of sand. Contract 2 was completed in September 1999, extending 4.3 miles from the southern portion of Monmouth Beach into the city of Long Branch, to Lake Takanasee in South Long Branch, and requiring 4.3 million cy of sand. The award of Contract 3 has not occurred and is subject to easements from the non-federal sponsor. When awarded, Contract 3 will extend from Long Branch to Deal Lake.

The first placement of renourishment material for Sea Bright and Monmouth Beach began in May 2002, eight years after initial construction began in 1994. This indicates that the project is performing better than anticipated through the first renourishment cycle.

Section II is divided into two contracts (Figure 168). Contract 1 (the South Reach) was completed in August 1999. It extends 5.9 miles from Shark River Inlet to the Manasquan Inlet, and required 4.1 million cy of sand. Contract 2 (the North Reach) was completed in 2001, and extends 3.1 miles from Asbury Park to the Shark River Inlet. The 2001 Contract 2 project utilized 3.1 million cy of material. Construction of the first renourishment project for Section II, however, is currently unfunded and subject to funding availability in the future.

Table 102 presents a summary of the nourishments conducted between 1986 and 2003 for the Sea Bright to Manasquan area.

Figure 167. Sandy Hook to Barnegat Inlet Authorized Shore Protection Project – Part I.

Figure 168. Sandy Hook to Barnegat Inlet Authorized Shore Protection Project – Part II.

Table 102. Beach Nourishment Projects (1986-2003) from Sea Bright to Manasquan Inlet.*

Date	Volume (cy)	Location
1989-1990	2,889,000	Sandy Hook
1994	70,000	Section II – South Reach
1994-1995	4,600,000	Section I – Reach 1A
1995	3,800,000	Section I – Reach 1B
1997-1998	3,700,000	Section 1 – Reach 2
1997	4,100,000	Section II – South Reach
1997-1998	287,000	Sandy Hook
1998	600,000	Section I – Reach 1A
1999	3,100,000	Section II – North Reach
2000	225,000	Section II – North Reach
2002	1,125,000	Section I – Reach 1A
2002	750,000	Section I – Reach 1B
2002	300,000	Sandy Hook

** Numbers in table 102 from New York District sediment budget study Table 3A (USACE, New York District, 2006)*

Project Concerns

Since initial construction of the Sea Bright to Manasquan Shore Protection Project a number of observations have been made:

- Over the years, erosion has greatly reduced the ability of the shoreline to provide adequate protection from coastal storms, contributing to potential economic losses and the threat to human life and safety.
- The shoreline along the project area is heavily armored with sea walls and groins.
- The economy in the project area relies heavily on tourism and recreation, but the beaches are so thin that their use for recreation is severely limited.

Potential Strategies

This section presents the potential strategies for the Sandy Hook to Barnegat Inlet, Sections I and II – Sea Bright to Manasquan that are intended to provide improved project performance, cost savings, or other benefits. These strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. Some of the strategies include a first-order technical analysis to evaluate their relative merit. These analyses are not intended to be detailed assessments and include some assumptions and simplifications. These analyses provide a preliminary estimate of the potential benefits that may be realized if the strategy is implemented. In other words, the analysis can be used as an initial screening tool to determine if a strategy warrants further consideration. Some strategies may require a more detailed analysis if formally pursued.

A. Beneficial Re-use of Shark River Inlet Material

Prior to 2000, the ocean entrance to Shark River Inlet required minor, infrequent maintenance dredging approximately every 7 to 10 years. As part of the Sea Bright to Manasquan Inlet Beach Erosion Control Project, in 1997 the U.S. Army Corps of Engineers placed approximately 5.3 million cy of fine to medium sand to the south of Shark River Inlet (Table 102). During 1999-2000, another 3.1 million cy of sand was placed to the north of the inlet, and in the fall of 2002, another 225,000 cy of sand was placed north of the inlet (Table 102). Following these large-scale beach nourishment projects, Shark River Inlet began to experience rapid shoaling at the entrance, dramatically increasing channel maintenance dredging requirements. Longshore transport of the nourishment sand has caused growth of an ebb-tidal shoal at the entrance to the inlet. To maintain the entrance channel for navigation, dredging is now needed semi-annually, despite the initial prediction that sand placed as part of the adjacent shore protection projects would only increase the maintenance dredging to a 2 to 3 yr cycle (Beck, 2011).

The ebb shoal at the entrance to the inlet has continued to develop requiring frequent dredging. Most recently the navigation channel through the ebb shoal was dredged in 2011. The same area was also dredged in June 2010, and then approximately every 6 months going back to 2006. Each time, 20,000 to 25,000 cy of dredged material was placed north of the L-jetty as a near shore berm in approximately 10-14 ft of water. The maximum annual volume removed was 59,702 cy in 2008.

Therefore, since 2005, sediment has been dredged from Shark River Inlet in association with the Federal Navigation Project. Historically, the material from the inlet has not been directly placed on the beach and instead placed in a nearshore berm. Therefore, this strategy proposes the beneficial use of sediment dredged from the Shark River Inlet for the Sea Bright to Manasquan Shore Protection Project by placing material directly on the beach. This approach is in direct concurrence with the Regional Sediment Management Initiative.

The potential benefit of this strategy is assessed through evaluation of the value of using the navigational material beneficially versus extracting all the required nourishment sediment from offshore. To determine the average annual amount of material dredged from Shark River Inlet, the USACE annual reports were used to calculate the cumulative maintenance dredging. Figure 169 presents the cumulative sediment volume dredged in Shark River Inlet from 2005 to 2009. Each black dot in the figure represents a dredging event, and shows the cumulative volume dredged as a function of time. The blue line in the figure represents a linear fit to the data and provides an average dredge quantity of approximately 31,750 cy per year.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this strategy would result in a cost savings of approximately $26 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments. This assumes periodic nourishment is conducted as every 6 years for Sea Bright to Manasquan. This analysis also assumes that:

- As a conservative estimate, the historic rate of 31,750 cy/yr of dredging would be required for the navigational channel at Shark River Inlet;
- the dredged material is beach compatible;
- the dredged material can be placed in the littoral zone or directly on the beach, such that adequate storm damage protection can be provided; and
- any incremental cost of placing the material on the beach is relatively insignificant.

Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

Assuming the Sea Bright to Manasquan nourishment was completed entirely by offshore borrow site material, this strategy reduces the overall offshore borrow site sediment needs by approximately 1.5 million cy over 50 years.

Under the existing authorities, if the material is suitable, the federal government can request that the material be placed directly on the beach. Permits are required to do so, but they can be obtained under the authorized navigation project.

Implementation of this strategy has few additional constraints. Table 103 presents a summary of the criteria evaluated for the beneficial re-use of Shark River Inlet strategy and ranks it as a high priority with a

Tier level of 2. As long as the sediment dredged is compatible for beach nourishment or nearshore placement and the quantity of dredging remains approximately the same as historic levels, this strategy should be pursued and implemented since it is directly in line with RSM strategies and initiatives.

The placement location for this material should be further investigated and optimized to ensure that a majority of the sediment does not return to the inlet and the shoreline area with the greatest priority is nourished. The placement location may also be reevaluated on an annual basis.

Table 103. Beneficial Re-use Shark River Inlet Strategy Summary.

Criteria	Summary
1. Authorization	Implement under federally-authorized navigational project.
2. Constraints	Potential incremental cost increases for dredge material placement
3. Cost Savings	$26 million over 50-year time horizon
4. Service Life	No change to existing service life of shore protection project or navigational dredging
5. Other Benefits	Reduced offshore sediment source requirements.
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Evaluate sediment compatibility obtain permits for placement of dredged material on beaches

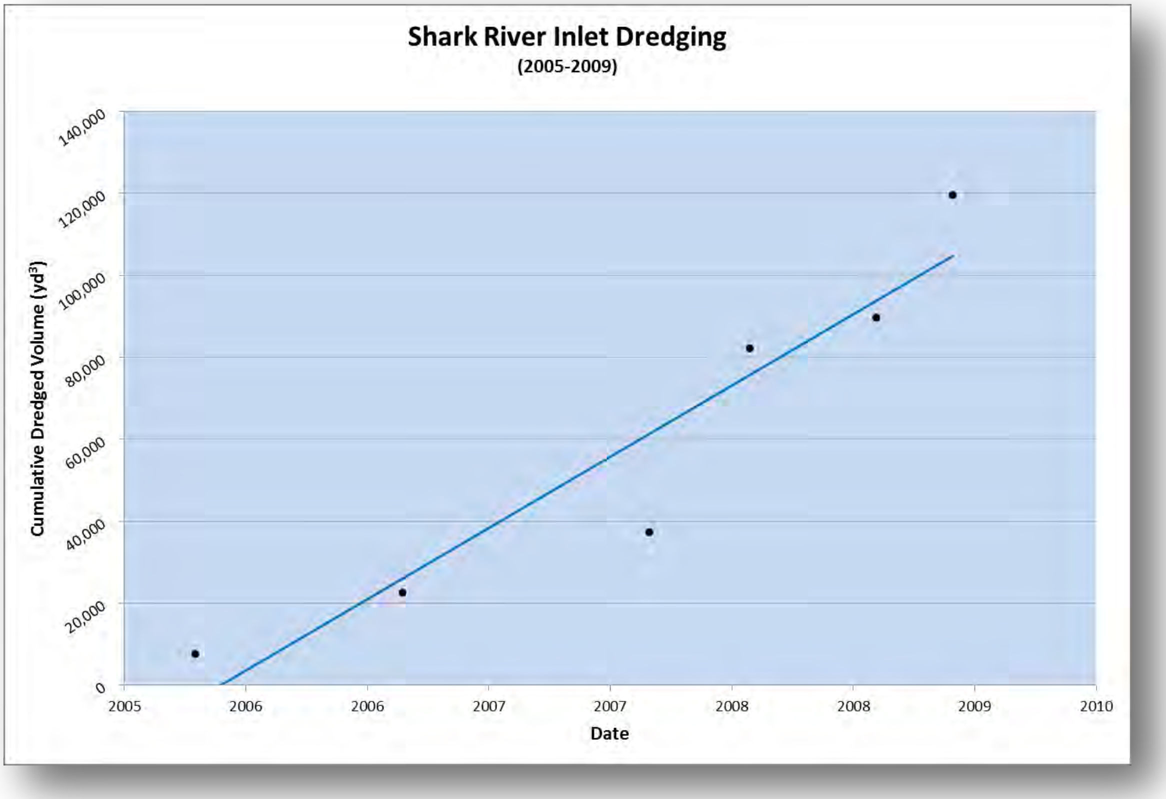


Figure 169. Cumulative dredge volume extracted from Shark River Inlet from 2005 to 2009.

B. Beneficial Re-use of Manasquan Inlet Material

This strategy intends to beneficially reuse sediment dredged from the Manasquan Inlet authorized navigation project for the Sea Bright to Manasquan shore protection project. Maintenance dredging of the federally-authorized project at Manasquan Inlet is required approximately 1 to 1.5 times per year to maintain safe navigation. The cumulative volume of material removed from Manasquan Inlet since 1998 is shown in Figure 170. Each black dot in the figure represents a dredging event, and shows the cumulative volume dredged as a function of time. The blue line in the figure represents a linear fit to the data and provides an average dredge quantity of approximately 40,400 cy per year for the period 1989 to 2009.

Using the same cost assumptions (dredge mobilization and demobilization costs of $2 million, and a unit price of $15/cy for sand), this strategy would result in a cost savings of approximately $33 million over a 50-year time horizon due to reduced volume requirements during periodic nourishments. This assumes periodic nourishment is conducted every 6 years for the Sea Bright to Manasquan shore protection project. This analysis also assumes that:

- the dredge rate of 40,400 cy/yr and frequency (averaging approximately every 1-2 years) at Manasquan Inlet continues;
- the dredged material is beach compatible;
- the dredged material can be placed directly on the beach, such that adequate storm damage protection can be provided; and
- any incremental cost of placing the material on the beach is relatively insignificant.
- Cost benefits of this strategy are compared to current operations and other strategies in the summary section.
- This strategy reduces the overall offshore borrow site sediment needs (approximately 2 million cy less over 50 years) while supporting the overall RSM initiative.

There are two pathways to implement this strategy assuming the dredged material is suitable for direct placement on the beach. The first would involve developing a beneficial re-use project using the Sea Bright to Manasquan shore protection authorities for implementation. However, the authority to construct the project does not include a provision for this type of beneficial reuse. As such, it would likely have to be modified and the project cost sharing adjusted to reflect a new purpose. All the attendant documentation would have to be developed to accomplish this, and a new PCA reflecting today's model agreement would have to be negotiated and signed.

The second way to implement this is to use the existing Manasquan Inlet navigation project authorities. Under the existing authorities, if the material is suitable, the federal government could request that the material be placed directly on the beach. Permits are required to do so, but they can be obtained under the authorized navigation project. If there is a cost differential to the navigation project, the State would likely have to pay the difference.

Implementation of this strategy has limited additional constraints; however, sediment compatibility of the Manasquan Inlet dredge material must be determined.

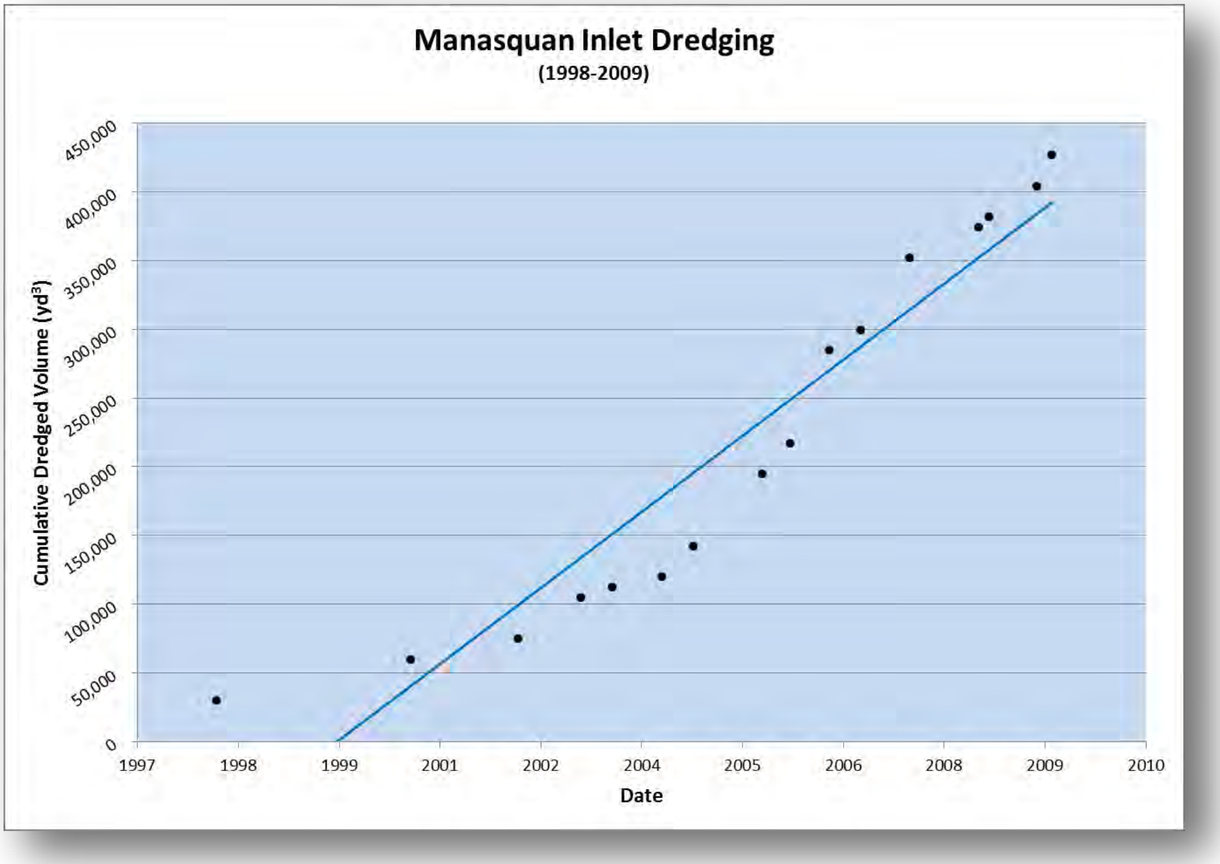


Figure 170. Cumulative dredge volume removed from Manasquan Inlet from 1998 to 2009.

Table 104 presents a summary of the criteria evaluated for the Manasquan Inlet beneficial re-use strategy and ranks it as a high priority with a Tier level of 1. As long as the sediment dredged is compatible for beach nourishment or nearshore placement and the quantity of dredging remains approximately the same as historic levels, this strategy should be further pursued since it is directly in line with RSM strategies and initiatives. Additionally, every effort should be made to coordinate inlet dredging (navigation project) with the periodic nourishment (shore protection project) to minimize dredge mobilization costs.

Table 104. Manasquan Inlet Beneficial Re-use Strategy Summary.

Criteria	Summary
1. Authorization	Implement under federally-authorized navigational project.
2. Constraints	Incremental cost increases for dredge material placement
3. Cost Savings	$33 million over 50-year time horizon
4. Service Life	No change to existing service life of shore protection project or navigational dredging
5. Other Benefits	Reduced offshore sediment source requirements.
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Evaluate sediment compatibility obtain permits for placement of dredged material on beaches.

C. Borrow Area Expansion or Establishment

Sediment sources for the initial construction of the Sea Bright to Manasquan project, as well as the periodic nourishment, have been from offshore borrow areas at Sea Bright and Belmar. Currently, the permitted offshore borrow sites do not have enough material to complete future renourishments. Therefore, unless the sediment needs of the shore protection project can be reduced (e.g., beach nourishment performance is enhanced), or alternative sediment sources are utilized (e.g., bypassing), additional offshore borrow location will be required.

This strategy is not specifically geared towards providing a cost savings, but rather at maintaining current operational costs since upland sand sources are likely more costly and relatively impractical for delivery of significant amounts of sediment to the beach (e.g., truck traffic, road repairs, time of construction, etc.).

Over a 50 year time horizon, the periodic nourishment sediment needs at Sea Bright to Manasquan are approximately 48,560,000 cy. Initial construction of Section I and Section II required 24,900,000. Overall, the Sea Bright to Manasquan project requires approximately 73,460,000 cy over a 50-year time horizon.

The original offshore borrow sites (Sandy Hook/Sea Bright, Belmar 1, Belmar 2) for the Sea Bright to Manasquan authorized shore protection project had approximately 25,100,000 cy remaining after initial construction of Section I and Section II. As such, there is a deficit of approximately 23,460,000 cy for renourishment of the project.

Continued expansion of existing sites or searches for new borrow sites is needed for this region, as significant additional material is required for periodic nourishments. In addition to borrow site searches in State waters, potential searches in Federal waters are warranted through cooperation with the Bureau of Ocean Energy Management, (BOEM).

This strategy can be accomplished under the existing project authorities as the provision of borrow areas for the life of the project is part of the authorization. It would require cost sharing likely at the same level as the project. Appropriate studies and environmental clearances would be needed.

The primary constraints with expansion or establishment of offshore borrow sites are environmental. Establishing offshore borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave and sediment transport processes also are needed. The physical and environmental delineation would add cost; however, once permitted, the construction costs associated with obtaining the offshore material are significantly lower than for upland material.

Table 105 presents a summary of the criteria evaluated for the offshore borrow area expansion and establishment strategy and ranks it as a high priority with a Tier level of 1. It is recommended that this strategy be pursued in advance of potential need, such that the borrow areas are established for future use. Established borrow sites may or may not be used to their full capacity if other strategies are implemented or sediment needs are reduced, but having permitted offshore sites available if needed for storm events or unforeseen circumstances is good planning. Next steps would be to initialize any studies and surveys needed to expand or establish new borrow sites for this region, which has a known deficit, and coordinate

with BOEM for any potential federal waters borrow sites.

Table 105. Borrow Area Expansion or Establishment Strategy Summary.

Criteria	Summary
1. Authorization	Accomplished under existing project authority
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Neutral
4. Service Life	Maintains current operations
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Initiate studies and surveys. Coordinate with BOEM

D. Sediment Bypassing of Manasquan Inlet

This strategy would involve implementation of sediment bypassing methodology to move sediment from the southerly updrift beaches of Manasquan Inlet to nourish beaches downdrift of the inlet. A number of previous studies evaluated conceptual designs and methodologies for bypassing sediment around Cape May Inlet (USACE, EM 1110-2-1616, 1991; U.S. Army Engineer District, Philadelphia, 1987; USACE, 2004), and this information is used to conduct a similar assessment for Manasquan Inlet.

Various bypassing alternatives have been considered at a conceptual design level and have been evaluated in preliminary analyses of bypassing of Cape May Inlet. (USACE, 2004; USACE, EM 1110-2-1616, 1991). For this preliminary analysis, it is assumed that a semi-mobile bypass system would be installed to pass sand around Manasquan Inlet. Additional alternatives (e.g., a floating dredge plant) could also be considered in a more detailed analysis of potential bypassing approaches if this strategy is further pursued. However, in this preliminary analysis, a sediment bypassing plant (similar to the system operated at Indian River Inlet in Delaware – see Figure 171) is considered as a baseline approach to potential bypassing. The USACE Philadelphia District (2004) developed an initial cost estimate for a bypass system. The cost estimate included initial construction costs, Operation and Maintenance (O&M) costs for the sand bypassing plant, Engineering and Design (E&D) costs, Construction Management (S&A) costs, as well as a contingency factor. Detailed breakdown of the cost estimate can be found in the USACE (2004) document. These values were used in the current analysis as well. The following cost estimates were utilized and are intended to provide a first-order estimate of cost impacts:

- An initial construction cost of $6,345,000 for the bypass plant
- O&M costs of $613,000 annually. Bypassing efforts would take place from September to April, 5 days per week, 6 hours per day, bypassing a maximum of approximately 140,400 cy/yr, as long as the sediment is available.
- Replacement of the pump system every 12-13 years at a fixed cost of $600,000
- Refurbishing/replacement of the system at year 25 for $6,345,000

Based on the historical dredging of Manasquan Inlet, it is expected that there would be approximately 40,400 cy/yr (as presented in Strategy B) of material deposited in Manasquan Inlet. The analysis assumes that this material could be intercepted on the updrift shoreline prior to getting into the inlet. There also may be more material available for bypassing that resides within the updrift fillet.

Figure 171. Indian River Inlet, Delaware fixed bypassing system (Photo courtesy of Tony Pratt, DNREC).

This strategy does not result in a significant cost savings due to the relatively small amount of sediment that is expected to be bypassed around Manasquan Inlet. In this initial analysis, the cost of establishing and maintaining the bypass system was greater than the amount of savings realized from the bypassing of the sediment. Therefore, bypassing at this particular inlet is not as highly recommended.

This would not require additional authority if pursued under the concept of value engineering. If it is cost effective, then whatever environmental clearances needed and the actual cost to construct it could be accomplished with construction funds. However, prior to implementation, significant environmental clearances would likely be required. Impacts and potential mitigation for this sensitive area would need to be evaluated in more detail prior to obtaining permits for project implementation.

Table 106 presents a summary of the criteria evaluated for the sediment bypassing strategy and ranks it as a low priority, due to the limited cost savings associated with lower sediment availability at Manasquan Inlet, and a Tier level of 2. The approach should be considered if it is determined that there is enough sediment available for bypassing. The strategy does have significant other benefits (e.g., reduce or eliminate dependence on offshore sediment sources, reduce sediment surplus on updrift beaches) and the approach takes advantage of beach compatible sediment already in the system. Next steps would involve a more detailed study of potential impacts caused by fillet extraction on adjacent beaches, finalization and design, and determining the right authorization approach and pathway to implement the bypassing project. Because of these uncertainties, another bypassing inlet should be implemented first to evaluate the performance of the system at a sediment rich inlet.

Table 106. Sediment Bypassing at Manasquan Inlet Strategy Summary.

Criteria	Summary
1. Authorization	Value engineering could be applied to implement.
2. Constraints	Significant environmental questions may remain for impacts on extraction of updrift fillet
3. Cost Savings	Minimal savings, ultimately dependent on sediment availability on updrift side of Inlet
4. Service Life	No change to existing service life of shore protection project
5. Other Benefits	Eliminate offshore sediment source requirements and environmental impacts. Improved management of sediment in littoral system.
6. Priority	Low
7. Tier Level	Tier 2
8. Next Steps	More detailed study of potential impacts caused by fillet extraction. Finalize and design project. Determine authorization approach.

Cost benefits of this strategy are compared to current operations and other strategies in the summary section.

E. Develop Nourishment Priorities with Strategic Coastal Structure Modifications

On average, the shoreline within the Sea Bright to Manasquan project area is accreting at a rate of 5.9 ft/yr. This rate is based on 30 years of recent data and therefore reflects the anthropogenic influence (nourishment) on the shoreline. Despite nourishment efforts, the project area still has erosional hotspots. Erosion in some areas (Figure 172) can be as great as 7.9 feet per year. Erosional hotspots are not unusual, and researchers (Smith et al., 1999) documented erosion at Monmouth Beach caused by spreading after initial placement, planform evolution, and the presence of littoral barriers. The most significant areas of erosion evident in this dataset also coincide with the unconstructed portion (Section I, Contract 3) of the shore protection project.

Due to the large scale of this nourishment project (6.1 million cy for each 6 year periodic nourishment), it is expected that funding for the full periodic nourishments may be difficult to consistently obtain. Therefore, this strategy includes prioritizing nourishment efforts to vulnerable developed areas that have shown the highest erosion. Completing these smaller priority based nourishments may be more manageable from both an operation and fiscal basis. As such, rather than wait for adequate funding to become available for the entire authorized project, critical erosional areas could be addressed more readily as funding becomes available.

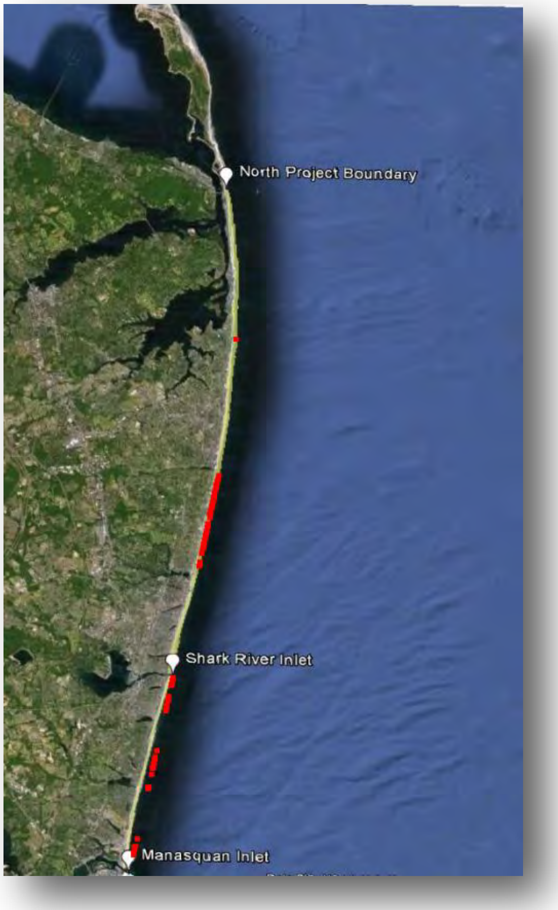


Figure 172. Erosional hotspots between Sea Bright and Manasquan Inlet. Identified from contemporary shoreline change data.

These identified priority areas must be sufficient in magnitude and length such that the smaller nourishment projects would still provide a reasonable service life and level of protection. The long term performance of a beach nourishment project depends on the local wave climate, storm frequency and intensity, the characteristics of native and fill sediments, and the physical shoreline length of the project. Longer projects have a longer design life as the nourishment functions more effectively. Utilizing the local wave climate information (WIS hindcast data) and some preliminary analysis of beach nourishment performance and sediment dispersion, a minimum length of 1.5 miles was the determined as a reasonable length for an adequately performing nourishment project.

Using the 1.5 mile criterion, historical shoreline change rates by station were investigated and five high priority locations located within the currently authorized project area were identified for potential priority nourishment projects. While a number of social, political, economic, and environmental factors may ultimately contribute to a final decision on potential nourishment projects, for this preliminary assessment only considers historical erosion rates.

Although much of the contemporary shoreline change exhibits accretion (due to anthropogenic nourishment effects), three more vulnerable shoreline segments were identified within the Sea Bright to Manasquan project area. These three areas occur at Loch Arbor and North Deal, Lake Como, and Sea Girt (Figure 173) and were determined based on their lower accretion rates compared to the average accretion across the entire project area. In addition, some of these areas may not have been nourished in the previous efforts. For example, the Deal region was not directly nourished due to political reasons. Therefore, potential strategic nourishments would also need to rely on additional factors beyond simply the observed shoreline change rates.

Assuming that a beach nourishment template similar to the authorized template would be applied at each priority nourishment area, an average volume of 55 cubic yards per linear foot of beach was assumed. Estimated project costs were calculated using $15/cy for sediment and combined mobilization/demobilization costs of dredging operations of $2,000,000 per project. Table 107 provides the estimated cost for each priority project and project length.

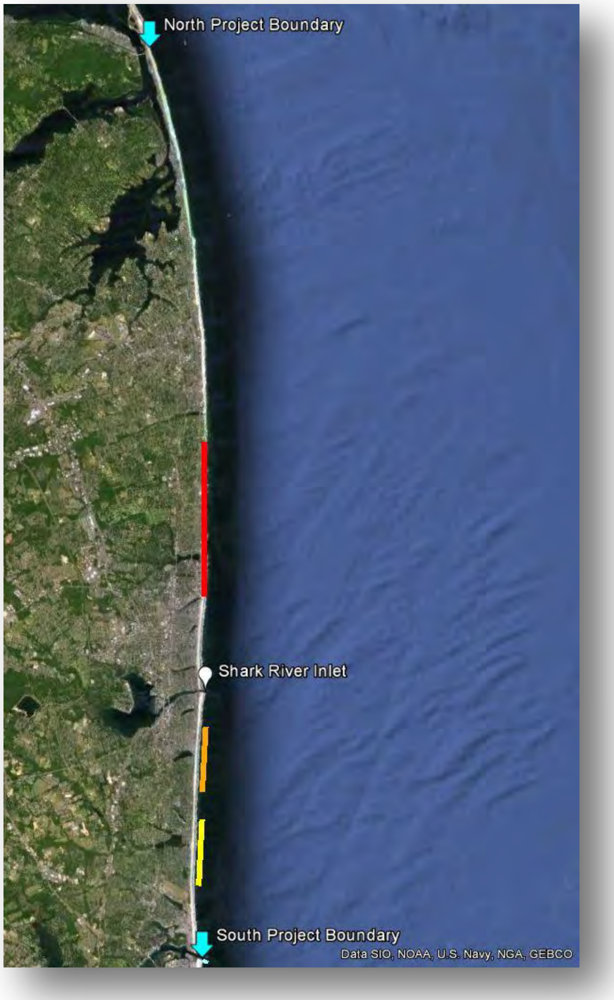


Figure 173. The three identified critically eroding areas within the Sea Bright to Manasquan authorized project area. The higher priority area is marked in red.

Table 107. Priority nourishment areas for Sea Bright to Manasquan Project Area.

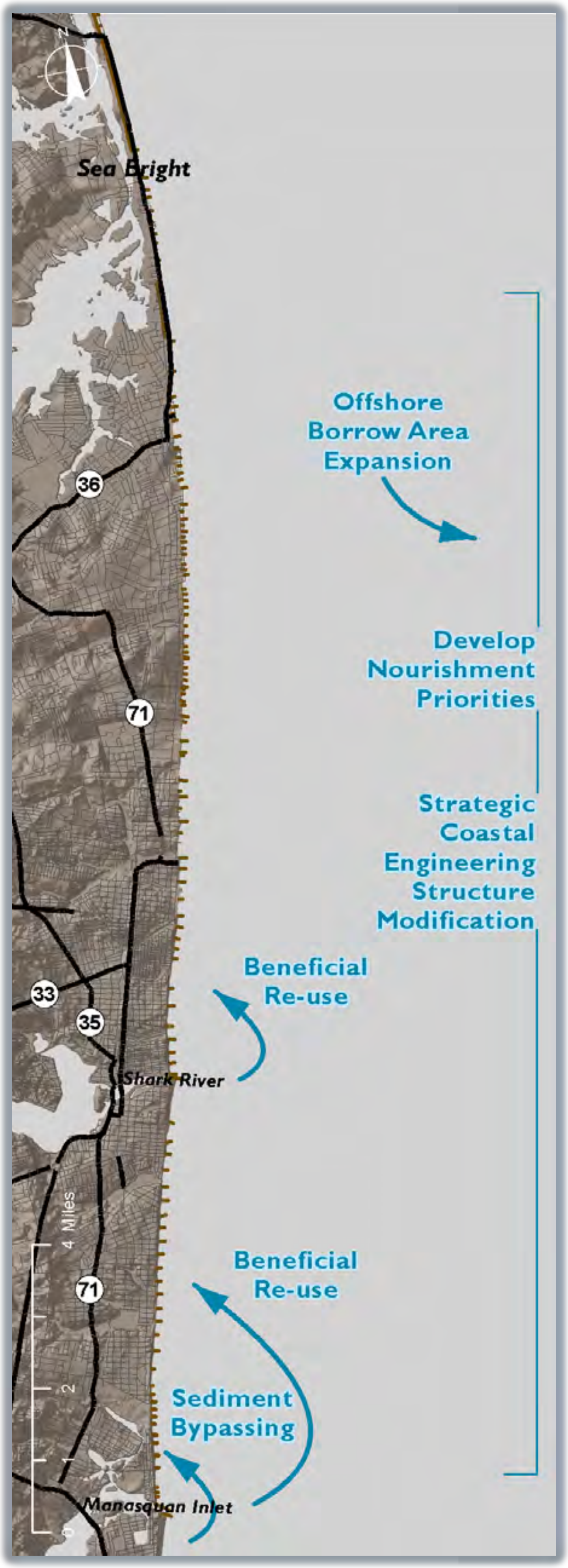
Location	Length (mi)	Estimated Cost (Millions)
Loch Arbor and North Deal	3.4	$16.8
Lake Como	1.5	$8.5
Sea Girt	1.6	$8.9

This strategy further recommends consideration of using groins to prolong the life of the proposed strategic nourishments in certain areas. This would require additional study and engineering assessments to evaluate utility, function, and value of potential structures to help retain sediment at strategic locations.

Table 108 presents a summary of the criteria evaluated for the prioritizing nourishment activities strategy and ranks it as an intermediate priority and a Tier level of 1. A Tier level of 1 was assigned since the USACE currently does some segmented nourishments in other areas of the coastline.

Table 108. Nourishment Prioritization Strategy Summary.

Criteria	Summary
1. Authorization	Use existing authorization to implement via value engineering
2. Constraints	Minimal
3. Cost Savings	Not specifically evaluated.
4. Service Life	Reduced overall service life compared to full project
5. Other Benefits	More continual sediment supply to beaches versus waiting for full funding
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Could be implemented as needed, more study required for potential use of strategic structures



Summary

This section presents a brief summary of all the strategies presented for Sea Bright to Manasquan shore protection project. The focus is on the potential cost savings and priority levels to assist in the identification and selection of strategies that could be implemented immediately and/or further pursued to more cost effectively manage sediment within the project area.

Table 109 summarizes all strategies focused on the prioritization and Tier level. The strategies presented in Table 109 are listed in order of priority and estimated ease of implementation.

Table 109. Sea Bright to Manasquan Strategy Summary.

Strategy	Prioritization	Tier
B. Beneficial Reuse: Manasquan Inlet	High	2
A. Beneficial Reuse: Shark River	High	2
C. Offshore Borrow Site Expansion	High	1
E. Nourishment Prioritization	Intermediate	1
D. Sediment Bypassing	Low	2

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Project Description

The Hereford Inlet to Cape May Inlet Shore Protection Project is not a federally authorized project yet, but this area is currently in a General Investigations/ Feasibility phase. The USACE Philadelphia District (District) is considering this project under the authority of multiple water resource project mission areas: Hurricane and Storm Damage Reduction; and Ecosystem Restoration and Section 111 mitigation. The District plans to combine these efforts for a multi-purpose approach to the study area, which includes the Atlantic Coast of Five Mile Island between Hereford Inlet and Cape May Inlet in Cape May County. Although this area is included within the geographic scope of the Townsends Inlet to Cape May Inlet Shore Protection Project, it is now being considered for a separate authorization.

The District will consider adjusting the beach in Wildwood and Wildwood Crest to eliminate clogged outfalls, ponded water, and interior flooding, decrease wave overtopping during storm events, and improve water quality across the project area. Beach fill, groins, revetments, breakwaters and bulkheads will be considered under the Hurricane and Storm Damage Reduction effort, designed to reduce damages caused by strong winds, waves, water levels and currents as a result of major storms. Utilizing dredged material for beach restoration, native vegetation restoration and rehabilitation of beach habitat will be the focus of the Ecosystem Restoration efforts, aimed at improving the long-term health of aquatic and terrestrial ecosystems. Section 111 efforts will examine the negative impacts resulting from construction of the Cape May Inlet jetty, including a large sand fillet depositing north of the jetties along Five Mile Island, causing maintenance and human health hazards in Wildwood and Wildwood Crest.

Project History

The Hereford Inlet to Cape May General Investigation was undertaken by the authority of the New Jersey Shore Protection Study in 1987. This study was concluded with the 1990 Report of Limited Reconnaissance, which did not identify critical problems between Hereford Inlet and Cape May Inlet and made recommendations to focus efforts in areas requiring immediate attention.

By the mid-90s, however, a number of shoreline problems developed between Hereford Inlet and Cape May Inlet, including erosion and excessive sand accretion. In January 2002, the Philadelphia District performed an analysis to determine if Federal interest existed and examined the erosion, storm damage vulnerability and public health issues arisen since the 1990 report. Analysis demonstrated clear Federal interest in pursuing a water resource project. North Wildwood was severely eroding, while the beaches of Wildwood and Wildwood Crest were accreting to an extent causing health and safety concerns.

Accretion in Wildwood and Wildwood Crest is causing extensive maintenance problems and health issues with the storm water management system because the excess sand clogs storm-water outfalls and creates pools of stagnant water, producing unhealthy beach conditions. During periods of heavy rain or high water, the City cannot access the stormwater outfalls for excavation, and the rainwater trapped in the pipes causes sections of the interior portion of Wildwood to flood during storms. Subsequent discharge of a large volume of previously impounded storm water also produces poor water quality at the beaches. This issue requires 19 storm water outfalls from Hereford Inlet to Cape May Inlet to be excavated daily. Historically, the beach did not extend past the outfalls, which allowed the stormwater to drain directly into the ocean. Recent accretion has caused the beach to grow 300-350 feet beyond the outfall points.

In contrast, North Wildwood is experiencing significant beach erosion and lost approximately 1,000 ft of beach between 1986 and 2004. This erosion has greatly reduced, and in some areas eliminated, the protective dune structure once in the area. Recently the City of North Wildwood placed a concrete barrier in front of its lifeguard headquarters to protect it from encroaching erosion. Although this may prevent damages, this does not represent a permanent solution and may increase toe scour and erosion in front of the structure. Figure 174 provides an overview of the potential authorized shore protection region.

Figure 174. Potential Hereford Inlet to Cape May Inlet Shore Protection Project.

Project Concerns

The following observations have been made regarding the potential Hereford Inlet to Cape May Inlet Project:

- Five Mile Island was originally not included for a Shore Protection Project authorization in 1990 because no immediate problems were observed.
- Wildwood and Wildwood Crest are currently experiencing excessive accretion, resulting in maintenance and health issues with the storm water system.
- North Wildwood is currently experiencing dramatic beach erosion and lost approximately 1000 ft of beach width between 1986 and 2004.

Potential Strategies

This section presents the potential strategies for the Hereford Inlet to Cape May Inlet Shore Protection Project intended to improve project performance, cost savings, or provide other benefits. Strategies were developed jointly with the U.S. Army Corps of Engineers, the State of New Jersey DEP, and the project team. Since this shore protection project has not been officially authorized, and no formal project plan has been set in place, no analyses of the potential strategies are presented herein since there can be no comparison to the authorized project. The strategies presented herein represent ideas to improve the project formulation. A more detailed analysis is recommended if a strategy is more formally pursued.

A. Project Cycle Synchronization

The project cycle synchronization strategy represents informally synchronizing the construction of authorized shore protection projects in close proximity. The intent is to reduce mobilization and demobilization costs by combining re-nourishments. The proposed North Wildwood periodic nourishment (once Hereford Inlet to Cape May Inlet Shore Protection Project is approved) would coordinate with the Stone Harbor periodic nourishment (estimated 498,000 cy every 3 years). Similar coordinated efforts have occurred in the past. For instance, in 2009, the State of NJ removed 1,431,400 cy from Hereford Inlet to nourish beaches in Stone Harbor and North Wildwood.

This strategy can be implemented at any time since existing authorities do not preclude re-nourishment as part of one contract as long as the funds for each are available and are not comingled. Requisite environmental clearances must be accomplished before award of such a contract. Provided the Hereford Inlet to Cape May Inlet Shore Protection Project is authorized, implementation has minimal constraints; limited to availability of dredging equipment and borrow site quantities, which already would be constraints.

Table 110 presents a summary of the criteria evaluated for the improved project coordination strategy and ranks this strategy as a high priority and easily implementable (Tier 1 level). This strategy should be eventually be pursued since the pathway to implementation is straightforward and there are no significant constraints.

Table 110. Project Cycle Synchronization Strategy Summary.

Criteria	Summary
1. Authorization	Project is not currently authorized
2. Constraints	No constraints expected beyond dredge availability and available borrow source material
3. Cost Savings	Not evaluated since authorized plan is not defined
4. Service Life	Not evaluated since authorized plan is not defined
5. Other Benefits	Reduction in logistical, management, and contracting requirements; Reduced environmental impacts on temporal scale
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Evaluate potential storm damage impacts, coordinate dredging, and implement

B. Increased Dredging of Hereford Inlet

The increased dredging of Hereford Inlet strategy seeks to expand the available nearshore borrow areas in the vicinity of North Wildwood. The intent of the strategy is to identify and expand inlet based borrow areas to nourish eroding beaches at North Wildwood.

There is a history of dredging and beneficial reuse at Hereford Inlet. Documentation of federal activity and investigation in Hereford Inlet is available in the Townsends Inlet to Cape May Inlet Feasibility Study (USACE, 1997). Federal dredging of the ebb shoal of Hereford Inlet occurred in 1967, and the state performed annual maintenance of the channel until 1976 (after which maintenance occurred as needed). The feasibility study identified a 145 acre area within Hereford Inlet with an estimated 2,500,000 cy of compatible sand. The study acknowledged the existence of greater reserves, but reduced the borrow area footprint to preserve the ebb shoal and maintain inlet hydraulics and benthic resources. USACE later refined this borrow area to include three permitted borrow areas (G, A-1, A-2) in Hereford Inlet. The estimated pre-project borrow area quantity was 4,050,000 cy based on feasibility studies. In 2009, the State of NJ removed 1,431,400 cy from Hereford Inlet to nourish beaches in Stone Harbor and North Wildwood. Based on this information, the remaining available sand from the Hereford Inlet borrow area was approximately 2,620,000 cy.

The Hereford Inlet to Cape May Inlet Feasibility Study Project Management Plan (USACE, 2005) indicates USACE/CERC identified additional potential borrow sources in Hereford Inlet that will require further investigation. As a preliminary estimate of extents and volume of these potential borrow sites, an investigation of historical aerial photography was completed. The assessment suggested the shoals of Hereford Inlet are substantial but migratory. Potential borrow areas are delineated based on the location of the ebb and flood tidal shoals in the latest available imagery (Google Earth, June 2011) to provide an estimate of the most probable location of sediment sources. Figure 175 delineates potential borrow areas, shown in green, and shows existing permitted (for the Townsends Inlet to Cape May Inlet Shore Protection Project) borrow areas in Hereford Inlet (white shaded areas).

The flood tidal shoal at Hereford Inlet is approximately 60 acres. At an average thickness of 10 to 15 ft, the flood tidal shoal borrow area could yield between 970,000 and 1,460,000 cy. The ebb tidal shoal at Hereford Inlet is approximately 200 acres. At an average thickness of 10 to 15 ft, the ebb tidal shoal borrow area could yield between 3,270,000 and 4,900,000 cy. This would provide additional future nourishment material for the North Wildwood area.

Once the Hereford Inlet to Cape May Inlet Shore Protection Project is authorized, expanded borrow areas within the inlet could be authorized by developing a beneficial reuse project using the coastal projects authorities to implement.

The primary constraints with expansion of the inlet borrow sites are environmental. Establishing borrow locations requires sand source delineation that typically includes a rigorous series of sampling and surveys using side scan sonar, jet probes, cores, grain size analysis, sub-bottom surveys, and environmental impact assessment. Impacts to wave, tidal currents, and sediment transport processes also are needed, especially to determine the potential impact from removal of a significant portion of the ebb or flood tidal shoals. The physical and environmental delineation would add cost; however, once permitted, the construction costs associated with obtaining the nearshore material are significantly lower than for upland material, and also likely lower than offshore sources due to the close proximity of the inlet material to the beach nourishment project(s).

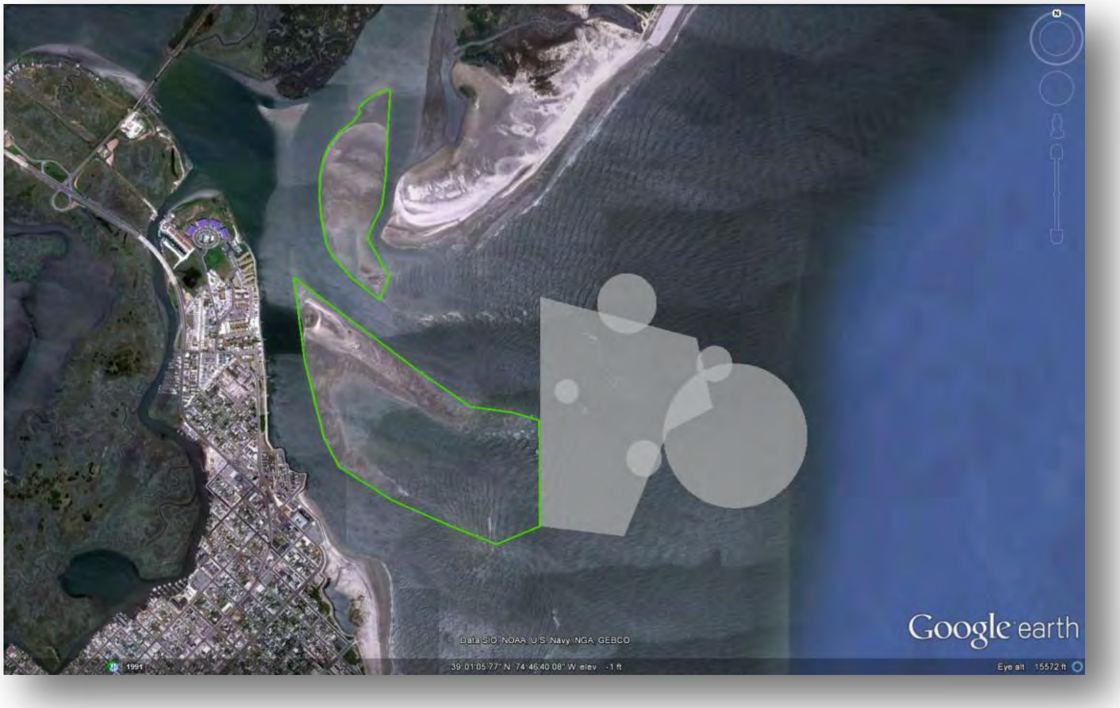


Figure 175. Potential borrow areas (green) at the ebb and flood tidal shoals of Hereford Inlet. Permitted borrow areas shown as shaded white. Image courtesy of Google Earth©.

Table 111 presents a summary of the criteria evaluated for the borrow area expansion in Hereford Inlet and ranks this strategy as an high priority for this region with a Tier level of 2, depending on the nourishment volume requirements and components of the authorized plan. Next steps for this strategy would be to initialize studies and surveys needed to expand the inlet borrow sites.

Table 111. Increased Dredging of Hereford Inlet Strategy Summary.

Criteria	Summary
1. Authorization	Project is not currently authorized
2. Constraints	Significant environmental studies, surveys, and impact analysis required
3. Cost Savings	Some cost savings expected due to close proximity of borrow sites
4. Service Life	No change to shore protection service life
5. Other Benefits	Advanced planning allowing for available sediment for emergency nourishments or unforeseen sediment needs
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	Initiate studies and surveys

C. Sediment Backpassing to North Wildwood

This strategy involves extracting sediment from a portion of the shoreline that is accreting and moving the material to an eroding updrift location. This methodology, called sediment backpassing, is intended to work with the natural littoral drift by recycling sand back updrift to the location where it initially resided. For example, material from North Wildwood is transported south to Wildwood where the shoreline is advancing and sediment is plentiful. The sediment backpassing strategy would recycle a portion of this material to North Wildwood, as shown conceptually in Figure 176.

As part of the Hereford Inlet to Cape May Inlet Feasibility Study, Clausner and Welp (2008) conducted a study to investigate the feasibility of mobile hydraulic back-passing for the Wildwood area. The study determined that in a time frame of two to four months, as much as 200,000 cubic yards (cy) of sand could be back-passed distances of up to 15,000 feet using the mobile system they evaluated.

Historic shoreline change data indicate the Wildwood area is accreting approximately 18.2 ft/yr (5.5 m/yr). In order to determine the potential volume available for backpassing, equilibrium beach profile theory was utilized to regress the shoreline shape landward. Only sediment accreting was identified as available for backpassing. The volume of sediment accreting in the area of Wildwood was calculated to be 820,000 cy annually, or 2,460,000 every three years. Not all of this excess material is available for extraction. Assuming the use of a 160 ft boom mounted pumping system, 91,000 cy/yr of sand are available to be backpassed to North Wildwood.

Figure 176. Sediment backpassing strategy for North Wildwood.

Over a 50-year time horizon, 91,000 cy/yr of sediment backpassing could create significant cost savings. This assumes a mobile backpassing system is readily available. Additional cost savings may be realized from reduced contracting and management requirements. Reduced impacts to offshore borrow sites would be another benefit to this strategy.

Potential constraints involve potential impacts on the beach where sand is extracted. This includes the ability of the beach to adequately serve the same function and level of protection as before the sediment removal. This strategy would also increase disturbance on the beaches, and overall air and noise pollution.

Table 112 presents a summary of the criteria evaluated for the sediment backpassing strategy and ranks this strategy as a high priority and Tier Level 1. This strategy is expected to be a primary component of the potential authorized plan.

Table 112. Sediment Backpassing to North Wildwood Strategy Summary.

Criteria	Summary
1. Authorization	Project is not currently authorized
2. Constraints	Dredge equipment availability, potential impacts to source beach
3. Cost Savings	Not evaluated since authorized plan is not defined
4. Service Life	Not evaluated since authorized plan is not defined
5. Other Benefits	Reduce sediment surplus at Wildwood while addressing sediment deficit at North Wildwood.
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Use value engineering to implement; assess environmental impacts on source beach.

D. Sediment Forepassing to Diamond Beach

This strategy involves extracting sediment from a portion of the accreting shoreline, and moving the material to a downdrift location. This methodology is intended to work with the natural littoral drift within a system by enhancing the downdrift transport of sand accumulating excessively at updrift locations. For example, the shoreline is advancing and sediment is plentiful at Wildwood. The sediment forepassing strategy would forward a portion of this material to Diamond Beach, as shown conceptually in Figure 177, with the intent to eventually provide material for bypassing of Cape May Inlet and for use at Cape May (if a bypass system is placed at Cape May Inlet).

Figure 177. Sediment fore-passing strategy for Diamond Beach.

As detailed in the sediment backpassing strategy (Strategy C), a similar amount of material could be available for sediment forepassing. Table 113 presents a summary of the criteria evaluated for the sediment forepassing strategy and ranks this strategy as an intermediate to low priority and Tier

Level 3. This strategy would depend on implementation of a sediment bypassing system at Cape May Inlet.

E. Beach Profile Distribution

This strategy involves reshaping of cross-shore profiles in the Wildwood and Wildwood Crest area, where recent accelerated accretion is causing extensive maintenance problems and health issues.

Currently, beaches at Wildwood and Wildwood Crest are relatively low and flat with an exceptionally wide berm. At its widest section, the beach at Wildwood is over ¼ mile wide (from boardwalk to high water line), and houses a convention center and multiple amusement piers.

Despite the width of the beaches at Wildwood and Wildwood Crest, the level of storm protection is quite low. The maximum berm elevation at Wildwood is 6.2 ft, and all dunes in the area have been eliminated. Dunes remain at Wildwood Crest, but dune crest elevations are relatively low.

Table 113. Sediment Forepassing to Diamond Beach Strategy Summary.

Criteria	Summary
1. Authorization	Project is not currently authorized
2. Constraints	Dredge equipment availability, potential impacts to source beach
3. Cost Savings	Not evaluated since authorized plan is not defined
4. Service Life	Not evaluated since authorized plan is not defined
5. Other Benefits	Reduce sediment surplus at Wildwood
6. Priority	Intermediate to Low
7. Tier Level	Tier 2
8. Next Steps	Only consider if sediment bypass system is installed at Cape May Inlet

The sediment profile redistribution strategy would move material from the low beach, where sediments are clogging storm drain outfalls, landward to the higher beach and dune areas. Reshaping the profile in this way would increase storm damage protection (increased berm elevations and dune resources) and reduce stormwater outfall maintenance.

Redistribution of sediment within the Wildwood area would require a study to evaluate potential benefits and impacts to the Wildwood shoreline resulting from the proposed redistribution. This would include changes to sediment transport patterns and assessment of storm damage benefits.

Table 114 presents a summary of the criteria evaluated for the sediment profile redistribution strategy and ranks this strategy as an intermediate priority with a Tier Level of 2.

Table 114. Sediment Profile Redistribution Strategy Summary.

Criteria	Summary
1. Authorization	Project is not currently authorized
2. Constraints	Impacts to shoreline and natural sediment transport patterns
3. Cost Savings	Not evaluated since authorized plan is not defined
4. Service Life	Not evaluated since authorized plan is not defined
5. Other Benefits	Improved storm damage protection, reduce storm water outfall maintenance
6. Priority	Intermediate
7. Tier Level	Tier 2
8. Next Steps	Evaluate potential for inclusion in authorized plan

F. Jetty Construction along Hereford Inlet

The intent of this strategy is to stabilize Hereford Inlet and prevent erosion along the shoreline of North Wildwood. A jetty could be constructed parallel to the north-facing shoreline of North Wildwood, tied to the end of either Hoffman Avenue or East Spruce Avenue, to protect the North Wildwood shoreline from tidal currents and wave impacts. The area between the proposed jetty and the existing shoreline could be filled with dredged material from Hereford Inlet to create additional upland areas.

USACE has considered jetties at Hereford Inlet in the past, but never implemented the measures due to costs and potential impacts. According to the Townsends Inlet to Cape May Inlet Feasibility Study (USACE, 1997), the WRDA of 1976 authorized Phase I Advanced Engineering and Design at Hereford Inlet. This project included jetties on both sides of the inlet. Section 501 of the WRDA of 1986 reauthorized this project; however, it was de-authorized in 1991 under Section 1001 of the WRDA. The Feasibility Study (USACE, 1997) again considered north and south jetties at Hereford Inlet. The design called for a north jetty extending 5,600 ft from Stone Harbor with a top elevation between 8 and 2 ft MLW, and a south jetty extending 1,000 ft south from the spur at J.F.K. Boulevard in North Wildwood. At the time of the Feasibility Study, the project was not constructable due to extensive erosion at Stone Harbor. The Feasibility Study further cited concerns about cost, inlet habitat change, and downdrift effects in deciding not to pursue the option.

Given improvements from the Stone Harbor Point Ecosystem Restoration project and advances in modeling capabilities, a southern jetty may be a viable strategy for sediment management in the area and further investigation may be considered to determine potential utility. Cost, inlet habitat change, and downdrift effects are still likely to limit the feasibility of this strategy.

Table 115 presents a summary of the criteria evaluated for the jetty construction strategy and ranks this strategy as a low priority and Tier Level 3.

G. Inlet Thalweg Relocation

The intent of this strategy is to reduce the ebb current forces occurring from Hereford Inlet likely scouring the North Wildwood shoreline, with an ancillary benefit of potential increased sediment availability for beneficial reuse from expanded dredging. The existing thalweg along the North Wildwood shoreline could be filled using dredged material from Hereford Inlet. Tidal flow capacity could be replaced and relocated by expanding an existing channel to the north.

Table 115. Jetty Construction along Hereford Inlet Strategy Summary.

Criteria	Summary
1. Authorization	Project is not currently authorized
2. Constraints	Cost, inlet impacts, habitat change, etc.
3. Cost Savings	Not evaluated since authorized plan is not defined
4. Service Life	Not evaluated since authorized plan is not defined
5. Other Benefits	Unknown
6. Priority	Low
7. Tier Level	Tier 3
8. Next Steps	Detailed study of jetty impacts

Past studies of Hereford Inlet (USACE, 1997) indicate the inlet channel (thalweg) is not in equilibrium and migrates significantly. Inlet shoals, beaches and spits store large quantities of sediment and redistribute the material on thalweg migration. Intervention of the natural migration process and redirection of the ebb flow could reduce erosion at North Wildwood, and yield material for beneficial reuse.

USACE considered inlet thalweg relocation (channel realignment) in the past, but never implemented measures due to uncertain impacts. The Townsends Inlet to Cape May Inlet Feasibility Study (USACE, 1997) considered realignment of the Hereford Inlet channel, proposing a 300 ft wide channel to -12 ft MLW. The Feasibility Study dropped this design due to potential downdrift impacts of dredging through the ebb shoal complex, but noted that small scale navigation dredging moving the channel away from North Wildwood could alleviate scour along North Wildwood and provide a source of sand for nourishment. Secondary assessment of this alternative recommended it in conjunction with other projects, such as the Stone Harbor Point ecosystem restoration. Dredging and realignment alone would yield only 190,000 cy, and would not result in quantifiable benefits for North Wildwood.

USACE considered inlet thalweg relocation in association with the Stone Harbor Point ecosystem restoration (USACE, 1997). The Feasibility Study proposed dredging the northern and southern existing channels with beneficial reuse on Champagne Island and/or Stone Harbor Point. This alternative required additional investigation since modeling capabilities were not sufficient to recommend optimal channel placement. Secondary and tertiary analyses centered on alleviating erosional forces on the southern tip of Stone Point Harbor, proposing either dredging in the southern channel or filling in the northern. The potential for increased flow through the southern channel and disrupted inlet hydraulics posed a risk for increased erosion at North Wildwood. The results of this analysis concluded that inlet hydraulics were too unpredictable to recommend intervention, and the Stone Point Harbor project should source sediment offshore.

Given advances in modeling capabilities enabling better prediction of inlet hydraulics and downdrift impacts, thalweg relocation of the southern channel may be a viable strategy for reducing scour along the North Wildwood shoreline and further investigation could be considered.

Table 116 presents a summary of the criteria evaluated for the inlet thalweg relocation strategy and ranks this strategy as a low priority and Tier Level 3.

H. Site-specific Coastal Processes Analysis

This strategy involves developing a comprehensive, coastal processes based, understanding of the prominent erosion at the north facing shoreline of North Wildwood and the prominent accretion that occurs along the shoreline of Wildwood. A site-specific study, intended to focus on detailing the coastal processes (waves, tidal currents, wave-induced currents, sediment transport, shoreline change, etc.), is recommended to identify potential alternatives that may improve the proposed shore protection authorization, or provide a better understanding of how to potentially modify the shore protection approach.

Table 116. Inlet Thalweg Relocation Strategy Summary.

Criteria	Summary
1. Authorization	Project is not currently authorized
2. Constraints	Inlet impacts, technical uncertainty, etc.
3. Cost Savings	Not evaluated since authorized plan is not defined
4. Service Life	Not evaluated since authorized plan is not defined
5. Other Benefits	Potential reduced dredging
6. Priority	Low
7. Tier Level	Tier 3
8. Next Steps	Detailed study of thalweg relocation impacts

The northern portion of North Wildwood has a recent history of beach erosion, losing more than 1,000 ft of beach and the protective dunes between 1986 and 2004. Concurrently, the beaches of Wildwood and Wildwood Crest have experienced accelerated accretion to the point that the wide beach berm clogs city stormwater outfalls.

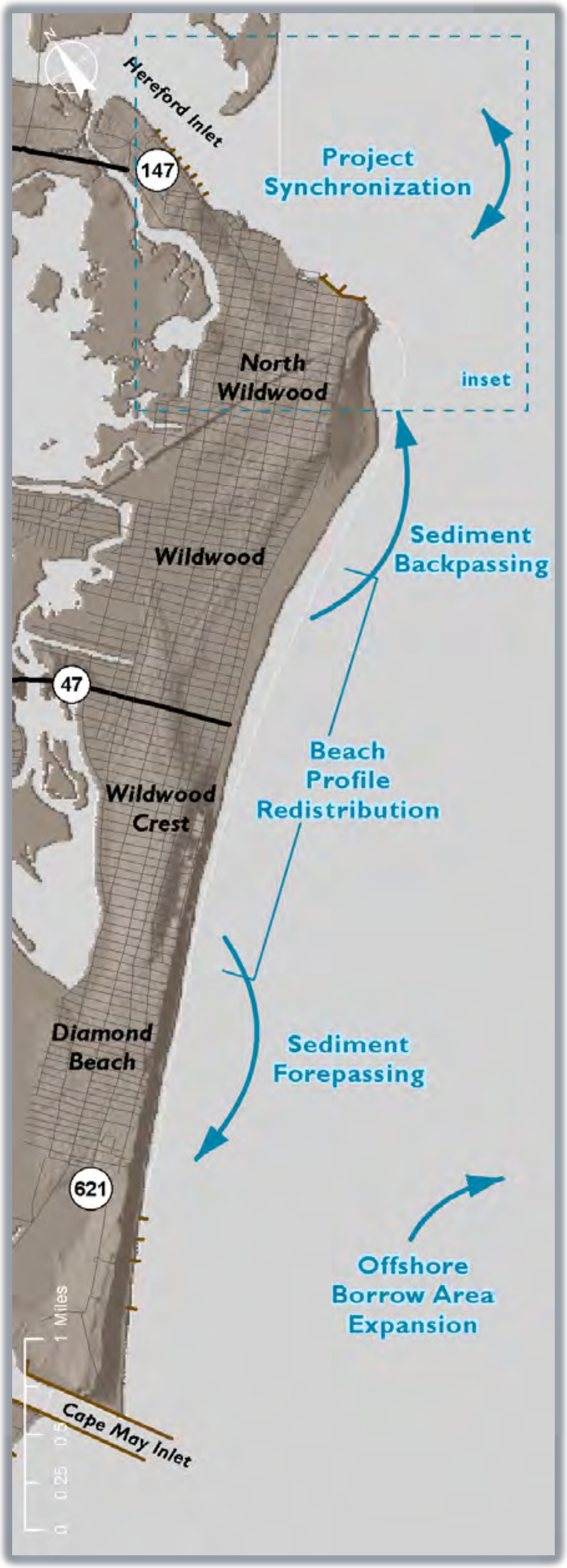
A number of studies have been conducted to evaluate alternatives at North Wildwood and Wildwood, and monitoring data have been collected that document the beach loss/gain; however, a comprehensive study that defines the cause and effect relationship between the dominant coastal processes and shoreline erosion/accretion has not been performed. This proposed strategy is intended to address knowledge gaps.

The intent of this strategy is to provide an improved understanding of the causes and nature of the significant erosion and accretion in the region. The study should be rooted strongly in applying scientific and engineering tools (i.e., data and models) to understand erosional and accretional processes. This should include coupled hydrodynamic, wave, and sediment transport modeling, supported by field observations. If the coastal processes and causes of the elevated erosions/accretions are better understood, a more advantageous mitigation approach could be implemented.

Table 117 presents a summary of the criteria evaluated for the site-specific coastal processes evaluation strategy, although many of the criteria are not applicable for this particular strategy and ranks this strategy as an intermediate priority with a Tier level of 1. Although there is no immediate cost savings associated with implementation of this strategy, future financial savings could be significant for the given investment.

Table 117. Site-Specific Coastal Processes Evaluation.

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings, potential future savings
4. Service Life	Not applicable
5. Other Benefits	An improved understanding of the coastal processes and potential mitigation options for Wildwood and North Wildwood
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study



Summary

This section presents a brief summary of the strategies presented for Wildwood. The focus is on potential cost savings and priority levels to assist identification and selection of strategies to more cost effectively manage sediment within the project area.

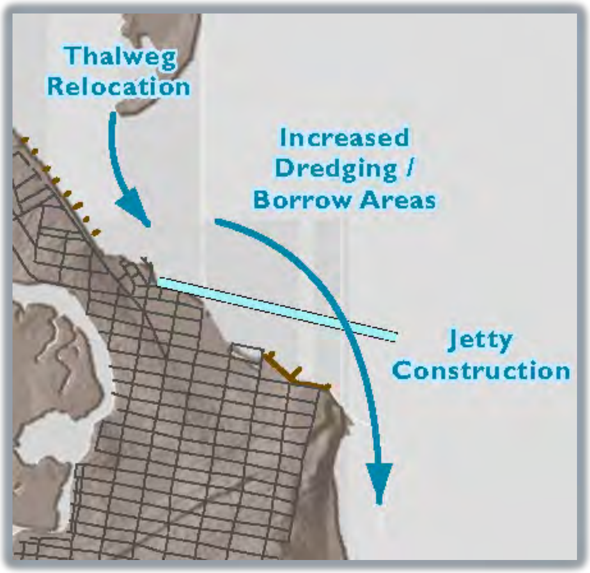


Table 118 presents an overarching summary of strategies focused on the prioritization and Tier level. The strategies presented in Table 118 are listed in order of priority and estimated ease of implementation.

Table 118. Wildwood Strategy Summary.

Strategy	Prioritization	Tier
A. Project Cycle Synchronization	High	1
C. Sediment Backpassing	High	1
B. Increased Dredging of Hereford Inlet	High	2
E. Profile Redistribution	Intermediate	2
H. Site Specific Coastal Processes Analysis	Intermediate	1
D. Sediment Forepassing	Intermediate to Low	2
F. Jetty Construction	Low	3
G. Thalweg Relocation	Low	3

CAPE MAY INLET

Project Description

The Cape May (Cold Spring) Inlet navigation project, authorized in 1907 and completed in 1911, allows for an entrance channel to Cape May Harbor that is 25 ft deep and 400 ft wide. The entrance is protected by two parallel rubblemound jetties approximately 4,500 ft long. The channel extends from the 25-ft depth curve in the ocean to a line 500 ft landward of a line joining the inner ends of the jetties (Figure 178). From there, the channel continues 20 ft deep and 300 ft wide to deep water in Cape May Harbor.

The Cape May Inlet project provides a safe navigation channel for commercial, recreational and U.S. Coast Guard use. The channel supports the largest fishery landing in New Jersey (13th largest in the U.S.), contributing $74 million dollars per year in direct fish value, and $300 million in economic value.

Figure 178. Cape May (Cold Spring) Inlet Authorized Navigation Project.

Project History

The Cape May Inlet project began with the construction of the jetties in 1911, which stabilized the inlet. Maintenance dredging of the inlet started in approximately 1919, and up until 1988, sediment dredged from the inlet was removed from the authorized channel using a hopper dredge and deposited offshore. During this period, dredging was performed on average every 2 to 3 years (Figure 179). The average annual dredge volume during this time was 60,000 cy per year. The cumulative dredge volume removed from Cape May Inlet between 1919 and 1988 was approximately 4.2 million cy. Since this time, dredging activities in Cape May Inlet have occurred on average twice per year, with the exception of 2007 when dredging was not performed. This increase in dredging frequency over the past 24 years took place as the equipment changed from a hopper dredge to sidecast dredging. The majority of maintenance dredging since 1988 utilized the sidecasting dredges, the Merritt, Schweitzer, and Fry. Typical annual sidecasting dredge quantities between 1988 and 2009 were approximately 95,000 cy per year. The only exceptions to sidecast dredging occurred in 2005 and 2009, when the Currituck hopper dredge was used to maintain the channel, placing sand west of the inlet in the nearshore zone, adjacent to US Coast Guard Training Facility beach.

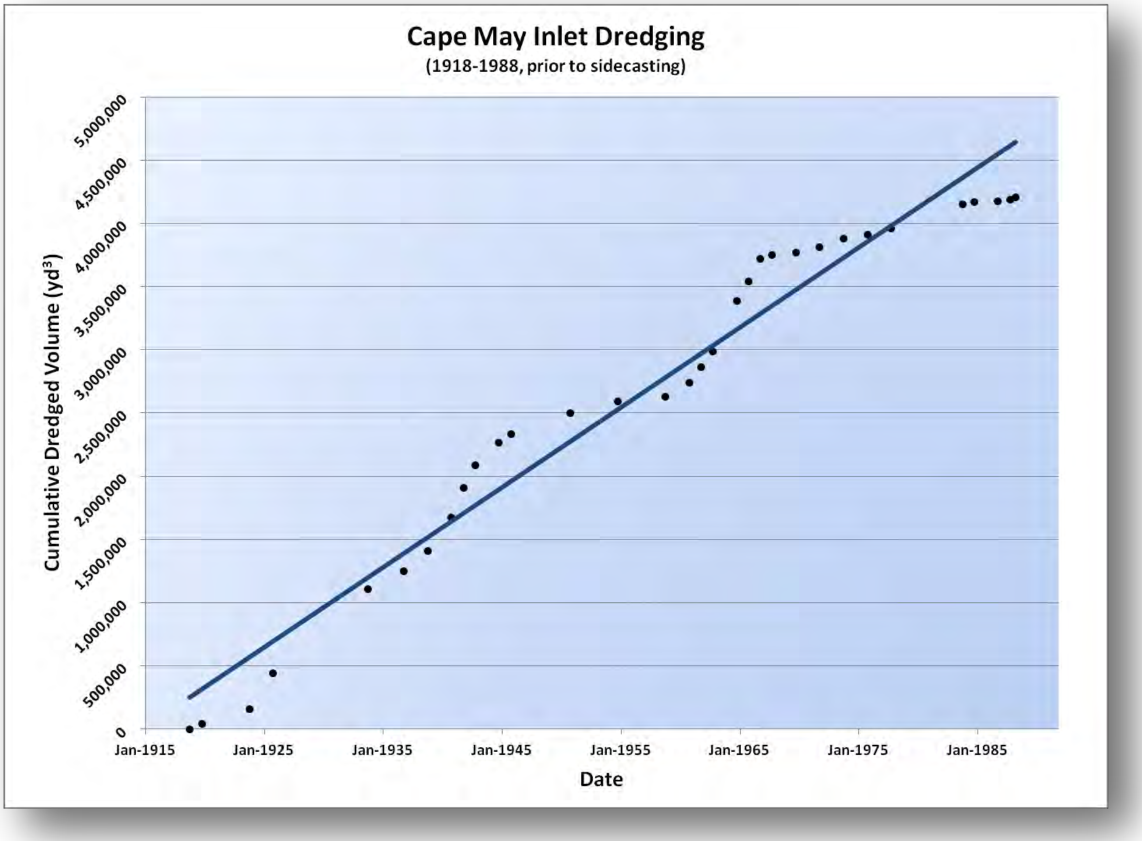


Figure 179. Cumulative dredge volume extracted from Cape May Inlet from 1919 to 1988.

In 2010, the Currituck hopper dredge removed 17,335 cy of sediment from the channel, and the USACE performed a structural condition assessment of the jetties. Additionally, emergency supplemental funds were received in November 2010 to repair a storm-damaged section of the Cape May Inlet jetties.

Project Observations

Since initial construction of the project, a number of developments have been observed:

- Jetty construction in the early 1900s caused an interruption in southerly moving littoral drift. As a result, there has been an accumulation of sediment on the updrift shoreline at the south end of 5-Mile Island, and erosion of the downdrift shoreline at the US Coast Guard Training Facility.
- Dredging is required to maintain water depths and channel widths for the Federally-authorized navigation project, despite the presence of the 4,500 ft long

jetties. Shoaling typically occurs just inside the end of the south jetty.

- Sidecast dredge equipment appears to be less efficient at maintaining the channel than a hopper dredge. Over the past 24 years since sidecast dredging has been the primary method of maintaining the channel, the frequency of dredging has increased, and the annual volume removed has increased by 35,000 cy per year.

Potential Strategies

A. Expanded Dredging Area

Expansion of the dredging area at Cape May Inlet is intended to minimize the frequency of dredging required to maintain safe navigation by increasing the width of the authorized navigation project at key location(s). This strategy could reduce operational costs associated with maintenance of the inlet by minimizing the number of times dredging is required.

The authorized project calls for an initial channel 400 ft wide, starting at the 25-ft depth contour in the ocean, and extending between the jetties to a point 500 ft landward of the inner ends of the jetties. The jetties are spaced approximately 820 ft apart, which leaves 210 ft on either side of the authorized channel that is not currently dredged. Areas of the channel that shoal most frequently are between Station 4+900 and 1+500, with the shallowest water depths forming in the 100 ft section adjacent to the updrift shoreline (3+00 to 4+500; Figure 180).

Figure 180. Cape May Inlet authorized navigation channel with areas of typical shoaling.

Expansion of the dredge footprint between Stations 4+500 and 1+500 would provide a wider channel for navigation, and could also serve as advance dredge areas in locations that receive the highest rates of sedimentation. The expanded dredge footprint could be achieved either by widening the channel or by reducing the slope of the existing dredged channel. A wider channel would provide a greater area for shoaling before encroachment on the navigation channel requires dredging, and more gradual side slopes on the dredged channel would minimize slumping of sediment back into the navigation channel. Both scenarios would require removal of a greater volume of sediment, but may minimize the frequency of dredging, which would save on the cost of channel maintenance. Table 119 presents a summary of the criteria evaluated for the expanded dredging area at Cape May Inlet strategy and ranks this strategy as a low to intermediate priority with a Tier level of 2.

Table 119. Expanded Dredge Area Strategy Summary

Criteria	Summary
1. Authorization	Requires a change to the authorized project
2. Constraints	Potential environmental studies, surveys, and impact analysis required
3. Cost Savings	May reduce dredge requirements and costs over a 50-year time horizon
4. Service Life	May reduce dredge frequency
5. Other Benefits	No additional benefits
6. Priority	Low to intermediate
7. Tier Level	Tier 2
8. Next Steps	Evaluate hydrographic surveys

B. Beneficial Re-use and Discontinue Sidecasting

This strategy intends to beneficially re-use sediment dredged from the Cape May Inlet authorized navigational project for the Cape May City authorized shore protection project and is in direct concurrence with the Regional Sediment Management Initiative. Dredging of the Cape May Inlet began in 1919, but up until 1988, the sediment dredged from the inlet was removed from the littoral system and deposited offshore. Since 1988, the USACE has been maintaining the channel using the sidecasting dredges the Merritt, Schweitzer, and Fry. Most of the work is conducted at a shoal that forms near the entrance to the inlet just inside the end of the south jetty. Typical sidecasting dredge quantities have been approximately 95,000 cy per year. In 1986-1988, and more recently in 2005 and 2009, the USACE hopper dredge Currituck has maintained the channel, and has placed sand west of the inlet in the nearshore zone seaward of the US Coast Guard Training Facility.

To determine the average annual amount of material dredged from Cape May Inlet, the USACE annual reports were used to calculate the cumulative maintenance dredging completed prior to sidecasting practices, irrespective of location or sediment type. Sidecasting volumes were not included in the analysis, since this dredging approach does not remove sediment from the inlet. Figure 178 presents the cumulative sediment volume dredged in Cape May Inlet from 1918 to 1988. The blue line in the figure depicts the linear fit of the data. The average dredge quantity throughout this period was approximately 60,000 cy per year, which is consistent with earlier USACE studies of Cape May Inlet dredging (USACE EM 1110-2-1616, 1991). Historically, non-sidecasting dredge frequency has been every 2.2 years.

The more recent dredging in Cape May Inlet, primarily completed by sidecasting, consists of a greater volume (approximately 95,000 cy/yr) and increased frequency (approximately twice a year) than historic dredging. This is likely due to the sidecast dredge methodology which does not remove sediment from between the jetties, but instead moves it approximately 100 ft beyond the edge of the navigation channel. In most cases tidal currents redistribute the material relatively quickly and return it to the channel. Discontinuing the use of sidecast dredging and returning to the hopper dredge methodology, would likely require maintenance dredging less frequently, and would ultimately reduce the total volume of sediment to be removed each time. The cumulative volume of material sidecast dredged at Cape May Inlet since 1986 is over 2.0 million cy, while the total volume removed via hopper dredging is less than 90,000 cy (Figure 181). Additionally, placement of dredged sand in the nearshore zone downdrift of the inlet would serve as a beneficial reuse by nourishing eroding beaches at the US Coast Guard Training Facility and Cape May City. This beneficial reuse would also alleviate pressures on offshore borrow sites which are currently insufficient to supply the shore protection projects at Cape May City and Lower Cape May Meadows.

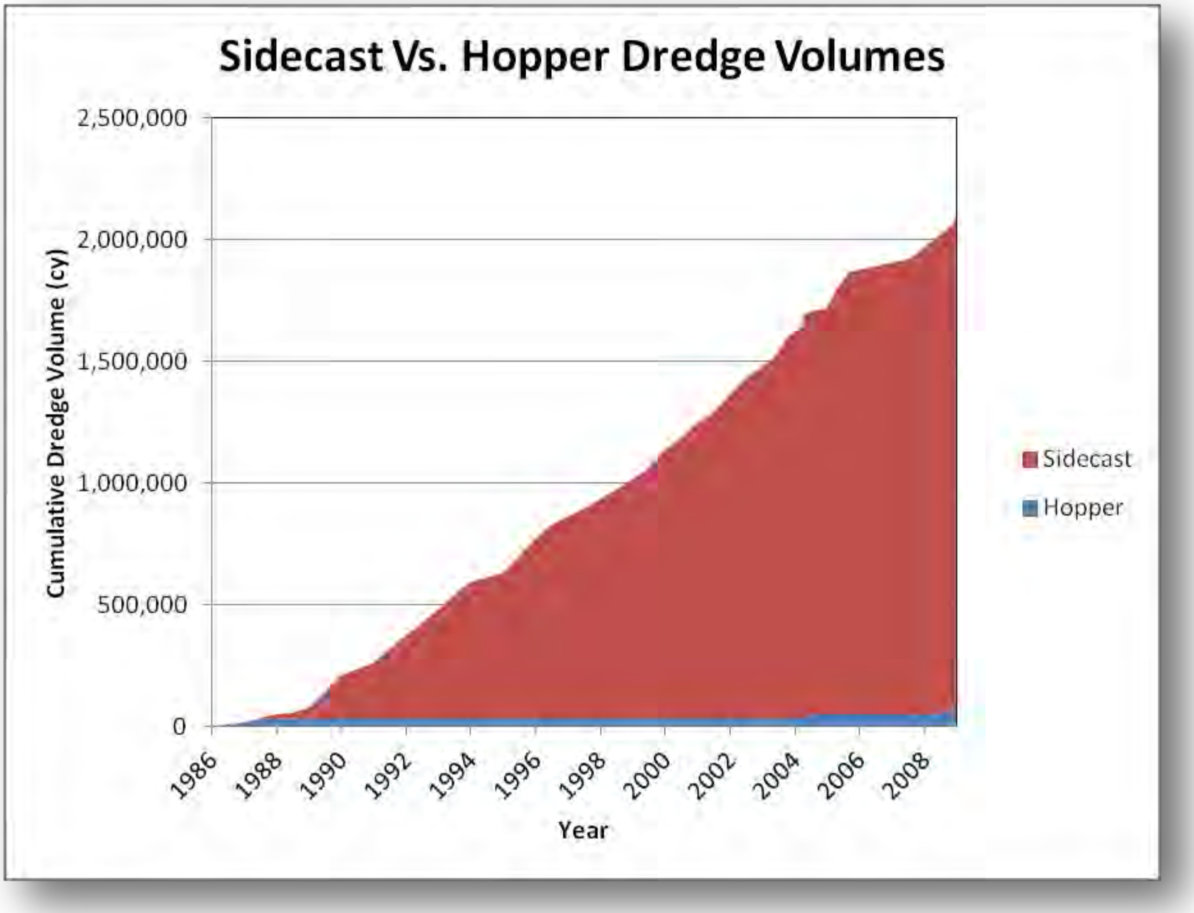


Figure 181. Comparison of sidecast and hopper dredge volumes from 1986 to 2009 at Cape May Inlet.

Assuming the dredged material is suitable for direct placement on the beach, one pathway to implement this strategy would involve using the existing Cape May Inlet navigation project authorities. Under the existing authorities, if the material is suitable, the federal government could request that the material be placed directly on the beach, rather than in an offshore location. Permits are required to do so, but they can be obtained under the authorized navigation project. If there is a cost differential to the navigation project, the State would likely have to pay the difference.

As long as the sediment dredged is compatible for beach nourishment or nearshore placement and the quantity of dredging remains approximately the same as historic levels, this strategy should be further pursued since it is directly in line with RSM strategies and initiatives. Additionally, every effort should be made to coordinate inlet dredging (navigation project) with the periodic nourishment (shore protection project) to minimize dredge mobilization costs. Table 120 presents a summary of the criteria evaluated for the beneficial reuse and discontinue sidecasting at Cape May Inlet strategy and ranks this strategy as a high priority with a Tier level of 1.

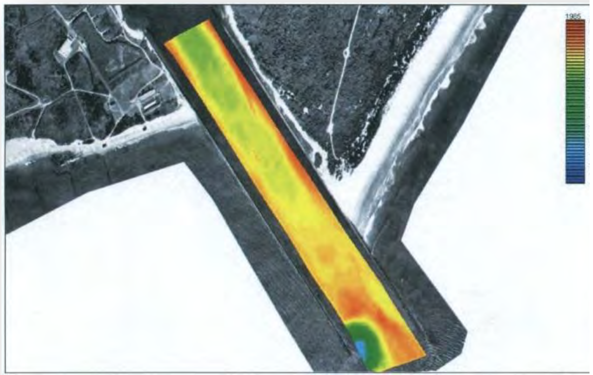
Table 120. Beneficial Reuse and Discontinue Sidecasting Strategy Summary

Criteria	Summary
1. Authorization	Implement under The Cape May Inlet to Lower Township Storm Damage Reduction Project
2. Constraints	Minimal since dredge sediments have been beneficially reused in the past
3. Cost Savings	Moderate over a 50-year time horizon
4. Service Life	No change to existing service life of navigational dredging or shore protection project
5. Other Benefits	Reduce frequency of dredging by discontinuing sidecasting and removing sediment from inlet area. Reduced offshore sediment source requirements. Interagency and state team building, RSM initiative
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Use value engineering to implement

C. *Characterize Shoal Formation*

This strategy is intended to characterize the frequency, location, and volume of typical shoal formation at Cape May Inlet. The goal of the strategy is to identify the primary cause(s) for shoaling so that inlet management practices can be optimized. Existing information indicates that shoals most commonly form near the entrance to the inlet. This shoaling is essentially confined to a zone near the ocean entrance, specifically between Stations 3+000 and 4+900 on the north side of the channel and between Stations 3+400 and 4+100 on the south side of the channel (Figure 182).

The last thorough characterization of shoal formation analyzed data from the period of 1965 to 1986. Although this study determined that an average amount of 11,000 cy per year were contributing to shoal formation, this study only analyzed the period when hopper dredging was the norm. Given that regular practices have changed, and more than 25 years have elapsed, it is crucial that an updated characterization of shoal formation be performed.



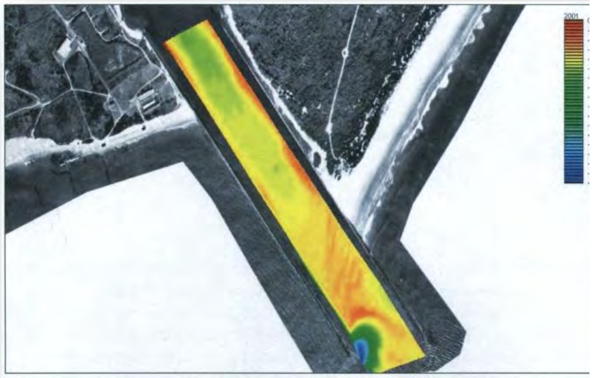


Figure 182. Historical bathymetric data for Cape May Inlet showing shoal locations. Top: 1985. Bottom: 2001.

Two principle analyses are required, to fully characterize the shoal formation. The first task includes an analysis of hydrographic surveys of the inlet to define specific shoaling problem areas and to derive estimates of shoaled quantities and rates. The second task consists of a field investigation of the inlet to define the spatial distribution of sediment types in the shoals.

Hydrographic surveys from 1986 through the present should be obtained for the inlet area. These surveys should exist from periodic channel examinations, as well as pre-dredge and post-dredge surveys. The following parameters should be calculated from the time series of hydrographic surveys: depth change over the interval between surveys, shoaling rate for each interval, and the volumetric equivalent of the depth change by area. Positive depth changes (depth decreasing over time) indicates shoaling, whereas negative depth changes (depth increases over time) represents dredged or scoured areas. Such analyses should provide a detailed basis for tracking the frequency, location, and volume of shoal formation, allowing for appropriate management decisions to be made about channel maintenance.

Field investigation is then recommended, because hydrographic survey data by itself is not sufficient to reliably identify the sediment types that are present in various segments of the project that experience shoaling. The identification of the types of sediment that accumulate is a critical parameter in identifying the source of shoaling.

Given the necessity of current and accurate data for making the best management decisions, this strategy should be pursued. Table 121 presents a summary of the criteria evaluated for characterizing shoal formation at Cape May Inlet strategy and ranks this strategy as a intermediate priority with a Tier level of 1.

Table 121. Characterize Shoal Formation Strategy Summary

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings; potential future savings
4. Service Life	No change to existing service life of navigational dredging or shore protection project
5. Other Benefits	An improved understanding of the coastal processes and potential management options for Cape May Inlet
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study

D. Sediment Bypassing

This strategy is intended to determine the feasibility of performing a sediment bypass operation around Cape May Inlet. As long ago as 1976, the plan for periodic nourishment of Cape May City included bypassing sand from north to south across Cape May Inlet. Plans that were developed in the 1980s included the use of the updrift fillet north of Cape May Inlet as the source of sand for periodic nourishment of Cape May City. However, this has never been accomplished, and all initial construction and periodic nourishment sand for the Cape May City project has been obtained from offshore borrow sites, or from land based sources. No sand has yet been bypassed across Cape May Inlet to Cape May City.

This strategy would involve implementation of sediment bypassing to move material from the northerly updrift beaches and jetty fillet region of Cape May Inlet, while at the same time providing material to nourish eroding beaches downdrift of the inlet. The strategy would also minimize sedimentation in the inlet and reduce the need for maintenance dredging.

A number of previous studies evaluated conceptual designs and methodologies for bypassing sediment around Cape May Inlet (USACE, 2004a; USACE, 1991; USACE, 1987). Additionally, the Phase I General Design Memorandum (USACE, 1980) indicated that the updrift fillet of Cape May Inlet should be considered for periodic nourishment of Cape May City. Therefore, sediment bypassing of Cape May Inlet has been considered a potential option for decades, but has yet to be implemented or demonstrated.

Various bypassing alternatives have been considered at the conceptual design level and have been evaluated in preliminary analyses. For example, the Philadelphia District of the (USACE, 1980) evaluated a fixed bypass plant similar to the one at Indian River Inlet (Figure 183). A floating dredge plant using Cape May fillet sediment and a floating dredge plant have also been considered. Previous studies (USACE, EM 1110-2-1616, 1991) also evaluated a fixed bypass plant and dredge adjacent to the updrift Cape May Inlet jetty.

Figure 183. Indian River Inlet, Delaware fixed bypassing system (Photo courtesy of Tony Pratt, DNREC).

For this preliminary analysis, it is assumed that a semi-mobile bypass system would be installed to bypass sand around Cape May Inlet, as a baseline approach to potential bypassing. Additional alternatives (e.g., a floating dredge plant) could also be considered in a more detailed analysis of potential bypassing approaches if this strategy of sediment bypassing is further pursued. The following cost estimates for a fixed bypass system were developed by the USACE (2004a), and are intended to provide a first-order estimate of cost impacts:

- An initial construction cost of $6,345,000 for the fixed bypass plant.
- O&M costs of $613,000 annually. Bypassing efforts would take place from September to April, 5 days per week, 6

hours per day, bypassing between 150,000 – 180,000 cy/yr.

- Replacement of the pump system every 12-13 years at a fixed cost of $600,000.
- Refurbishing/replacement of the system at year 25 for $6,345,000.

This strategy would result in a cost savings of approximately $25 million over a 50-year time horizon, assuming that approximately 150,000 – 180,000 cy of sediment would be bypassed each year to match the authorized periodic nourishment cycle. This cost savings is based on a dredge cost estimate of $8.75/cy. The cost savings does not include the additional savings that would be realized due to the reduction in other source material needed for beach nourishment for Cape May City. The need for other nourishment sources would be significantly reduced due to the delivery of bypass material.

Based on the recent sediment budget completed for the New Jersey coastline (USACE-NAP, 2006), as well as the Cape May Inlet sediment budget completed as part of this feasibility report (Cape May Inlet authorized navigational project), it is expected that there will be adequate sediment available updrift of Cape May Inlet for bypassing. In addition to reducing the navigational dredging of Cape May Inlet, this strategy provides additional benefits, including, but not limited to:

- A new and steady source for beach nourishment material for Cape May City.
- Reduced reliance on offshore borrow sites, of which currently permitted borrow sites are becoming depleted.
- Minimizing environmental impacts to offshore borrow sites.
- Promoting RSM approach through appropriate redistribution of sediment already in the littoral system.
- Reduced sediment surplus at Wildwood, which may assist in alleviating clogged storm water outfalls, beach access length, and ponding of water in low lying berm regions.
- Improved stakeholder relations and community team building.

If bypassing sand can be shown to significantly alter maintenance practices and reduce costs at the inlet, then the authority exists to implement bypassing, since the federal authorization was not specific as to how maintenance should be conducted. However, prior to implementation, significant environmental clearances would be required. The property immediately updrift of the Cape May Inlet jetties is occupied by the U.S. Coast Guard; however, the property directly to the north of the Coast Guard is managed by the U.S. Fish and Wildlife Service as a National Wildlife Refuge. This property has strict regulations, and may be significantly impacted by extraction of the fillet for bypassing. Specifically, there is endangered piping plover nesting with the Coast Guard property areas. Impacts and potential mitigation for this sensitive area would need to be evaluated in more detail prior to obtaining permits for project implementation.

It is recommended that this strategy be pursued further as the long-term cost savings are significant, other benefits are considerable (e.g., take advantage of beach compatible sediment already in the system, reduce or eliminate dependence on offshore sediment sources, reduce sediment surplus at Wildwood, etc.) and the approach reduces the need for maintenance dredging in the Cape May Inlet. Next steps would involve a more detailed study of potential impacts caused by fillet extraction on adjacent beaches, finalization and design of a demonstration project, and determining the right authorization approach and pathway to implement the bypassing project. Table 122 presents a summary of the criteria evaluated for sediment bypassing at Cape May Inlet strategy and ranks this strategy as a high priority with a Tier level of 2.

Table 122. Sediment Bypassing Strategy Summary

Criteria	Summary
1. Authorization	May reduce maintenance requirements of Cape May Inlet navigational project, making authorization less problematic. Additionally, value engineering could be applied to implement.
2. Constraints	Significant environmental questions remain (e.g., endangered species habitat). Need to check sediment compatibility
3. Cost Savings	Moderate over a 50-year time horizon
4. Service Life	Reduced navigational dredging requirements for Cape May Inlet.
5. Other Benefits	Reduced maintenance dredging. Improved management of sediment in littoral system. Reduced sediment surplus at Wildwood. Improved stakeholder relations
6. Priority	High
7. Tier Level	Tier 2
8. Next Steps	More detailed study of potential impacts caused by fillet extraction. Finalize and design project. Determine authorization approach for construction.

E. Improve Local Sediment Budget

This strategy intends to produce an improved local sediment budget for the Cape May Inlet area. A sediment budget can be a useful tool in investigating observed coastal changes and estimating future changes and management alternatives. It can also be a potential tool to help solve local sediment-related problems by designing solutions that take into account a regional strategy.

A sediment budget accounts for all sediment movement, both natural and mechanical, within a defined area over a specified period of time. The defined area is represented by a series of control volumes. Each control volume represents an area of similar geographic and littoral characteristics. Sediment fluxes connect each control volume to one another and they represent either a sediment source or sink to the control volume. Sediment sources include activities or processes such as beachfills, longshore transport, shoreline erosion, and inlet shoal growth. Sediment sinks include longshore transport, shoreline accretion, dredging activities, and inlet shoal reduction. A balanced sediment budget indicates that the sediment sources, sinks, and net change within each individual control volume equals zero.

Once the control volumes are established, the following information should be gathered and analyzed to develop an improved local sediment budget:

- Historical shoreline change should be quantified using digitized historical aerial photos.
- Potential longshore transport rates due to waves should be quantified.
- Hydrographic surveys should be analyzed to quantify changes at inlet shoals.
- Dredging records for the inlet should be compiled and used to calculate annual dredge rates. The method of dredging should also be documented (e.g., hopper vs. sidecast) so that shoaling rates can be adjusted to reflect complete removal of

- Sediment from the inlet (hopper) versus redistribution of sediment within the inlet (sidecast).

Table 123 presents a summary of the criteria evaluated for improving the local sediment budget at Cape May Inlet strategy and ranks this strategy as an intermediate priority with a Tier level of 1.

Table 123. Improve Local Sediment Budget Strategy Summary

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings, potential future savings
4. Service Life	Not applicable
5. Other Benefits	An improved understanding of the coastal processes and potential management options for Cape May Inlet
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study

Table 124. Cape May Inlet Strategy Summary

Strategy	Prioritization	Tier
B. Beneficial Reuse and Discontinue Sidecasting	High	1
D. Sediment Bypassing	High	2
C. Characterize Shoal Formation	Intermediate	1
E. Improve Local Sediment Budget	Intermediate	1
A. Expanded Dredging Area	Low to Intermediate	2

Summary

This section presents a brief summary of all the strategies presented for the Cape May (Cold Spring) Inlet. The focus is on potential cost savings and priority levels associated with strategies that could be implemented immediately and/or further pursued to more cost effectively maintain Cape May Inlet for navigation purposes.

Table 124 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies are listed in order of priority and estimated ease of implementation.

ABSECON INLET

Project Description

The Absecon Inlet navigation project is located on the boundary between Atlantic and Ocean Counties, New Jersey. The authorized project provides for an inlet entrance 20 ft deep at mean low water and 400 ft wide (Figure 184). A channel spur 15 ft deep and 200 ft wide is also authorized from the inlet channel to Clam Creek, as well as a turning basin 15 ft within Clam Creek. The total length of the authorized channel is 1.5 miles. The project was approved by HD 375, 67th Congress and HD 504, 79th Congress.

Maintenance of this project provides a safe, reliable navigation channel for commercial, recreational and U.S. Coast Guard use. The inlet contributes to an annual fisheries value of over $24 million per year. The U.S. Coast Guard Station Atlantic City at the Clam Creek entrance also requires passage through Absecon Inlet to carry out their mission and to perform critical safety and search and rescue operations.

Figure 184. Absecon Inlet authorized navigation project.

Project History

Dredging began at Absecon Inlet in 1915. Since the jetties were constructed in the mid-1950s, the inlet has remained relatively stable. The jetty on the south side of Absecon Inlet was constructed in 1948, extended in 1962, and repaired by the State in 1983. The State project increased the elevation of the jetty from 7 to 11 ft above mean low water. Prior to 1977, maintenance dredging occurred almost every year removing an average annual volume of 140,400 cy of sand. The maximum volume removed in a single year was 790,517 cy, and the minimum volume removed was 14,510 cy. This routine dredging maintained the channel alignment straight out to the Atlantic Ocean from the inlet mouth. When regular dredging was discontinued in 1977, the channel migrated to the south due primarily to intrusion of the updrift ebb tidal shoal. In addition to the jetties, other shore protection structures along the inlet frontage include a bulkhead with stone revetment built in 1993, as well as eight (8) groins installed between 1930 and 1958.

Recently, nearby shore protection projects have required large volumes of sand to be dredged from Absecon Inlet, rendering regular maintenance dredging unnecessary. Over the past 26 years, dredging of the inlet channel to its authorized depth has been performed as part of the Absecon Island federally authorized Shore Protection Project. Initial construction of the Absecon Island Shore Protection Project used 7,000,000 cy of sand from the inlet in 2004. Storm rehabilitation in 2011 used 1,100,000 cy of sand from the inlet, and the 1st periodic nourishment of Atlantic City and Ventnor in 2012 used 1,325,000 cy of sand from Absecon Inlet.

Project Observations

Since initial construction of the project, a number of developments have been observed:

- The Clam Creek entrance experiences frequent shoaling that needs to be addressed to ensure safe navigation.
- Environmental constraints (e.g., plover habitat on the north beach – Brigantine) may preclude certain strategies or require additional permitting.
- Requirements for annual dredging to maintain the federally authorized navigation project at Absecon Inlet have been nearly eliminated by periodic ebb shoal and channel dredging for beach nourishment along Absecon Island.

Potential Strategies

A. Ebb Shoal Dredging

This strategy considers the potential benefits of focusing dredging activities in the area where an ebb shoal regularly forms. Absecon Inlet sedimentation processes and shoaling areas, studied in the 1990s, are depicted in Figure 185 (USACE, 1996). The formation of an ebb shoal on the seaward side of Absecon Inlet is the result of a combination of wave, current, and longshore transport processes. As shown in Figure 184 the shoal tends to form on the north side of the channel as it exits the inlet.

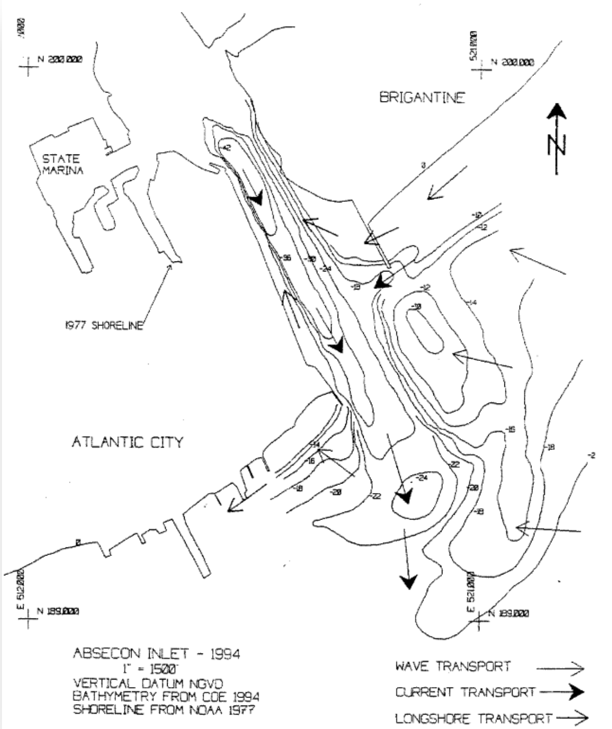


Figure 185. Sediment pathways in Absecon Inlet. (Figure taken from USACE, 1996).

Although increased ebb shoal dredging has been considered as a potential strategy for supplying sand to nearby shore protection projects on Absecon Island, recent analyses have shown this strategy may in fact create more harm than good. Since initial construction of the navigation project, the USACE has performed further hydrological studies in Absecon Inlet. These studies indicate that it may be beneficial to preserve the general structure of the Absecon Inlet ebb shoal, since removal may significantly affect flow dynamics in and around the inlet, which may lead to heightened erosion problems along the adjacent shoreline (USACE, 2011). As such, alternative offshore borrow sites G and H are now being proposed to meet the needs of the adjacent shore protection projects (Figure 186).

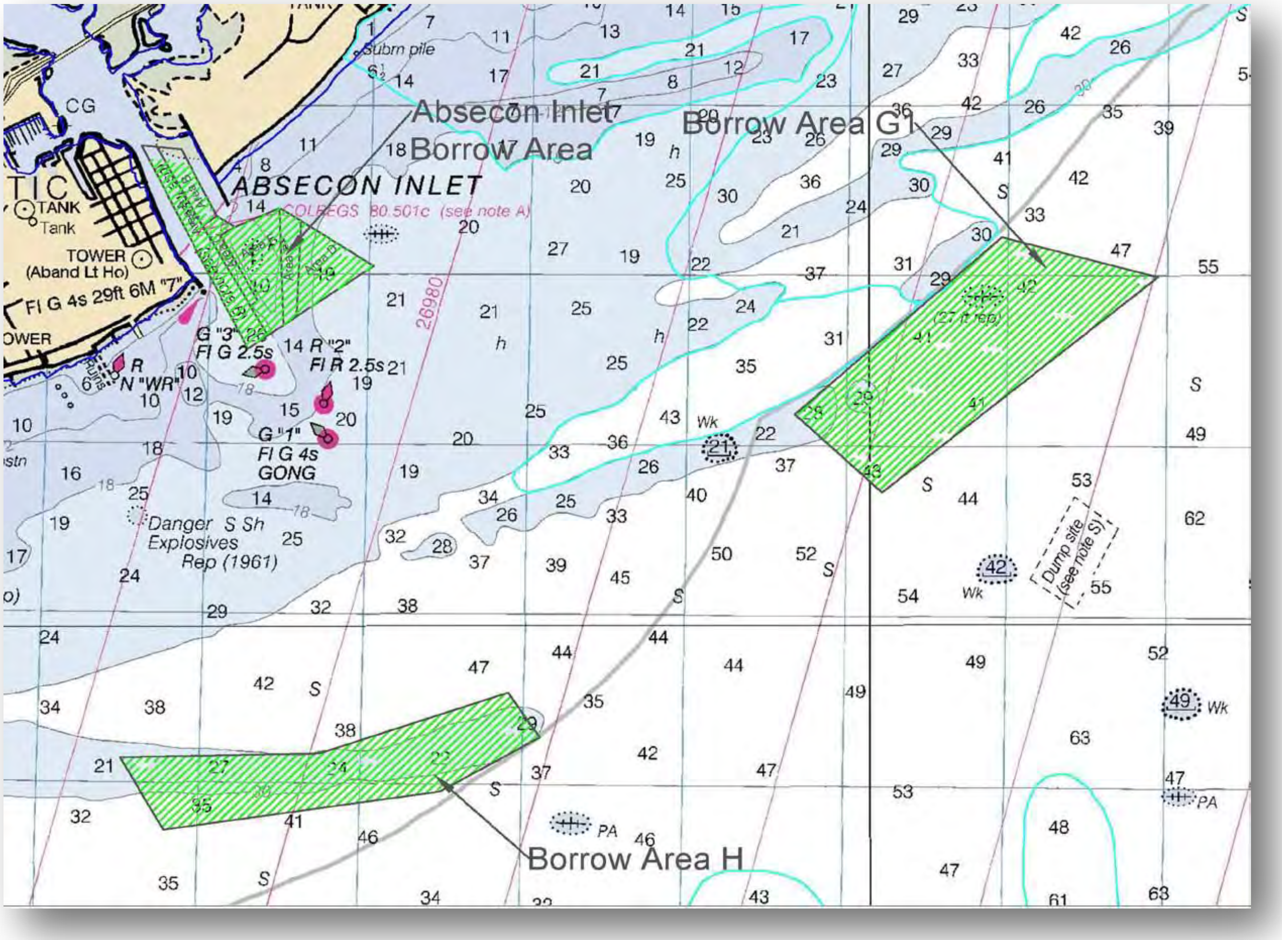


Figure 186. Location of existing borrow area in Absecon Inlet and the newly proposed Borrow Areas H and G. (Figure taken from USACE, 2011).

Absecon Inlet is relatively stable and maintenance dredging is no longer needed to maintain a safe navigation channel given the high volume of material removed in recent years for nearby nourishment projects. Given this, and the desire to maintain the ebb shoal to minimize adverse effects on local flow dynamics, the strategy of focusing maintenance dredging on the ebb shoal should be considered only if necessary to provide sand for beach nourishment projects. Alternative borrow sites, as highlighted in Figure 186, should be utilized first. Table 125 presents a summary of the criteria evaluated for the ebb shoal dredging at Absecon Inlet strategy and ranks this strategy with a low priority with a Tier level of 2.

Table 125. Ebb Shoal Dredging Strategy Summary

Criteria	Summary
1. Authorization	Requires a change to the authorized project
2. Constraints	Potential for further environmental studies, surveys, and impact analyses
3. Cost Savings	Unlikely since beneficial reuse of channel sediments on nearby beaches reduces need for maintenance dredging. Existing costs for navigation dredging are already low
4. Service Life	No change to existing service life of navigational dredging
5. Other Benefits	No additional benefits
6. Priority	Low
7. Tier Level	Tier 2
8. Next Steps	Continue beneficial reuse of channel sediments on nearby beaches

B. Bulkhead Improvements and Expansion

The bulkhead improvements and expansion strategy is intended to minimize sedimentation in Absecon Inlet caused by erosion of the adjacent shoreline. This strategy would reduce the need for maintenance dredging and would also have the added benefit of shore protection for the affected properties along the inlet frontage. Bulkhead improvements and expansion would be considered for properties along the south side of the inlet that currently do not have erosion control structures.

The northeast-facing orientation of the Atlantic City inlet frontage is vulnerable to storm damage during northeasters. This vulnerability was made evident through the damage caused by storms in 1991 and 1992. This and other storm damage has demonstrated the need to evaluate additional shore protection measures for the south side of Absecon Inlet.

Although most of the Atlantic City shoreline fronting Absecon Inlet is protected with bulkheads or revetments, there are two (2) stretches of shoreline that do not have shore protection. These include a 1,000 ft section between Oriental Ave. and Atlantic Ave., and an approximate 550 ft stretch between Melrose Ave. and Madison Ave (Figure 187). Currently these two inlet facing shorelines contain a boardwalk in various states of disrepair. Although there are a series of seven (7) groins along the Atlantic City side of Absecon Inlet, these two areas contain no other shore protection structures. The groins function to reduce the alongshore transport of sediment; however, they do not prevent erosion of the shoreline, nor do they prevent sediment from entering the navigation channel. As such, this strategy would expand and improve upon the current shore protection to secure these areas against further erosion and to provide increased protection from storm action.

Plans for such improvements have already been designed and were included in the 1996 USACE Final Feasibility Report and Final EIS for the Brigantine Inlet to Great Egg Harbor Inlet (Absecon Island) Storm Damage Reduction Project (USACE, 1996). The authorized project includes two timber sheet-pile bulkheads along the Absecon Inlet frontage. The anchored bulkheads will tie in to the existing bulkhead located along North Maine Ave. The bulkheads will be constructed to a top elevation of +14 ft NGVD29 with pile anchors and tie-backs. A revetment of 3-5 ton rough quarrystone will be constructed to an elevation of +5 feet NGVD29 on the seaward side of the bulkhead. Although included in the 1996 plan, adequate funding for the bulkhead construction has not yet been attained, and the upgraded bulkhead system has not yet been constructed. Since this strategy could provide a benefit to maintenance of the federally authorized navigation project at Absecon Inlet, it should be pursued.

Figure 187. Proposed bulkhead expansions in Atlantic City along the Absecon Inlet shoreline.

Table 126 presents a summary of the criteria evaluated for the bulkhead improvements and expansion at Absecon Inlet strategy and ranks this strategy with a intermediate priority with a Tier level of 1.

Table 126. Bulkhead Improvements and Expansion Strategy Summary

Criteria	Summary
1. Authorization	No change since the strategy is already authorized as part of the Brigantine Inlet to Great Egg Harbor Inlet, Absecon Island Shore Protection Project
2. Constraints	None since the project has already been approved
3. Cost Savings	Minimal reduction in dredge requirements and costs over a 50-yr time horizon
4. Service Life	Minimal reduction in dredge frequency
5. Other Benefits	Additional benefit of shore protection for Atlantic City frontage of Absecon Inlet
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Proceed with project when funds become available

C. *Modified Dredge Template*

This strategy considers the benefit of changing the orientation of the authorized channel for Absecon Inlet. Modifying the dredge template is intended to minimize the frequency of dredging that is required to maintain safe navigation by relocating the channel to an area of the inlet that is naturally deeper. This strategy could reduce operational costs associated with maintenance of the inlet by minimizing the frequency at which dredging is required.

The authorized project provides for an inlet entrance 20 ft deep at mean low water and 400 ft wide, extending back to the entrance channel to Clam Creek, which is maintained at 15 ft deep and 200 ft wide. However, the seaward 1,000 ft of the entrance channel is commonly less than the authorized 20 ft depth, and in some cases the channel is as shallow as 9 ft (Figure 188). The water depths are shallowest in the area where the channel cross the ebb tidal delta. By relocating the seaward end of the channel to the south, the channel would align with an area of the inlet that is naturally deeper, formed by tidal current scour. The dark blue area shaded in Figure 187 indicates the area from a March 2008 survey where water depths are 20 ft or greater. The red outline suggests a modified dredge template or orientation that would take advantage of naturally deeper areas of the inlet.

Figure 188. Potential modified dredge template at Absecon Inlet.

Modification of the dredge footprint to the south would provide a deeper channel for navigation that would be at or near the authorized dredge depth of 20 ft. This modification would also reroute the channel south of the ebb shoal, which the District has determined is beneficial for hydraulics of the inlet. In this way, ebb shoal dredging could be avoided. This strategy would not only minimize the volume of sediment that needs to be dredged, but would also preserve the ebb shoal and the stable local flow dynamics of the inlet, both of which result in a reduction in overall cost. As such, this strategy should be pursued.

Table 127 presents a summary of the criteria evaluated for the modified dredge template at Absecon Inlet strategy and ranks this strategy with a intermediate priority with a Tier level of 2.

Table 127. Modified Dredge Template Strategy Summary

Criteria	Summary
1. Authorization	Requires a change to the authorized project
2. Constraints	Potential for further environmental studies, surveys, and impact analyses
3. Cost Savings	Minimal reduction in dredge requirements and costs over a 50-yr time horizon since current maintenance dredging is limited
4. Service Life	Minimal reduction in dredge frequency since current maintenance dredging is limited
5. Other Benefits	Keeps structure of ebb shoal intact
6. Priority	Intermediate
7. Tier Level	Tier 2
8. Next Steps	Evaluate hydrographic surveys to identify optimum channel orientation

D. Beneficial Re-use

Over approximately the past 15 years, significant amounts of sediment have been dredged from Absecon Inlet and used for nourishment on Absecon Island. These dredging events have removed enough sediment from the inlet that the federal navigation channel has not required maintenance dredging for at least the same time period. Although the material dredged from Absecon Inlet has recently been used for nourishment of Absecon Island, historically the material from the inlet was not beneficially reused. Therefore, this strategy encourages the continued beneficial use of sediment dredged from Absecon Inlet for the Absecon Island authorized shore protection project. This strategy is in direct concurrence with the RSM Initiative.

The potential benefit of this strategy is assessed through evaluation of continued beneficial reuse of dredged sediment versus use of an offshore borrow site to supply the required beach nourishment. To determine the average annual amount of material dredged from Absecon Inlet, the USACE annual reports were used to calculate cumulative maintenance dredge volumes. As a conservative estimate of sediment dredged from the navigation channel, only the routine federal maintenance dredging records were used to estimate an average annual volume available. Figure 189 presents the cumulative volume removed from Absecon Inlet between 1959 and 1976. The blue line in the figure depicts the linear fit of the data. The average dredge quantity throughout this period was approximately 140,400 cy per year.

More recent dredging in Absecon Inlet from 1986 to 2012 has resulted in greater annual dredged volumes (approximately 330,000 cy/yr) than historically removed. This reflects additional sediment dredged from outside the authorized navigation footprint, as needed to support the Absecon Island shore protection project (Table 128).

Table 128. Atlantic City and Ventnor nourishment history.

Date	Volume (cy)	Project/Source
2004	7,000,000	Initial Const./Absecon Inlet
2011	1,100,000	Storm Rehabilitation/ Absecon Inlet
2012	1,325,000	1st Periodic Nourishment

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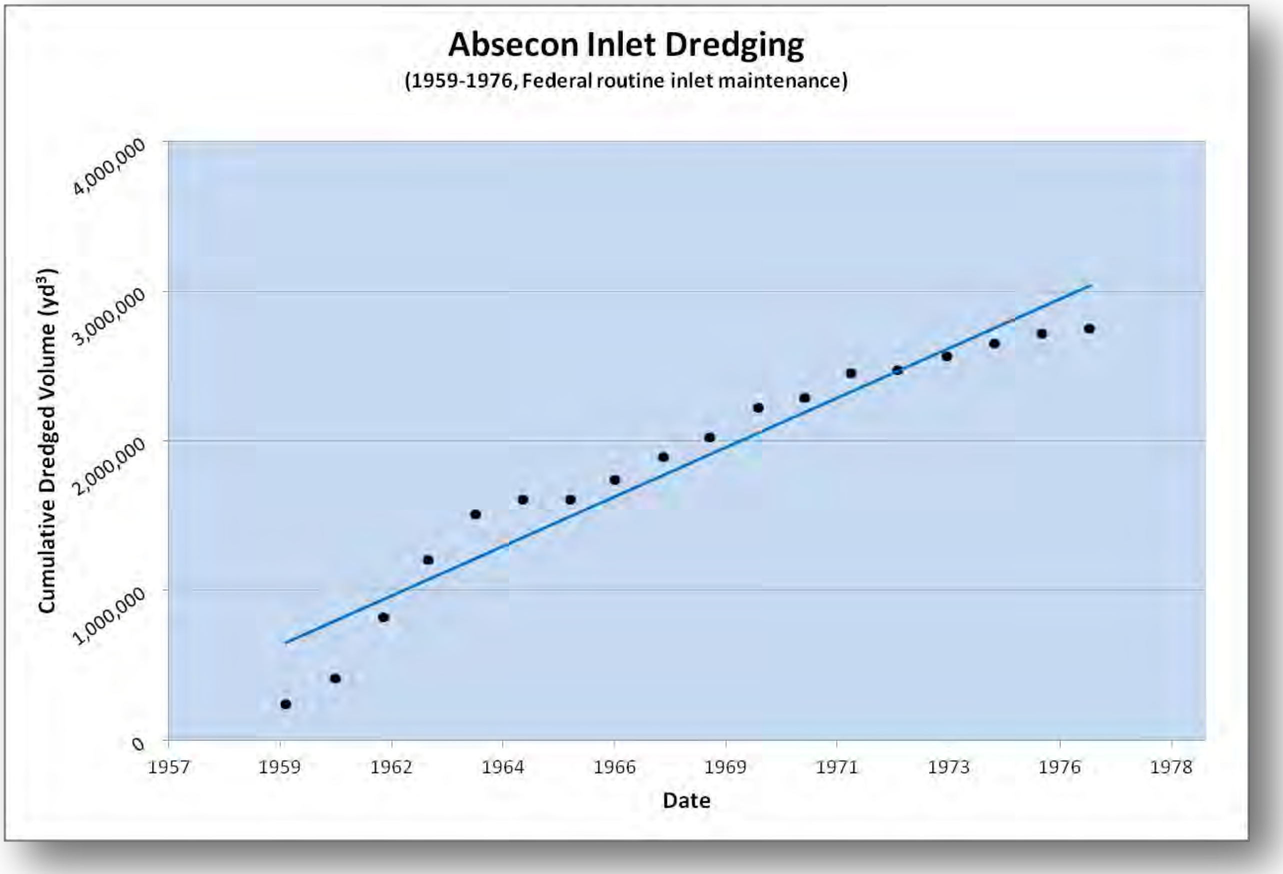

Figure 189. Cumulative dredge volume removed from Absecon Inlet from 1959 to 1976.

Early investigations performed for the Brigantine Inlet to Great Egg Harbor Inlet, Absecon Island Shore Protection Project identified two (2) potential offshore borrow areas as sources of sand for the beach. It was discovered through subsequent investigations however; that Borrow Area B did not contain a suitable grain size for the Absecon Island project, and the other offshore borrow area did not have sufficient quantities of sediment to support the nourishment project. As a result, the Absecon Inlet navigation channel and borrow area has been used as a source of nourishment material for the shore protection project.

However, the USACE would like to reduce reliance on the Absecon Inlet channel and borrow area as a source for nourishment, as a means to preserve the general structure of the Absecon Inlet ebb shoal. As such, the USACE is investigating alternative sources of material for the Absecon Island shore protection project (USACE, 2011).

Considering this strategy is already being implemented to a certain extent (Absecon Inlet is serving as a borrow site), a change to the authorization is not a limitation. Under the existing authorities, if the dredge material is suitable, the federal government can continue to request that the sand be placed directly on the beach. The required permits can be obtained under the authorized navigation project. Implementation of this strategy has relatively few additional constraints.

Table 129 presents a summary of the criteria used to evaluate the beneficial re-use of Absecon Inlet sediment strategy. This strategy is ranked as a high priority with a Tier level of 1. As long as the dredged sediment is compatible for beach nourishment or nearshore placement, and the quantity of dredging remains approximately the same as historic levels, this strategy should be pursued and implemented since it is directly in line with RSM strategies and initiatives.

Table 129. Beneficial Reuse Strategy Summary

Criteria	Summary
1. Authorization	No additional authorization needed since strategy is already implemented as part of the Absecon Island shore protection project
2. Constraints	None since the project has been performed previously
3. Cost Savings	Reduction in maintenance requirements and costs over a 50-yr time horizon since dredging would be implements as part of the Absecon Island shore protection project
4. Service Life	Reduction in dredge frequency for navigational purposes
5. Other Benefits	Reduced demands on offshore borrow sites for nourishment at Absecon Island
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Continue beneficial reuse of channel sediments on nearby beaches

E. Improve Local Sediment Budget

This strategy intends to produce an improved local sediment budget for the Absecon Inlet area. A sediment budget can be a useful tool in investigating observed coastal changes and estimating future changes and management alternatives. It can also be a potential tool to help solve local sediment-related problems by designing solutions that take into account a regional strategy.

A sediment budget accounts for all sediment movement, both natural and mechanical, within a defined area over a specified period of time. The defined area is represented by a series of control volumes. Each control volume represents an area of similar geographic and littoral characteristics. Sediment fluxes connect each control volume to one another and they represent either a sediment source or sink to the control volume. Sediment sources include activities, or processes, such as beachfills, longshore transport, shoreline erosion, and inlet shoal growth. Sediment sinks include longshore transport, shoreline accretion, dredging activities, and inlet shoal reduction. In a balanced sediment budget the sum of sediment sources, sinks, and net change within each individual control volume must equal zero.

Once the control volumes are established, the following information should be gathered and analyzed to develop an improved local sediment budget:

- Historical shoreline change should be quantified using digitized historical aerial photos.
- Potential longshore transport rates due to waves should be quantified.
- Hydrographic surveys should be analyzed to quantify changes at inlet shoals.

Dredging records for the inlet should be compiled and used to calculate annual dredge rates. The method of dredging should also be documented (e.g., hopper vs. sidecast) so that shoaling rates can be adjusted to reflect complete removal of sediment from the inlet (hopper) versus redistribution of sediment within the inlet (sidecast).

The Absecon Inlet has a number of unique characteristics that should also be considered, such as the Absecon Inlet finger shoal location, volume, and the rate of sedimentation.

Once all necessary information is gathered, this strategy should be further pursued. Having detailed knowledge of the sediment budget in and around the inlet will allow for the most efficient and cost effective management of inlet dredging (navigation project) and periodic nourishment (shore protection project) to nearby beaches. Table 130 presents a summary of the criteria evaluated for the Absecon Inlet strategy to improve the local sediment budget. This strategy is ranked as a high priority with a Tier level of 1.

Table 130. Improve Local Sediment Budget Strategy Summary

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings, potential future savings
4. Service Life	Not applicable
5. Other Benefits	An improved understanding of the coastal processes and potential management options for Absecon Inlet
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study

Summary

This section presents a brief summary of all the strategies presented for Absecon Inlet. The focus is on potential cost savings and priority levels associated with strategies that could be implemented immediately and/or further pursued to more cost effectively maintain Absecon Inlet for navigation purposes.

Table 131 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies are listed in order of priority and estimated ease of implementation.

Table 131. Absecon Inlet Strategy Summary.

Strategy	Prioritization	Tier
D. Beneficial Reuse	High	1
B. Bulkhead Improvements and Expansion	Intermediate	1
E. Improve Local Sediment Budget	Intermediate	1
C. Modified Dredge Template	Intermediate	2
A. Ebb Shoal Dredging	Low	2

BARNEGAT INLET

Project Description

Barnegat Inlet is located between Barnegat Light, Long Beach Island and Island Beach State Park in Ocean County, New Jersey. The federally authorized navigation project at Barnegat Inlet provides a 300 ft wide channel (8 ft deep) through the inlet and 10 ft deep channel through the outer bar. A channel of suitable hydraulic characteristics extends in a northwesterly direction from the inlet throat to Oyster Creek, and then to deep water in Barnegat Bay. A channel 8 ft deep and 200 ft wide is also authorized between the main inlet channel and Barnegat Light Harbor (Figure 190). The original project authorization also included two converging stone jetties to protect the inlet channel. The Barnegat Inlet project was adopted as HD 73-19 in 1935 and modified as HD 74-85 in 1937 and HD 79-358 in 1946. Initial construction of this project was completed in 1940.

The federal navigation project at Barnegat Inlet is critical to a large fishing fleet consisting of full time commercial, charter, and recreational vessels. These vessels contribute $30 million of economic value to the nation, and an annual fisheries value of over $23 million per year. The US Coast Guard designates the facility at Barnegat Inlet as "Surf Station" due to the hazardous inlet conditions. The Coast Guard requires safe passage through the federal channel to fulfill their Homeland Security mission, as well as critical life safety, search and rescue operations.

Figure 190. Barnegat Inlet Authorized Navigation Project.

Project History

Since original construction of the arrowhead jetties at Barnegat Inlet in 1939-1940, a number of engineering activities have taken place in an effort to improve navigational safety and minimize maintenance of the channel. In 1943 a sand dike was constructed on the bay side of the inlet eliminating one interior channel and reducing the minimum cross-sectional area of the inlet. The north jetty was raised and made impermeable in 1974 and numerous dredging activities in the 1970s and 1980s were completed to keep the inlet navigable.

In 1985 the Supplemental Appropriation Act contained language stating that the existing project was not working as projected and, in fact, had created a hazard to navigation. As a result, the following administratively approved modifications were constructed in 1991 as design deficiency measures: a new south jetty 4,270 ft in length along an alignment generally parallel to the existing north jetty, and a navigation channel 300 ft wide to a depth of 10 ft below mean low water.

Dredging quantities at Barnegat Inlet were at a minimum in 1991 at about 170,000 cy following completion of the new south jetty. Annual dredging volumes steadily increased over the next 6 years, reaching a maximum in 1997 of about 355,000 cy. Since this time dredging volumes have generally decreased, with the exception of 2002 and 2003 when greater dredge volumes were required for channel maintenance. Since completion of the south jetty the inlet has required dredging between one and four times per year. The average annual removal volume over the past seven years has been 129,750 cy.

This inlet is most frequently dredged with the hopper dredge Currituck, and material is placed in the nearshore zone at Long Beach Island.

Project Observations

Since initial construction of the project and realignment of the south jetty, a number of developments have been observed:

- A large ebb tidal shoal tends to form in the ocean to the south of the inlet entrance.
- The flood shoals at Barnegat Inlet are extensive, forming as a result of the flood tidal dominant system.
- Barnegat Inlet is located within a sediment transport nodal zone that divides predominantly southward moving longshore transport from northward moving longshore transport. Depending on regional conditions, the nodal zone can be located to the north or south of the inlet. Consequently, Barnegat Inlet tends to act as a sediment sink, with material accumulating in and around the navigation channel.
- Realignment of the south jetty and dredging of the main channel in 1991 was expected to create a self flushing system that would not require maintenance dredging. Although annual dredging is still necessary to maintain the channel, navigation safety has improved since the shoals do not shift as they did prior to jetty reconstruction.

Potential Strategies

A. Expand Dredging Area

Expansion of the dredging area at Barnegat Inlet is intended to minimize the frequency of dredging required to maintain safe navigation by increasing the width of the authorized navigation project at key location(s). This strategy could reduce operational costs associated with maintenance of the inlet by minimizing the number of times dredging is required.

The authorized project calls for an initial channel 300 ft wide with depths of 8 ft through the inlet and 10 ft through the outer bar. A channel around the flood shoal complex in a northwesterly direction from the inlet throat to Oyster Creek is also maintained. The jetties are spaced 1,000 ft apart at the inlet entrance and approximately 1,800 ft apart at the ends closest to Barnegat Bay. The channel location is offset slightly closer to the north jetty, although shoaling of the navigation channel still occurs from the south side. Shoaling from the flood tidal delta also encroaches on the channel as it sweeps to the southwest past Barnegat lighthouse (Figure 191).

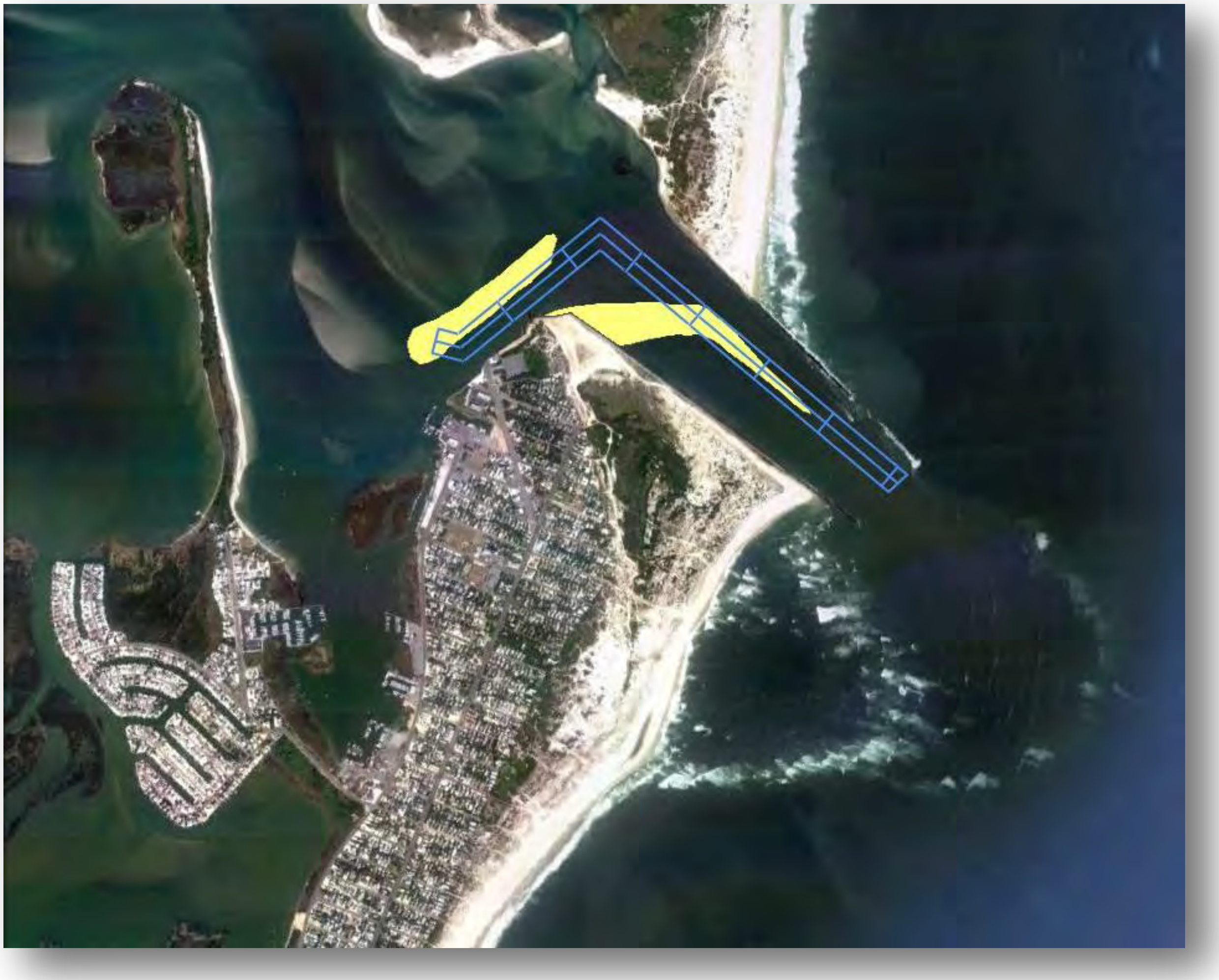

Figure 191. Typical shoal locations at Barnegat Inlet.

Expansion of the dredge footprint in the shoal locations shown in Figure 191 would provide a wider channel for navigation, and could also serve as advance dredge areas in locations that receive the highest rates of sedimentation. The expanded dredge footprint could be achieved either by widening the channel or by reducing the slope of the existing dredged channel. A wider channel would provide a greater area for shoaling before encroachment on the navigation channel would require dredging.

Also, more gradual side slopes on the dredged channel would minimize slumping of sediment back into the navigation channel. Both scenarios would require removal of a greater volume of sediment, but it may minimize the frequency of dredging, saving channel maintenance costs. Table 132 presents a summary of the criteria evaluated for the expanded dredge area at Barnegat Inlet strategy and ranks this strategy as a low to intermediate priority with a Tier level of 2.

Table 132. Expand Dredge Area Strategy Summary

Criteria	Summary
1. Authorization	Requires a change to the authorized project
2. Constraints	Potential environmental studies, surveys, and impact analysis required
3. Cost Savings	May reduce dredge requirements and costs over a 50-year time horizon
4. Service Life	May reduce dredge frequency
5. Other Benefits	No additional benefits
6. Priority	Low to intermediate
7. Tier Level	Tier 2
8. Next Steps	Evaluate hydrographic surveys

B. Beneficial Re-use

This strategy intends to beneficially reuse sediment dredged from the Barnegat Inlet authorized navigation project for the Long Beach Island shore protection project. This strategy is in direct concurrence with the Regional Sediment Management Initiative.

Maintenance dredging of the federally-authorized project at Barnegat Inlet is required approximately one to four times per year to maintain safe navigation. The cumulative volume of material removed from Barnegat Inlet since 1986 is shown in Figure 192. The blue line in the figure depicts the linear fit of the data. The average dredge quantity throughout this period was approximately 240,440 cy per year for the period 1986 to 2009.

Recent dredge requirements over the past seven years have been lower, averaging approximately 129,750 cy/yr. The reduced dredge requirement can be attributed to reconstruction of the south jetty which minimized sand transport into the channel. The inlet reconfiguration also altered the flow dynamics which deflated the flood tidal delta and allowed incoming sediment to move further into Barnegat Bay. The change in transport patterns caused reduced infilling and less dredging.

Maintenance dredging at Barnegat Inlet since 1992 has been conducted almost exclusively with the USACE hopper dredge, the Currituck. Dredged materials have been placed in the nearshore zone south of the inlet near the community of Barnegat Light. Although this approach helps to maintain navigational safety in the inlet, and potentially makes sand available for onshore transport to Long Beach Island, the beneficial reuse could be enhanced by directly placing the dredged material on beaches south of Barnegat Inlet. This strategy would require hydraulic dredge equipment to move sand from the channel to the beach nourishment site.

Further investigations should be performed to identify the optimum location along Long Beach Island for placement of the dredged material. Wave transformation and sediment transport modeling could be utilized to identify the migration area of the nodal zone, and beneficial reuse planned for beaches outside (south) of the migration area. This strategy would minimize transport of sediment back towards Barnegat Inlet, and would reduce demands on offshore borrow sites for shore protection at Long Beach Island.

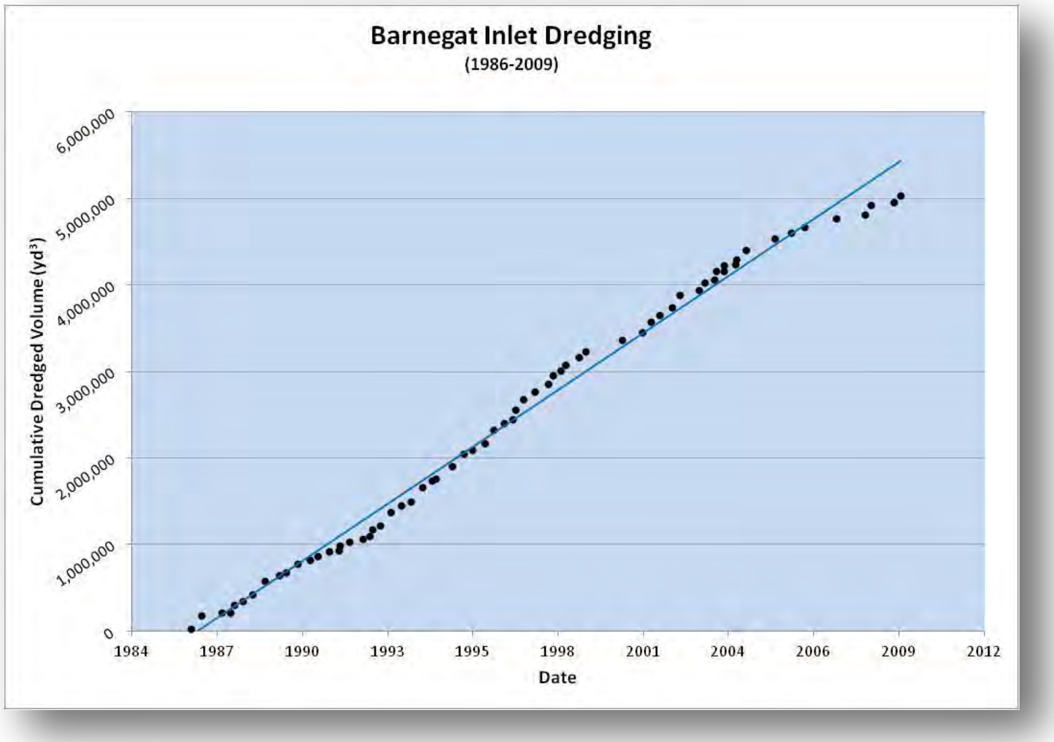

Figure 192. Cumulative dredge volume removed from Barnegat Inlet from 1986 to 2009.

Table 133 presents a summary of the criteria evaluated for beneficial reuse at Barnegat Inlet, and ranks this strategy as a high priority with a Tier level of 1.

Table 133. Beneficial Reuse Strategy Summary

Criteria	Summary
1. Authorization	No change to the authorized project required
2. Constraints	Potential for further environmental studies, surveys, and impact analyses
3. Cost Savings	Minimal reduction in dredge requirements and costs over a 50-yr time horizon since costs for direct beach placement are greater than hopper dredge
4. Service Life	No change to existing service life of navigational dredging
5. Other Benefits	Reduced demands on offshore borrow sites for nourishment at adjacent shore protection sites
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Proceed with project when funds become available

C. Characterize Navigational Channel Shoaling

This strategy intends to characterize the frequency, location, and volume of typical shoal formation at Barnegat Inlet. The goal of the strategy is to identify the primary cause(s) for shoaling so that inlet management practices can be optimized. Existing information indicates that shoals most commonly form on the south side of the channel between the jetties. Shoaling from the flood tidal delta also encroaches on the channel as it sweeps to the southwest past Barnegat lighthouse (Figure 191). Additionally, patterns of shoaling in the vicinity of the flood tidal delta have changed since the south jetty was realigned. The main channel south of the flood delta has deepened and migrated further to the southwest, and the central portion of the flood tidal delta has deflated by as much as 2.5 meters (Figure 193).

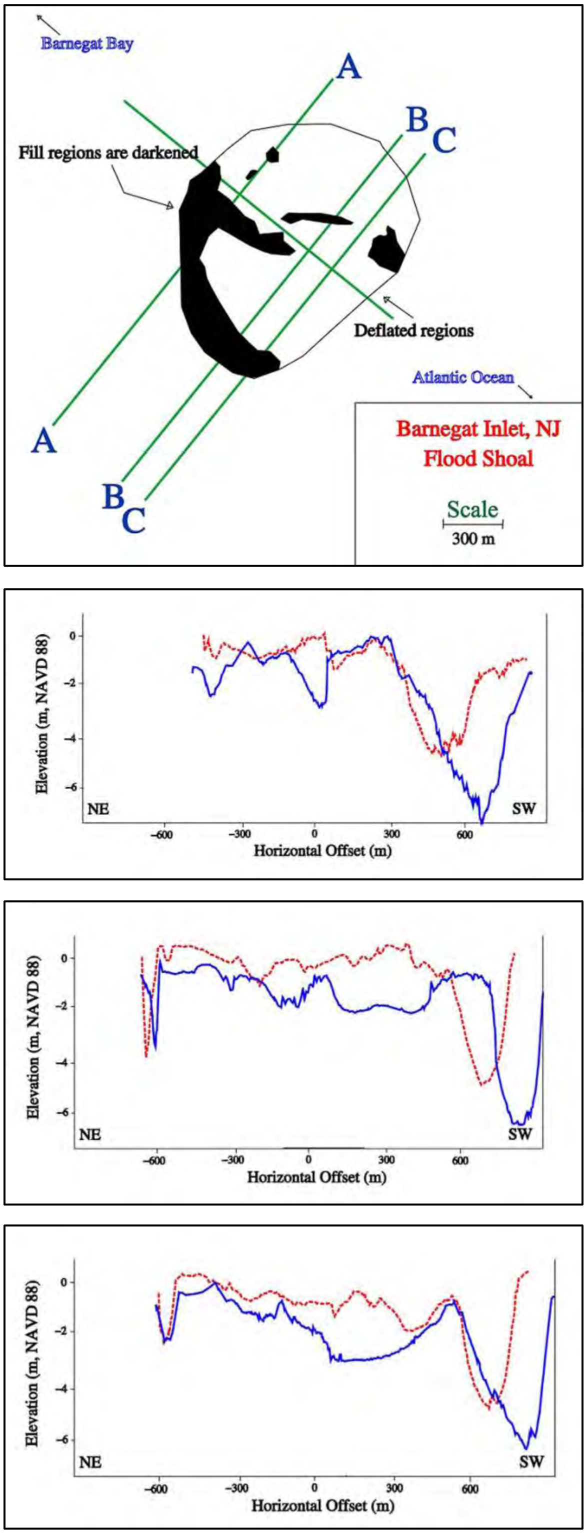

Figure 193. Bathymetric data for the flood shoal at Barnegat Inlet showing changes in morphology between 1992 and 1997 (from Seabergh et al., 2003).

To fully characterize shoal formation at Barnegat Inlet, three principle analyses are required. The first task should include an analysis of hydrographic surveys of the inlet to define specific shoaling problem areas and to derive estimates of shoaled quantities and rates. The second task should consist of a field investigation of the inlet to define the spatial distribution of sediment types in the shoals. The third task requires an evaluation of inlet hydrodynamics and the impacts of channel dredging on shoaling patterns.

Hydrographic surveys from 1992 through the present should be obtained for the inlet area. These surveys should exist from periodic channel examinations, as well as pre-dredge and post-dredge surveys. The following parameters should be calculated from the time series of hydrographic surveys: depth change over the interval between surveys, shoaling rate for each interval, and the volumetric equivalent of the depth change by area. Such analyses would provide a detailed basis for tracking the frequency, location, and volume of shoal formation, allowing for appropriate management decisions to be made about channel maintenance and/or relocation.

Field investigation is recommended because hydrographic surveys are not sufficient to reliably identify the sediment types that are present in various segments of the project that experience shoaling. The identification of the types of sediment that accumulate is critical for identifying the source of shoaling.

Finally, numerical modeling of inlet hydrodynamics should be performed to identify flow patterns and velocities during flood and ebb flow conditions. Inlet hydrodynamics during storm conditions should also be evaluated. Model results should be used to determine tidal current driven sediment transport and causes for shoal formation. Impacts of channel dredging and/or channel reorientation on inlet shoaling could then be evaluated using the numerical model. Table 134 presents a summary of the criteria evaluated for characterizing the shoal formation at Barnegat Inlet strategy and ranks this strategy as an intermediate priority with a Tier level of 1.

Table 134. Characterize Navigational Channel Strategy Summary

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings; potential future savings
4. Service Life	No change to existing service life of navigational dredging or shore protection project
5. Other Benefits	An improved understanding of the coastal processes and potential management options for Cape May Inlet
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study

D. Improve Local Sediment Budget

This strategy is intended to produce an improved local sediment budget for the Barnegat Inlet area. A sediment budget can be a useful tool in investigating observed coastal changes and estimating future changes and management alternatives. It can also be a potential tool to help solve local sediment-related problems by designing solutions that take into account a regional strategy.

A sediment budget accounts for all sediment movement, both natural and mechanical, within a defined area over a specified period of time. The defined area is represented by a series of control volumes. Each control volume represents an area of similar geographic and littoral characteristics. Sediment fluxes connect each control volume to one another and they represent either a sediment source or sink to the control volume. Sediment sources include activities or processes such as beachfills, longshore transport, shoreline erosion, and inlet shoal growth. Sediment sinks include longshore transport, shoreline accretion, dredging activities, and inlet shoal reduction. A balanced sediment budget indicates that the sediment sources, sinks, and net change within each individual control volume equals zero.

Once the control volumes are established, the following information should be gathered and analyzed to develop an improved local sediment budget:

- Historical shoreline change should be quantified using digitized historical aerial photos.
- Potential longshore transport rates due to waves should be quantified.
- Hydrographic surveys should be analyzed to quantify changes at inlet shoals.
- Dredging records for the inlet should be compiled and used to calculate annual dredge rates. The method of dredging should also be documented (e.g., hopper vs. sidecast) so that shoaling rates can be adjusted to reflect complete removal of sediment from the inlet (hopper) versus redistribution of sediment within the inlet (sidecast).

Table 135 presents a summary of the criteria evaluated for improving the local sediment budget at Barnegat Inlet strategy and ranks this strategy as an intermediate priority with a Tier level of 1.

Table 135. Improve Local Sediment Budget Strategy Summary

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings, potential future savings
4. Service Life	Not applicable
5. Other Benefits	An improved understanding of the coastal processes and potential management options for Barnegat Inlet
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study

Summary

This section presents a brief summary of all the strategies presented for the Barnegat Inlet project. The focus is on potential cost savings and priority levels associated with strategies that could be implemented immediately and/or further pursued to more cost effectively maintain Barnegat Inlet for navigation purposes.

Table 136 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies are listed in order of priority and estimated ease of implementation.

Table 136. Barnegat Inlet Strategy Summary.

Strategy	Prioritization	Tier
B. Beneficial Re-use	High	1
C. Characterize Navigational Channel Shoaling	Intermediate	1
D. Improve Local Sediment Budget	Intermediate	1
A. Expand Dredging and Modify Placement	Low to Intermediate	2

MANASQUAN INLET

Project Description

Manasquan Inlet is a Federal Navigation Channel located on the Atlantic Coast at the boundary between Monmouth and Ocean Counties, New Jersey. Constructed in 1930, the project provides for a channel 14 ft deep and 250 ft wide, protected by jetties and bulkheads, from the Atlantic Ocean to the inshore end of the north jetty. From there, it continues 12 ft deep and 300 ft wide to within 300 ft of the New York and Long Branch Railroad Bridge (Figure 194).

The Manasquan Inlet project provides a safe, reliable navigation channel for commercial, recreational and U.S. Coast Guard use with an annual fisheries value of over $20 million/year. During the summer months, over 500 vessels pass through the channel each day. The U.S. Coast Guard Station at Manasquan requires a safe channel to fulfill their mission and provide critical life safety, search and rescue operations.

Figure 194. Manasquan Inlet Authorized Navigation Project.

Project History

Prior to construction of the inlet jetties, Manasquan Inlet had migrated between its present location and 1 mile north (based on surveys dating back to 1839). On a number of occasions prior to jetty completion in 1931, the inlet closed completely.

Stabilization of the inlet was first attempted between 1881 and 1883 with the construction of timber jetties. These, as well as subsequent timber jetties constructed in 1922 failed. This led to Congressional authorization of the present project layout in 1930. Originally, the authorized channel was 250 ft wide and 10 ft deep between the jetties and 300 ft wide and 8 feet deep for the interior channels. In 1935, the authorized channel depth was increased to 14ft and the interior channel depth to 12 ft deep.

Through the mid-1970s, the jetties were damaged by storms and sedimentation in the inlet became a problem. Beach erosion north of the inlet and accretion to the south emphasized the impact of the jetties on the littoral system. Shoaling of the navigation channel increased as the structures deteriorated and became more permeable. Numerous repairs were attempted using armor stone of up to 12 tons, without success.

A major rehabilitation of the jetties was completed in 1982 using dolos armor units, after multiple studies demonstrated that these were more stable than natural stone or other existing concrete armor unit designs. Subsequent maintenance was performed in 1995 using concrete filled nylon bags to address the exposed stone core at the tip of the south jetty, and in 1997 using CORE-LOC armor units to rehabilitate void areas in both jetties.

Since 1998, maintenance dredging at Manasquan Inlet has been performed approximately every 1-2 years, with an average annual removal volume of 40,400 cy. The maximum volume of sand removed from the inlet was 89,775 cy in 2006, while the minimum volume was 15,000 cy in 2008. Maintenance dredging is most often performed using the government hopper dredge, the Currituck. Dredged material is then disposed at a nearshore placement site located approximately 2,000 ft north of the inlet.

Project Observations

Since initial construction of the project, a number of developments have been observed:

- Jetty construction in the early 1930s caused an interruption in northerly moving littoral drift. As a result, there has been an accumulation of sediment on the updrift shoreline at the north end of Point Pleasant Beach, and erosion of the downdrift shoreline in the community of Manasquan.
- Annual maintenance dredging volumes are relatively low as compared with the other federal navigation projects in New Jersey.

Potential Strategies

A. *Sediment Bypassing*

This strategy would determine the feasibility of performing a sediment bypass operation around Manasquan Inlet. This would involve implementation of a sediment bypassing system to move material from the southern updrift beaches and jetty fillet region of Manasquan Inlet, while at the same time providing material to nourish eroding beaches downdrift of the inlet to the north. The strategy would also minimize sedimentation in the inlet and reduce the need for maintenance dredging.

Sediment bypassing around Manasquan Inlet could be accomplished using a semi-mobile bypass system or a floating dredge plant. Based on the average annual dredge volume of 40,400 cy, a total of 2,020,000 cy of sand could be bypassed over a 50-year time horizon. Table 137 presents a summary of the criteria evaluated for the sediment bypassing at Manasquan Inlet strategy and ranks this strategy as a low priority with a Tier level of 2.

Table 137. Sediment Bypassing Strategy Summary

Criteria	Summary
1. Authorization	Requires a change to the authorized project
2. Constraints	Potential environmental studies, surveys, and impact analysis required
3. Cost Savings	May reduce dredge requirements and costs over a 50-year time horizon
4. Service Life	No change to existing service life of navigational dredging
5. Other Benefits	Supply sand directly to eroding downdrift beaches in support of the Sea Bright to Manasquan Shore Protection Project. Reduced offshore sediment source requirements. Interagency and state team building, RSM initiative
6. Priority	Intermediate
7. Tier Level	Tier 2
8. Next Steps	Use value engineering to implement

B. Beneficial Re-use

This strategy intends to beneficially reuse sediment dredged from Manasquan Inlet for the Sea Bright to Manasquan Inlet Authorized Shore Protection Project. Although less likely, dredged sediments could also be beneficially reused on the updrift Shore Protection Project, Manasquan Inlet to Barnegat Inlet. This strategy is in direct concurrence with the Regional Sediment Management Initiative.

Maintenance dredging of the federally-authorized project at Manasquan Inlet is required annually to maintain safe navigation. The cumulative volume of material removed from Manasquan Inlet since 1998 is shown in Figure 195. The blue line in the figure depicts the linear fit to the data. The average dredge quantity throughout this period was approximately 40,400 cy per year for the period 1998 to 2009.

Maintenance dredging at Manasquan Inlet has been conducted almost exclusively with the USACE hopper dredge, the Currituck. Dredged materials have been placed in the nearshore zone north of the inlet near the community of Manasquan. Although this approach helps to maintain navigational safety in the inlet, and potentially makes sand available for onshore transport to eroding downdrift beaches, the beneficial reuse could be enhanced by directly placing the dredged material on beaches north of Manasquan Inlet. This strategy would require hydraulic dredge equipment to move sand from the channel to the beach nourishment site.

Table 138 presents a summary of the criteria evaluated for the beneficial reuse at Manasquan Inlet strategy and ranks this strategy as a high with a Tier level of 1.

Table 138. Beneficial Reuse Strategy Summary

Criteria	Summary
1. Authorization	No change to authorized project required
2. Constraints	Potential for further environmental studies, surveys, and impact analyses
3. Cost Savings	Minimal reduction in dredge requirements and costs over a 50-yr time horizon since costs for direct beach placement are greater than hopper dredge
4. Service Life	No change to existing service life of navigational dredging
5. Other Benefits	Reduced demands on offshore borrow sites for nourishment at adjacent shore protection sites
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Proceed with project when funds become available

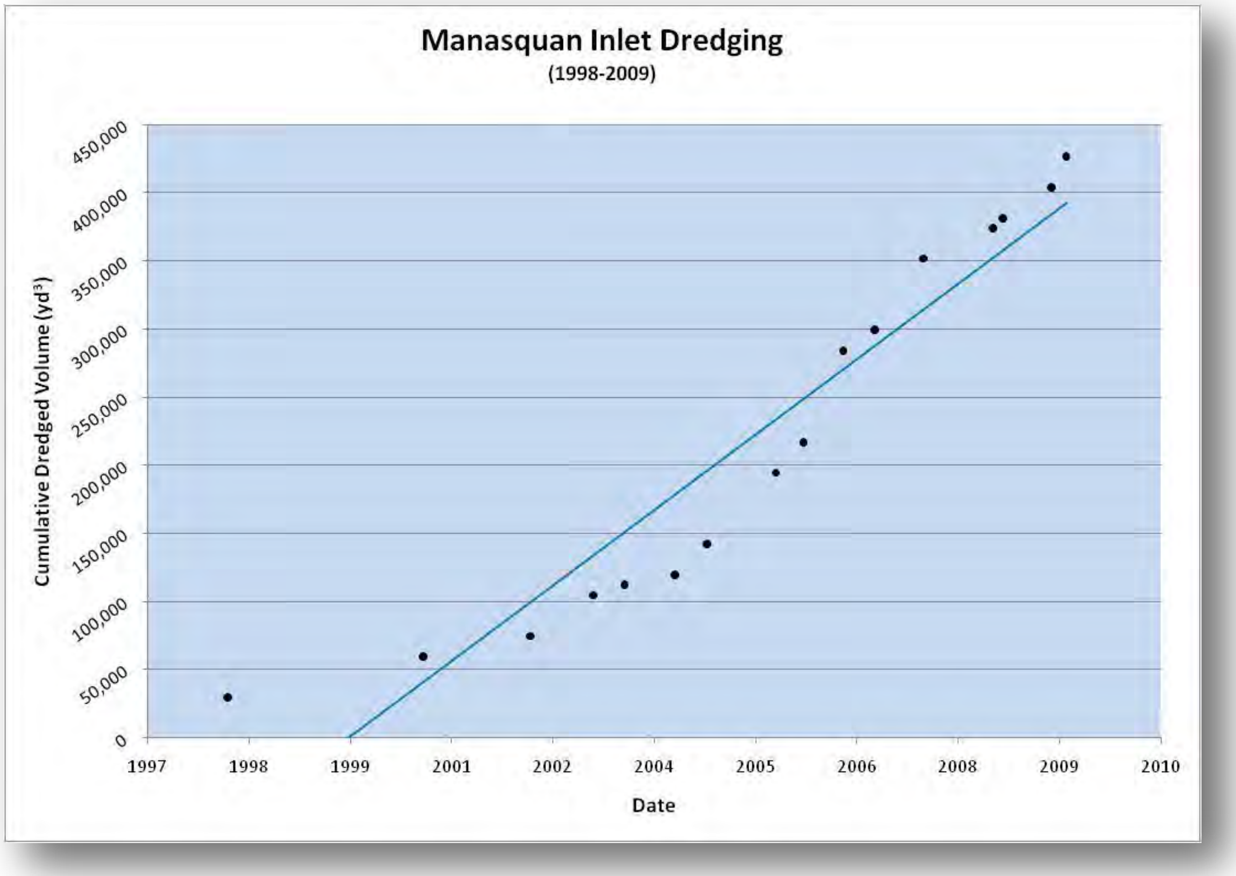

Figure 195. Cumulative dredge volume removed from Manasquan Inlet from 1998 to 2009.

C. *Modify Placement Location*

This strategy intends to consider an alternative placement location for material removed from Manasquan Inlet with a hopper dredge. Historically, dredged material has been placed in a designated disposal area located approximately 2,000 ft north of the inlet entrance because this location had been identified as the most cost effective. However, there are concerns that sediment placed in this location is being transported back into the inlet, thus requiring additional dredging.

To address this, an alternative disposal location has been identified approximately 1,000 yards further to the north (identified by the yellow square in Figure 196) that would beneficially place sand in the littoral transport system moving north, and away from the inlet. This strategy would potentially reduce the transport of sand back into the inlet and minimize maintenance dredging operational costs over the long term despite increased travel times. The new placement site would be approximately 1 mile north of Manasquan Inlet, and thus outside the influence of the inlet transport system.

The strategy of a modified placement location was identified based on coastal technical analysis and coordination between the Philadelphia and New York Districts. Table 139 presents a summary of the criteria evaluated for the modify placement location at Manasquan Inlet strategy and ranks this strategy as a high with a Tier level of 1.

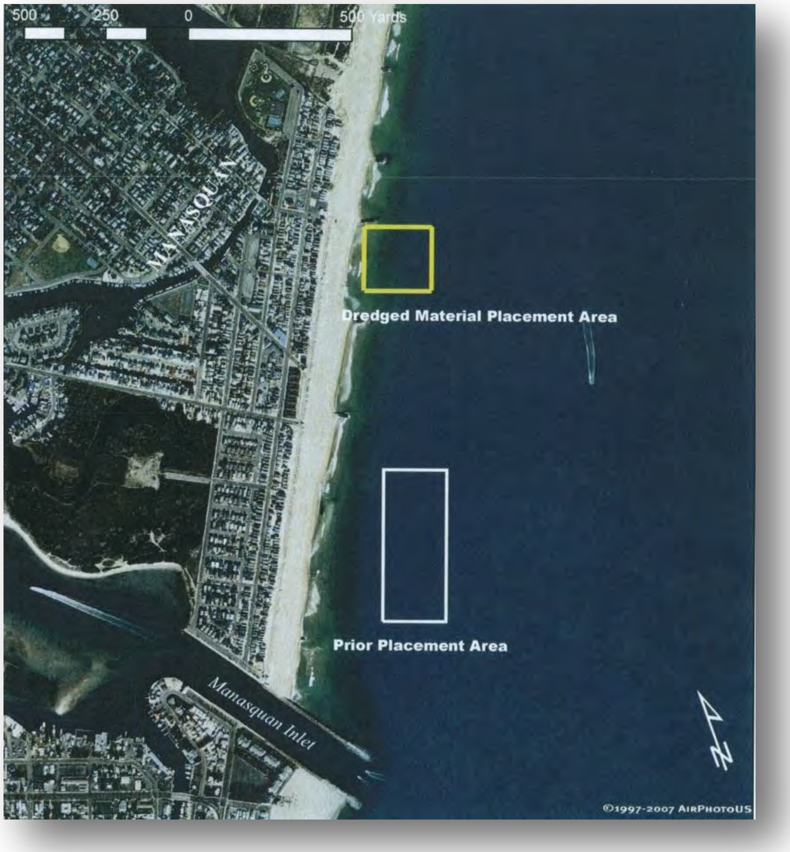

Figure 196. Alternate dredge placement sites for sediment removed from Manasquan Inlet.

Table 139. Modify Placement Location Strategy Summary

Criteria	Summary
1. Authorization	No change to the authorized project required
2. Constraints	Minimal since dredge sediments have been beneficially reused in the past; however, physical impacts at new placement site would need to be investigated
3. Cost Savings	May reduce dredge requirements and costs over a 50-year time horizon
4. Service Life	May reduce dredge frequency
5. Other Benefits	Reduced offshore sediment source requirements. Interagency and state team building, RSM initiative
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Proceed with project when funds become available

D. Improve Local Sediment Budget

This strategy is intended to produce an improved local sediment budget for the Manasquan Inlet area. A sediment budget can be a useful tool in investigating observed coastal changes and estimating future changes and management alternatives. It can also be a potential tool to help solve local sediment-related problems by designing solutions that take into account a regional strategy.

A sediment budget accounts for all sediment movement, both natural and mechanical, within a defined area over a specified period of time. The defined area is represented by a series of control volumes. Each control volume represents an area of similar geographic and littoral characteristics.

Sediment fluxes connect each control volume to one another and they represent either a sediment source or sink to the control volume. Sediment sources include activities or processes such as beachfills, longshore transport, shoreline erosion, and inlet shoal growth. Sediment sinks include longshore transport, shoreline accretion, dredging activities, and inlet shoal reduction. A balanced sediment budget indicates that the sediment sources, sinks, and net change within each individual control volume equals zero.

Once the control volumes are established, the following information should be gathered and analyzed to develop an improved local sediment budget:

- Historical shoreline change should be quantified using digitized historical aerial photos.
- Potential longshore transport rates due to waves should be quantified.
- Hydrographic surveys should be analyzed to quantify changes at inlet shoals.
- Dredging records for the inlet should be compiled and used to calculate annual dredge rates. The method of dredging should also be documented (e.g., hopper vs. sidecast) so that shoaling rates can be adjusted to reflect complete removal of sediment from the inlet (hopper) versus redistribution of sediment within the inlet (sidecast).

Table 140 presents a summary of the criteria evaluated for the strategy of improving the local sediment budget at Manasquan Inlet and ranks this strategy as an intermediate priority with a Tier level of 1.

Table 140. Improve Local Sediment Budget Strategy Summary

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings, potential future savings
4. Service Life	Not applicable
5. Other Benefits	An improved understanding of the coastal processes and potential management options for Manasquan Inlet
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study

Summary

This section presents a brief summary of all the strategies presented for the Manasquan Inlet project. The focus is on potential cost savings and priority levels associated with strategies that could be implemented immediately and/or further pursued to more cost effectively maintain Manasquan Inlet for navigation purposes.

Table 141 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies are listed in order of priority and estimated ease of implementation.

Table 141. Manasquan Inlet Strategy Summary.

Strategy	Prioritization	Tier
B. Beneficial Re-use	High	1
C. Modify Placement Location	High	1
D. Improve Local Sediment Budget	Intermediate	1
A. Sediment Bypassing	intermediate	2

SHARK RIVER

Project Description

The Shark River Inlet Federal Navigation project is located in Monmouth County, NJ connecting the small Shark River estuary with the Atlantic Ocean, and is the southern-most coastal inlet maintained by the New York District. Authorized in 1945, the inlet is stabilized by two parallel rock jetties, which are 525 ft long (north jetty) and 950 ft long (south jetty). The federal navigation project provides for an entrance channel that is 18 ft deep and 150 ft wide from the Atlantic Ocean to a point 500 ft landward of the inlet the entrance channel then connects to a channel 12 ft deep and 100 ft wide through the Main and South Channels to the Route 35 Bridge. Additionally, the channel extends 8 ft deep and 100 ft wide to the upper limit of the Belmar Municipal Boat Basin, for a total project length of approximately 1.7 miles.

Project History

Two curved jetties were initially built at the entrance of the Shark River Inlet in 1915. Between 1948 and 1951, the State of New Jersey rebuilt and realigned the jetties to extend parallel into the ocean. Additionally, a 500-ft long shore-parallel spur extends north from the north jetty. The spur was built to protect the landward end of the jetty during northeasters and to contain sediment north of the inlet.

Prior to the year 2000, the ocean entrance to Shark River Inlet required minor, infrequent maintenance dredging approximately every 7 to 10 years. As part of the Sea Bright to Manasquan Inlet Beach Erosion Control Project, in 1997 the U.S. Army Corps of Engineers placed approximately 5.3 million cy of fine to medium sand to the south of Shark River Inlet. During 1999-2000, another 3.1 million cy of sand was placed to the north of the inlet, and in the fall of 2002, another 225,000 cy of sand was placed north of the inlet. Following these large-scale beach nourishment projects, Shark River Inlet began to experience rapid shoaling at the entrance, dramatically increasing channel maintenance dredging requirements. Longshore transport of the nourishment sand has caused growth of an ebb-tidal shoal at the entrance to the inlet. To maintain the entrance channel for navigation, dredging is now needed semi-annually, despite the initial prediction that sand placed as part of the adjacent shore protection projects would only increase the maintenance dredging to a 2 to 3 yr cycle (Beck and Kraus, 2011a).

The ebb shoal at the entrance to the inlet has continued to develop requiring frequent dredging. Most recently the navigation channel through the ebb shoal was dredged in 2011. The same area was also dredged in June 2010, and then on average every 6 months going back to 2006. Each time, approximately 20,000 to 25,000 cy of dredged material was placed north of the L-jetty as a near shore berm in approximately 10-14 ft of water. The maximum annual volume removed was 59,702 cy in 2008.

Project Observations

Since initial construction of the project, a number of developments have been observed:

- Until 2000, the Shark River Inlet entrance required minor, infrequent maintenance dredging.
- Between 1997 and 2000, almost 7 million cy of sand was placed as part of nourishment projects on adjacent beaches. Since then, Shark River Inlet maintenance dredging has been required semiannually.

Potential Strategies

A. Expand Dredging of Ebb Shoal

This strategy aims to expand maintenance dredging to control the recent and continued formation of the ebb shoal. Although surveys in 1995 and 1998 did not indicate the presence of an ebb shoal, accelerated channel shoaling at the Shark River Inlet entrance in recent years has occurred. The shoaling, due primarily to the transport of sand placed as part of a nourishment project, is expected to increase in volume over the next two decades to reach about 1.2 million cy (Kraus and Allison, 2009). An April 2000 survey, made after nourishment of both the south beach (1997) and the north beach (1999-2000), indicated shoal encroachment from both north and south, with considerable sand entering the entrance of the inlet from the north (Kraus, 2009).

A study performed by (Beck and Kraus, 2011a) outlines the process by which this shoal forms. Pre-dredging surveys from 2002 indicated variable, but continued encroachment into the channel by jetty-tip shoals. A 2003 survey following the 2002 dredging showed a clear channel, but with shoals directly adjacent to it. High waves and strong currents then pushed sand along these shoals and into the channel, as shown by another survey performed later in 2003. This survey showed the formation of an entrance bar, part of the horseshoe-shaped ebb shoal morphology characteristic of wave-dominated inlets. Surveys from 2005-2007 demonstrated consistent ebb shoal development. This analysis (Beck and Kraus, 2011a) indicates that the shoal accumulates at a rate of approximately 30,000 to 45,000 cy per year. As seen in Figure 197, the shoal volume increased rapidly from 1999 to about 2005. However, frequent dredging after 2006 has limited further growth.

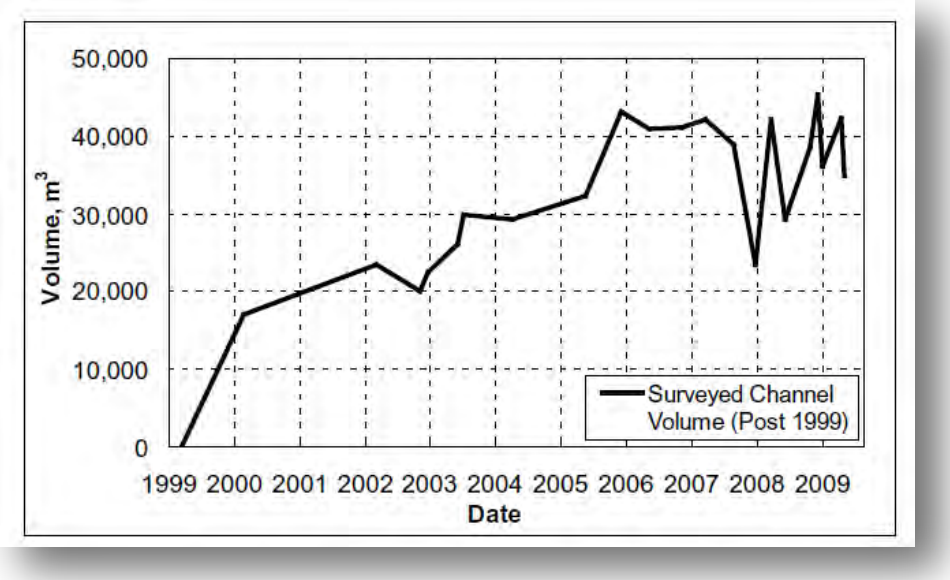

Figure 197. Volumetric change of the entrance channel to Shark River inlet (Figure from Beck and Kraus, 2010).

In general, ebb shoals will naturally bypass most of the sand arriving to them after reaching an equilibrium volume, unless the sand is intercepted. The equilibrium volume in the case of the Shark River Inlet is disruptive to navigation and increased maintenance dredging is required. To help reduce the frequency of required maintenance dredging, sand contributing to and located in the ebb shoal should be directly targeted and removed during navigation channel maintenance. That portion could be bypassed mechanically or hydraulically during periodic channel maintenance. Given the localized problem the ebb shoal creates, this strategy of expanding dredging of the ebb shoal should be further pursued.

Table 142 presents a summary of the criteria evaluated for the expansion of dredging at Shark River Inlet strategy and ranks this strategy with an intermediate priority and a Tier level of 2.

Table 142. Expand Dredging of Ebb Shoal Strategy Summary

Criteria	Summary
1. Authorization	Requires a change to the authorized project
2. Constraints	Potential for further environmental studies, surveys, and impact analyses
3. Cost Savings	Minimal reduction in dredge requirements and costs over a 50-yr time horizon
4. Service Life	Minimal reduction in dredge frequency
5. Other Benefits	Benefit of additional sand for shore protection of adjacent beaches and reduced demand on offshore borrow sites
6. Priority	Intermediate
7. Tier Level	Tier 2

B. *Jetty Extensions*

This strategy is intended to reduce the amount of sand entering the inlet system, and therefore reduce required maintenance dredging and costs, by extending the length of the jetties. Currently, the jetties on either side of Shark River Inlet are different lengths. In general, dual jetties of unequal lengths tend to introduce an asymmetry in the local current, waves, sand transport, and morphology change at inlets. To alleviate this, the northern jetty could be lengthened to focus the ebb current more centrally within the inlet, and to push the ebb shoal further offshore. To accomplish this, the northern jetty would need to be extended approximately 270 ft further offshore.

In addition to affecting the ebb current, the jetties also directly impact the sediment transport patterns and littoral drift. The south (up-drift) jetty impounds considerable quantities of sand along the beach (Kraus 2009). However, the short length of both jetties allows sand to be transported around the ends of the jetties. This allows the formation of a transverse, diagonal sand bar across the channel from the tip of the north jetty to the landward end of the south jetty. Although this bar is likely formed by the ebb current, the source of the sand in the channel is thought to be marine in origin rather than derived from the bay (Kraus, 2009). Extension of both jetties may therefore be a worthwhile consideration in an effort to reduce the amount of sand transported around the jetties and into the inlet.

Although an increase in length of the north jetty may reduce the need for ebb shoal dredging, it may also produce negative effects as well. A potential negative of this strategy is a reduction in the ability of longshore currents to bypass sand naturally, further depriving already sand-deprived beaches of incoming sand. Although this does not negate the positive effects that could be attainted through jetty extension, it requires a careful study and a detailed engineering design if this strategy is to be pursued. Table 143 presents a summary of the criteria evaluated for the jetty extensions at Shark River Inlet strategy and ranks this strategy with an intermediate priority and a Tier level of 3.

Table 143. Jetty Extensions Strategy Summary

Criteria	Summary
1. Authorization	Requires a change to the authorized project
2. Constraints	Requirement for further environmental studies, surveys, and impact analyses
3. Cost Savings	Potential reduction in dredge requirements and costs over a 50-yr time horizon
4. Service Life	Potential reduction in dredge frequency
5. Other Benefits	No additional benefits
6. Priority	Intermediate
7. Tier Level	Tier 3
8. Next Steps	Obtain funding for potential study

C. *Beneficial Re-use*

This strategy intends to beneficially re-use material dredged from Shark River Inlet during routine maintenance to provide material for nearby nourishment projects. Furthermore, since increased shoaling rates at the inlet are likely caused by transport of material from recent nourishment at adjacent beaches, it would be beneficial to retain that material for beach maintenance, rather than disposing of it offshore.

As discussed previously, prior to nearby beach nourishment projects, an ebb shoal was not present at Shark River Inlet because it is situated on a sand-deprived coast. However, following the nourishment project, shoal formation was observed. Dredging required to manage this shoal could be beneficially reincorporated into the beach nourishment projects and/or paired with a sediment bypassing routine to reestablish the littoral connection between beaches on either side of the inlet.

Currently, the material dredged from the inlet entrance, which is composed of beach-suitable sands, is placed in a nearshore disposal site located between the second and third groins located 0.6 and 1.0 km north of the inlet (Beck and Kraus, 2011a). Direct placement as beach nourishment should be pursued, and is estimated to supply approximately 31,750 cy per year of sand. Table 144 presents a summary of the criteria evaluated for the beneficial reuse at Shark River Inlet strategy and ranks this strategy with a high priority and a Tier level of 1.

Table 144. Beneficial Re-Use Strategy Summary

Criteria	Summary
1. Authorization	No change to authorized project required
2. Constraints	Potential for further environmental studies, surveys, and impact analyses
3. Cost Savings	Minimal reduction in dredge requirements and costs over a 50-yr time horizon since costs for direct beach placement are greater than hopper dredge
4. Service Life	No change to existing service life of navigational dredging
5. Other Benefits	Reduced demands on offshore borrow sites for nourishment at adjacent shore protection sites
6. Priority	High
7. Tier Level	Tier 1
8. Next Steps	Proceed with project when funds become available

D. *Improve Local Sediment Budget*

This strategy is intended to produce an improved local sediment budget for the Shark River Inlet area. A sediment budget can be a useful tool in investigating observed coastal changes and estimating future changes and management alternatives. It can also be a potential tool to help solve local sediment-related problems by designing solutions that take into account a regional strategy.

A sediment budget accounts for all sediment movement, both natural and mechanical, within a defined area over a specified period of time. The defined area is represented by a series of control volumes. Each control volume represents an area of similar geographic and littoral characteristics. Sediment fluxes connect each control volume to one another and they represent either a sediment source or sink to the control volume. Sediment sources include activities or processes such as beachfills, longshore transport, shoreline erosion, and inlet shoal growth. Sediment sinks include longshore transport, shoreline accretion, dredging activities, and inlet shoal reduction. A balanced sediment budget indicates that the sediment sources, sinks, and net change within each individual control volume equals zero.

Once the control volumes are established, the following information should be gathered and analyzed to develop an improved local sediment budget:

- Historical shoreline change should be quantified using digitized historical aerial photos.
- Potential longshore transport rates due to waves should be quantified.
- Hydrographic surveys should be analyzed to quantify changes at inlet shoals.
- Dredging records for the inlet should be compiled and used to calculate annual dredge rates. The method of dredging should also be documented (e.g., hopper vs. sidecast) so that shoaling rates can be adjusted, if necessary, to reflect complete removal of sediment from the inlet (hopper) versus redistribution of sediment within the inlet (sidecast).

Table 145 presents a summary of the criteria evaluated for improving the local sediment budget at Shark River Inlet strategy and ranks this strategy as an intermediate priority with a Tier level of 1.

Table 145. Improve Local Sediment Budget Strategy Summary

Criteria	Summary
1. Authorization	Not applicable
2. Constraints	Not applicable
3. Cost Savings	No immediate savings, potential future savings
4. Service Life	Not applicable
5. Other Benefits	An improved understanding of the coastal processes and potential management options for Shark River Inlet
6. Priority	Intermediate
7. Tier Level	Tier 1
8. Next Steps	Obtain funding for potential study

Summary

This section presents a brief summary of all the strategies presented for the Shark River Inlet project. The focus is on potential cost savings and priority levels associated with strategies that could be implemented immediately and/or further pursued to more cost effectively maintain Shark River Inlet for navigation purposes.

Table 146 presents an overarching summary of all strategies focused on the prioritization and Tier level. The strategies are listed in order of priority and estimated ease of implementation.

Table 146. Shark River Inlet Strategy Summary

Strategy	Prioritization	Tier
C. Beneficial Reuse	High	1
D. Improve Local Sediment Budget	Intermediate	1
A. Expand Dredging of Ebb Shoal	Intermediate	2
B. Jetty Extensions	Intermediate	3

RECOMMENDATIONS AND IMPLEMENTATION

The information presented in previous chapters of this System Optimization Report comprehensively addresses Regional Sediment Management (RSM) practices in the context of the numerous federal shore protection and navigation projects along New Jersey shoreline. The Understanding the Coast section provides an understanding of the New Jersey shoreline, including: shoreline geomorphology; review of existing studies and primary coastal processes; summary of shoreline changes and trends; anthropogenic influences on the shoreline and coastal processes; and a characterization of the sediment budget, sediment sources/sinks, along with sediment transport and inlet bypassing. The ***Understanding the Coast*** section sets the stage for inter-relationships between the natural environment and man's influence on this developed coastline, which provides the basis for optimizing federal shore protection activities. The RSM Overview section then introduces the RSM concept and approach, how it can be integrated into the NJ Alternative Long-Term Nourishment Study, and offers a tiered approach for classifying, evaluating, and implementing shore protection alternatives. There are three tiers:

- Tier 1 recommendations are achievable in the short-term within existing authorizations. It is expected that individual analyses (e.g., economic, cost justification) could be performed and documented in a Memorandum for Record (MFR) to provide justification for implementation. Following the justification, recommendations would be approved and implemented at a District level. Construction general funds could be used to conduct the analyses and implement (design and construct) the strategies. The majority of strategies identified in this System Optimization Report (SOR) are classified as Tier 1.
- Tier 2 recommendations are achievable within existing authorities, but require either documentation (position paper or Value Engineering Study) or a decision document (Engineering Design Report [EDR] and Limited Reevaluation report [LRR]). Recommendations will be approved at the District level (EDR) or the Division level (LRR). Construction general funds could be used to conduct analyses and implement strategies.
- Tier 3 recommendations require a new congressional authority (i.e., WRDA), or study (i.e., Chief's Report of General Reevaluation Report) to implement strategies. The existing December 17, 1987 authority for the New Jersey Shore Protection Authority can be used to perform feasibility analyses for selected strategies identified in the SOR. Recommendations will be approved at Headquarters and Congressional level.

Under this tiered approach, ***The Broad Regional Strategies, Authorized Shore Protection Projects***, and ***Authorized Federal Navigation Projects*** sections of this System Optimization Report proceed to evaluate regional and site-specific activities or strategies (e.g., essentially projects) that can be implemented to advance the RSM approach, with the primary objectives of reducing cost, reducing sand requirements, and minimizing environmental impact.

This summary reviews the overall recommendations for Broad Regional Strategies, Shore Protection Projects, and Navigation Projects. As expected, there are regional strategies that can be integrated with project-specific recommendations. There also are several types of projects or strategies that apply to multiple areas or authorized federal project boundaries. This Section, then, demonstrates how the regional and site-specific strategies can be integrated. Finally, a Strategy Implementation Flowchart is offered that presents regional program strategies developed from the higher priority strategies, along with example action plans for how to implement three (3) specific projects within the context of the existing Project Authorization. The three specific projects are: Cape May Inlet Sediment Bypassing; Cape May City and Cape May Meadows Project cycle synchronization; and Sand Backpassing at Brigantine.

Broad Regional Recommendations

To advance RSM strategies for federally-authorized projects in New Jersey, there are strategies that should be applied to the coastline as a whole. Broad regional strategies involve system-wide approaches, and span multiple projects or benefit sediment management practices along the New Jersey coastline. Some broad regional strategies require upfront investment, and do not have a quantitative known cost advantage currently (e.g., system wide monitoring), but are expected to pay dividends in the future in the form of greater understanding of coastal processes and multiple uses of monitoring data that can advance an adaptive management approach to shoreline protection.

Eight (8) broad regional strategies for RSM are summarized in Table 147, which provides a preliminary evaluation according to the alternatives analysis criteria. These broad regional strategies are intended to supplement data collection and analyses to optimize design of existing authorized shore protection projects. The strategies also provide a mechanism for long-term data collection, monitoring project performance, and refining designs and construction templates through an adaptive management approach that allows future projects to be refined based on performance of prior projects. This information is intended to benefit the understanding of site-specific processes (e.g., hotspots and nodal points) that influence beach nourishment along the New Jersey coastline. There also may be a need to optimize performance on a scaled-back template, considering the potential for limited future funding that may alter how/when authorized projects can be constructed and maintained.

Project-Specific Recommendations

Potential actions and strategies were evaluated on an authorized project-by-project basis, based on a consistent set of criteria:

- **Authorization Limitations** – Each strategy or potential action was evaluated in context of two types of authorizations: (1) Study authorization and (2) Construction authorization. The existing study authority for the New Jersey coast can be used to accomplish any of the strategies that are, in effect, studies of specific actions. Conversely, the construction authorizations are generally specific to the individual project and are limiting in the type of adjustments that can be made to the project they authorize.
- **Constraints** – Each strategy or potential action was assessed relative to potential constraints (e.g., logistics, public interest, political, cost concern, limited benefits, environmental, engineering, and federal authorization) that may limit the implementation of the strategy or action.
- **Potential Cost Savings** – The potential long- and short-term cost implications on the authorized project associated with each strategy or action were evaluated.

- **Service Life** – Where feasible for a particular action or strategy, the potential implications on the performance of the project (e.g., the service life of a coastal structure or nourishment project) were assessed.
- **Other Benefits** – Each potential action and strategy was also evaluated from the perspective of less quantifiable benefits, such as environmental benefits, stabilized regional shoreline or littoral cell, benefits to adjacent shorelines or adjacent authorized shore protection projects, expected reductions in dredging requirements, benefits to public usage or perception, net reduction in offshore borrow site reliance, and/or implementable solutions transferred to multiple project locations.

Based on the above criteria, each potential action or strategy was assigned a **tier level** and a **priority level**. The site specific strategies presented in the Authorized Shore Protection projects section provides a detailed assessment of every action and strategy. Table 148 summarizes the highest priority recommendations for each authorized project, including tier level, a brief description, the USACE business line, the required implementation action, and the justification document. Other actions in the Authorized Shore Protection project section include intermediate and lower priority items based on the preliminary analysis herein, which may also be pursued depending upon local interests and requirements.

Regional Programmatic Strategies

Based on the combined Project-Specific Recommendations (Table 148, there are five (5) high priority programmatic strategies spanning multiple projects, including:

- Sediment backpassing
- Inlet sediment bypassing
- Nourishment cycle synchronization
- Inlet beneficial re-use and borrow area expansion
- Nourishment prioritization
- Structural improvements

Figure 198 illustrates the high priority recommendations, with site-specific applications. For instance, nourishment cycle synchronization was shown to benefit multiple authorized projects, including Cape May City and Cape May Meadows, Avalon and Sea Isle City, and Absecon and Brigantine Islands, specifically.

Table 147. Broad Regional Strategies: Action Items, Priorities and Tier Level

1. Recommendation		2. Priority	3. Tier Level
Wave/Sediment Transport Modeling	Complete spectral wave model for NJ coast; Complete physics-based longshore sediment transport modeling for NJ coast; Use combined results to refine sediment budgets, optimize nourishment design, and minimize sand requirements/cost.	**2**	**1**
Refined Regional Geomorphic Change Analysis	Update shoreline change and bathymetric change computations for NJ shoreline; develop consistent plan to incorporate ongoing monitoring data; Use results to refine "living" sediment budgets on a regular basis.	**2**	**1**
Improved, Living Sediment Budget	Update existing USACE sediment budgets based on results of wave/sediment transport modeling and refined regional geomorphic change analysis; Develop user-friendly tool for "living" sediment budget that can be updated when new monitoring data are collected; Maintain "living" sediment budget and use results for adaptive management of shore protection projects to minimize sand requirements, cost, and environmental impacts.	**3**	**1**
Enhanced Project Monitoring Plan	Supplement ongoing shoreline surveying plan with profiles at strategic locations; Perform detailed bathymetric surveys at inlets and other key locations; Analyze and formulate monitoring data for input to "living" sediment budget; Collect nearshore wave and current data; Incorporate data into wave/sediment transport models and to refine design parameters; Develop georeferenced database for monitoring data; Expand geophysical data sets; particular in inlets, to expand sediment sources for nourishment.	**1**	**1**
Sediment Needs vs. Sediment Availability and Borrow Area Development	Pursue permits for authorized borrow sites to expand available sand to offset future sand deficits for renourishment, particularly offshore Cape May; Expand set of offshore and inlet-based sediment sources for future beach nourishment.	**1**	**1**
Dredge Diversity Assessment	Pursue acquisition of a mobile dredging system to directly remove sand from inlets and nearshore areas and pumpout directly to the dry beach.	**1**	**1**
Environmental Demonstration Studies	Implement environmental observation initiatives to quantify potential impacts associated with expanded inlet dredging; Pursue pilot projects for expanded inlet dredging and expand to full-scale based on environmental monitoring data; Perform expanded environmental monitoring surveys as basis for pilot installation of structures to maintain erosional hotspots and implement full-scale structures at hot-spots based on outcome of environmental surveys.	**2**	**2**
Breach Contingency Plan	Develop breach contingency plans for the following for (4) areas: North Beach/Harvey Cedars on Long Beach Island; Island Beach State Park; Strathmere (Whale Beach); and Lower Cape May Meadows	**3**	**2**

Table 148. Highest Priority Project-Specific Recommendations (Highest Priority Projects denoted with arrow)

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Lower Cape May Meadows/Cape May City, and Cape May Inlet						
►	Project (Cycle) Synchronization	1	Combine periodic nourishment efforts of authorized shore protection projects at Lower Cape May Meadows (4 yrs) and Cape May City (2 yrs) to reduce mobe/demobe costs. Extension of the LCMM nourishment cycle from 2- to 4-years would require a new authorization.	Shore Protection	Evaluate potential storm damage impacts, ensure Federal funding stream, coordinate dredging, and implement.	MFR - NAP
	Beneficial Re-use at Cape May Inlet (and discontinue sidecasting)	1	Enhance current beneficial use practices by placing dredged material on/near the beaches south of Cape May Inlet.	Navigation	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, and implement.	MFR - NAP
►	Sediment Bypassing at Cape May Inlet	2	Develop a semi-mobile bypass or floating dredge plant system to bypass sediment from north to south across Cape May Inlet.	Shore Protection	Conduct more detailed analysis of potential impacts caused by fillet extraction. Finalize and design project in an MFR. Use existing construction authorization.	VE Study
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP
	Nourishment Prioritization/Feeder Beach	1	Focus nourishments including feeder beach/overfill at highly-eroded areas of Coast Guard Beach to allow sediment to naturally migrate to southwest.	Shore Protection	Conduct detailed beach nourishment dispersion analysis, conduct engineering cost and benefits analysis, implement more detailed monitoring program and data analysis.	MFR - NAP

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Avalon/Stone Harbor						
►	Sediment Backpassing	2	Move sand from an accreting shoreline (southern Avalon) to an eroding shoreline within the project (northern Avalon).	Shore Protection	Assess potential storm damage and environmental impacts, obtain required permits, and coordinate dredging prior to implementation.	VE Study
	Offshore Borrow Site Expansion/Increased Dredging of Townsends and Hereford Inlets	1/2	Expand current or establish new offshore (Tier 1) and inlet (Tier 2) borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP/ EDR
Ludlam Island and Peck Beach (Great Egg Harbor Inlet to Townsends Inlet)						
►	Project (Cycle) Synchronization (with Avalon/Stone Harbor)	1	Combine periodic nourishment efforts of authorized shore protection projects at Avalon/Stone Harbor (construction phase; 3 yr cycle) with Ludlam Island (PED phase; 5 yr cycle) to reduce mobe/demobe costs; Extension of the Ludlam Island nourishment cycle from 5 to 6 years would require a new authorization.	Shore Protection	Evaluate potential storm damage impacts, ensure Federal funding stream, coordinate dredging, and implement.	MFR - NAP
	Borrow Area Expansion at Townsends and Corson's Inlets	2	Beneficially reuse sediment dredged from Townsends and Corson's Inlets for periodic nourishments on Ludlam Island (Townsends Inlet not a current authorized borrow area for the GEHI to Townsends Inlet).	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Obtain permits.	EDR

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Ocean City (Great Egg Harbor and Peck Beach)						
►	Borrow Area Expansion at Great Egg Harbor Inlet	2	Expand current Great Egg Harbor Inlet borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Obtain permits.	EDR
	Project (Cycle) Synchronization (with Peck Beach)	1	Combine periodic nourishment efforts of authorized shore protection projects at Great Egg Harbor and Peck Beach (construction phase; 3 yr cycle) with the Peck Beach component of the GEHI to Townsends Inlet (PED phase; 3 yr cycle) project. Formally aligning the Federal authorizations of these projects would require a new authorization.	Shore Protection	Conduct feasibility and PED analyses (LRR); obtain construction authorization.	MFR - NAP
	Nourishment Prioritization/Adaptive Management	1	Focus nourishments including feeder beach/overfill at highly-eroded areas of Ocean City (north of 20th Street) to allow sediment to naturally migrate to south.	Shore Protection	Conduct detailed beach nourishment dispersion analysis, engineering cost and benefits analysis, and implement more detailed monitoring program and data analysis.	MFR - NAP
►	Sediment Backpassing	2	Move sand from an accreting shoreline (central Ocean City) to an eroding shoreline within the project (northern Ocean City).	Shore Protection	Assess potential storm damage and environmental impacts, obtain required permits, and coordinate dredging prior to implementation.	VE Study
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Absecon Island and Absecon Inlet						
	Project (Cycle) Synchronization (with Brigantine Island)	1	Combine periodic nourishment efforts of authorized shore protection projects at Absecon Island (3 yr cycle) and Brigantine Island (6 yr cycle) to reduce mobe/demobe costs. Extension of the Absecon Island project from a 3 to 6 yr cycle would require a new authorization.	Shore Protection	Evaluate potential storm damage impacts, ensure Federal funding stream, coordinate dredging, and implement.	MFR - NAP
	Beneficial Re-use at Absecon Inlet	1	Beneficially reuse sediment dredged from Absecon Inlet on Absecon Island on a regular basis.	Navigation	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, implement.	MFR - NAP
►	Sediment Bypassing at Absecon Inlet	2	Develop a semi-mobile bypass system to bypass sediment from Brigantine Island to Absecon Island across Absecon Inlet.	Shore Protection	Conduct more detailed analysis of potential impacts caused by fillet extraction. Finalize and design project in an LRR. Identify construction authorization.	LRR
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP
	Bulkhead improvements and expansion along Absecon Inlet frontage	3	Raising or lengthening the Absecon Inlet southern jetty; addition of low-profile or T-Head groins at Atlantic City; improvements along Atlantic City Absecon Inlet frontage.	Navigation	Re-analysis required; identify permitting requirements and non-Federal sponsor with the requisite cost sharing; obtain new project construction authorization	New WRDA Authorization
►	Borrow Area Expansion/ebb shoal dredging at Absecon Inlet	2	Dredge channel to south of existing bootleg at Absecon ebb shoal locations which have high infilling rates.	Navigation	Evaluate hydrographic surveys to assess optimal channel; evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, implement.	EDR

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Brigantine Island						
▶	Sediment Backpassing	2	Moving sand from an accreting shoreline (central Brigantine) to an eroding shoreline within a nourishment area (northern Brigantine).	Shore Protection	Assess potential storm damage and environmental impacts, obtain required permits, and coordinate dredging prior to implementation.	VE Study
Long Beach Island and Barnegat Inlet						
	Beneficial Re-use at Barnegat Inlet	1	Expand current Barnegat Inlet dredging to include flood shoals; enhance current beneficial use practices by placing dredged material on/near the beaches south of Barnegat Inlet.	Navigation, Shore Protection	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, implement.	MFR - NAP
	Borrow Area Expansion at Little Egg Inlet	2	Beneficially reuse sediment dredged from Little Egg Inlet to expand nearshore borrow areas in the vicinity of Long Beach Island (Little Egg Inlet not a current authorized borrow area for the Long Beach Island Shore Protection Project).	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Obtain permits.	EDR
	Sediment Bypassing at Barnegat Inlet	2	Develop a semi-mobile bypass or floating dredge plant system to bypass sediment from north to south across the inlet, or from the fillet south of the inlet to Long Beach Island beaches.	Shore Protection	Conduct more detailed analysis of potential impacts caused by inlet shoal extraction. Finalize and design project in an LRR. Identify construction authorization.	LRR
	Nourishment Prioritization	1	Prioritize nourishment efforts to vulnerable developed areas with significant erosion; Potentially evaluating functionality and improvements to new groins to prolong life of proposed strategic nourishments in certain areas.	Shore Protection	Obtain real estate easement agreements from holdout communities, conduct detailed beach nourishment dispersion analysis, conduct engineering cost and benefits analysis, and implement more detailed monitoring program and data analysis. Additional study needed for potential improvements associated with new strategic structure(s).	MFR-NAP

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP
Island Beach (Manasquan to Barnegat) and Manasquan Inlet						
	Nourishment Prioritization	1	Prioritizing nourishment efforts to vulnerable developed areas with significant erosion.	Shore Protection	Obtain real estate easement agreements from holdout communities, conduct detailed beach nourishment dispersion analysis, conduct engineering cost and benefits analysis, and implement more detailed monitoring program and data analysis.	MFR-NAP
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAP

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Sea Bright to Manasquan and Shark River Inlet						
▶	Sediment Bypassing at Manasquan Inlet	2	Develop a semi-mobile bypass or floating dredge plant system to bypass sediment from south to north across the inlet.	Shore Protection	Coordinate with CENAN since Sea Bright to Manasquan shore protection project is under CENAN jurisdiction. Conduct more detailed analysis of potential impacts caused by inlet shoal extraction. Finalize and design project in an LRR. Identify construction authorization.	LRR
	Beneficial Re-use at Manasquan Inlet (Modify placement location)	1	Enhance current beneficial use practices by placing dredged material on/near the beaches at an alternate location farther north of Manasquan Inlet.	Navigation	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, and implement.	MFR - NAN
	Beneficial Re-use at Shark River Inlet	1	Expand current Shark River Inlet dredging to include ebb shoal complex; Enhance current beneficial use practices by placing dredged material on/near the beaches rather than in the form of a nearshore berm.	Navigation	Evaluate sediment compatibility, evaluate detailed long-term costs savings and benefits, identify additional appropriations, obtain permits for placement of dredged material on beaches, and implement	MFR - NAN
	Nourishment Prioritization	1	Prioritize nourishment efforts to vulnerable developed areas with significant erosion.	Shore Protection	Conduct detailed beach nourishment dispersion analysis, conduct engineering cost and benefits analysis, implement more detailed monitoring program and data analysis	MFR - NAN
	Offshore Borrow Site Expansion	1	Expand current or establish new offshore borrow areas.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Coordinate with BOEM for sediment under Federal jurisdiction.	MFR - NAN

	Strategy	Tier	Description	Business Line	Implementation Action	Justification Document
Wildwood						
	Project (Cycle) Synchronization (with Stone Harbor)	1	Combine periodic nourishment efforts of authorized shore protection projects at Wildwood (feasibility phase) with Stone Harbor (construction phase; 3 yr cycle) to reduce mobe/demobe costs.	Shore Protection	Evaluate potential storm damage impacts, ensure Federal funding stream, coordinate dredging, and implement.	MFR - NAP
	Increased Dredging of Hereford Inlet	2	Identify and expand inlet-based borrow areas at Hereford Inlet.	Shore Protection	Initiate geotechnical, benthic and cultural surveys/studies to identify available sediment quantities. Obtain permits.	MFR - NAP
►	Sediment Backpassing	1	Move sand from an accreting shoreline (Wildwood) to an eroding shoreline within the project (North Wildwood).	Shore Protection	Assess potential storm damage and environmental impacts, obtain required permits, and coordinate dredging prior to implementation.	Component of potential authorized plan

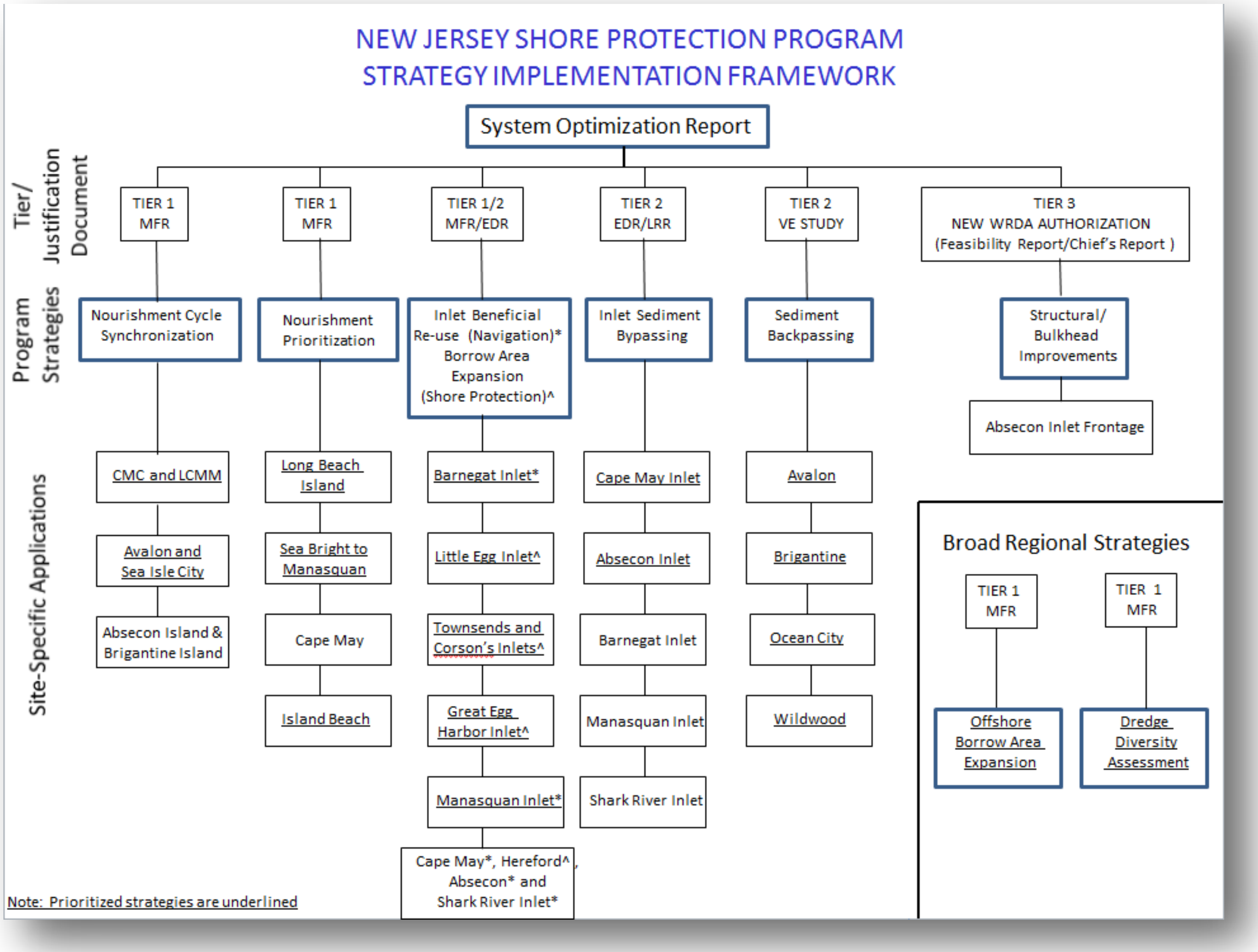

Figure 198. Summary of Strategy Implementation Framework.

The highest priority Broad Regional Recommendations also are supportive of the Project-Specific Recommendations:

- Offshore Borrow Area Sustainability/Expansion - Data produced from the enhanced project monitoring plan will quantify sediment sources and sinks to gauge effectiveness of and plan future sediment backpassing and bypassing operations, and to improve inlet sediment management. Enhanced data also will expand the geophysical data available to identify and delineate new borrow areas to improve overall sand supply sustainability. Enhanced data also will help characterize environmental impacts to facilitate permitting of project-specific improvements.
- Sediment Needs vs. Availability revealed the need for new borrow sites to offset future deficits. Specifically, there are project-specific needs at Lower Cape May Meadows/Cape May Point and Cape May City, among other areas.

- The dredge diversity assessment revealed the need for a mobile dredging system that can directly benefit project-specific recommendations for sediment backpassing and bypassing, and associated improved inlet management.

Examples of Strategy Implementation

There are a number of high priority strategies that should be considered for implementation (Table 148, Figure 197). This section provides three examples of how these strategies could be implemented, and included the specific pathway for implementation.

The three (3) specific high priority strategies consider include: Cape May Inlet Sediment Bypassing; Cape May City and Cape May Meadows Project cycle synchronization; and Sand Backpassing at Brigantine. These examples provide the path forward for these specific projects that also can be generally followed for implementing the other recommended strategies. Similar authorization pathways could also be developed for each specific strategy that the Corps may decide to pursue.

A. Cape May Inlet Sediment Bypassing Implementation

Technical details, analysis and approach for Sediment Bypassing of Cape May Inlet are presented in the Cape May City section of the Authorized Shore Protection projects (Strategy D). There are two approaches for achieving authority to implement this alternative. First, although the authorization for the Cape May City project does not include specific authority to bypass sediment, it may be possible to use the existing federal navigation project at the inlet to address whether bypassing sand significantly alters the maintenance of the inlet and is cost effective. If so, then the authority exists to implement bypassing since the inlet Authority is not specific for how maintenance should be conducted. Since the maintenance responsibility is all federal, no new cost sharing or PCA would be required. Additionally, rather than attempt to change the Cape May City shore protection authority, value engineering could be applied to determine the effectiveness of bypassing at reducing the long-term nourishment costs compared to the sediment bypassing implementation cost. The long-term maintenance of such a facility (e.g., fixed bypass plant) would likely be the responsibility of the non-federal sponsor, although it may be possible to make it a shared cost (similar to the project itself). The need to develop quantitative benefit is also reduced by this approach, as the benefits are in the form of reduced nourishment costs.

The second approach is to interpret the existing shore protection project authorization as including the ability to bypass sand. This is based upon the original authorization, which includes bypassing sand across the inlet from a fillet just off shore.

In either case, prior to implementation, appropriate environmental clearances would be required. The property immediately updrift of the Cape May Inlet jetties is occupied by the U.S. Coast Guard; however, the property directly to the north of the Coast Guard is managed by the U.S. Fish and Wildlife Service as a National Wildlife Refuge. This property has strict regulations, and may be impacted by extraction of the fillet for bypassing.

Specifically, there is piping plover nesting with the Coast Guard property areas. Impacts and potential mitigation for this sensitive area would need to be evaluated prior to obtaining permits for project implementation.

The following steps are recommended to implement this project change:

1. Presume the authority exists to proceed according to the original provision for sand bypassing from the fillet, and adjust the project components based upon information gathered since initial construction.
2. Coordinate the potential change with the sponsor.
3. Refine the design and cost, including the annual operating costs and replacement costs associated with the bypass.
4. Refine the cost saving estimate associated with implementing the bypass.
5. Annualize both costs and develop a benefit to cost ratio for implementing the bypass.
6. Prepare and EA and FONSI to address the environmental impacts associated with the change.
7. Prepare final plans and specs and costs.
8. Advertise and construct.

For ongoing funding, the district should evaluate the budgetary strategy since O&M funds would likely be required annually in addition to funds appropriated based upon the new renourishment cycle. The change would also require the sponsor to change how it arranges its contributions to the project. If this needs to be formalized in a change to the Project Construction Agreement, the District will have to presume it has the authority to execute this at the District level. If not, the District will need some form of a decision document, which, if required, should be limited to a revision of the long term nourishment plan, and not a formal Limited Reevaluation Report. This would be consistent with the interpretation that the authority exists to implement and to change the PCA at the district level.

B. Cape May City and Cape May Meadows Project Cycle Synchronization

Combining the nourishment schedules for the Lower Cape May Meadows/Cape May Point Project and the Cape May City project is recommended to achieve substantial cost savings. The two projects are in close proximity and synchronization can result in substantial construction cost savings, primarily related to equipment mobilization costs.

A project cycle synchronization strategy can be implemented at any time since existing authorities do not preclude re-nourishment as part of one contract as long as the funds for each are available and not comingled. The implementation of this strategy has minimal constraints; limited to availability of dredging equipment and borrow site quantities, which are already constraints of current operations. All requisite environmental clearances must be accomplished before award of such a contract.

On the other hand, a formal combination would require a reauthorization since each project was authorized separately. This approach should be carefully considered because the cost sharing requirements for the State of New Jersey are significantly different for each project – approximately 11% for the Cape May City project and 35% for the Cape May Meadows project. The following steps would be necessary:

1. The Corps will have to produce a Limited Reevaluation Report documenting the changes and to address the following matters:
   - Refine the potential savings to the project's life cycle costs on an annualized basis for combining the nourishment cycles.
   - Confirm whether combining the cycles changes the level of protection of the individual projects.
   - Identify significant environmental issues associated with combining the two (potential benefits and/or impacts), and secure appropriate environment approvals via EA and FONSI as required.
   - Whether the PCA for the projects has to be changed to reflect the new nourishment cycle for each project.
2. The Corps will need the appropriate supporting documentation including:
   - a. An Environmental Assessment and FONSI for the change
   - b. Any permits required to implement the change
   - c. Engineering and cost analysis to support the estimated savings, and
   - d. An assessment at to the impact on the level of protection.
   - e. Proposed PCA language changes.

Therefore, as an alternative, if the combination of the nourishment cycles can be shown to have no impact on the respective project's performance in terms of level of protection and net benefits, the Corps should utilize value engineering authority to implement the proposed project cycle synchronization. For Cape May City, this strategy does not recommend formal combination of the projects, rather just synchronization of the mobilization of Cape May City and Lower Cape May Meadows.

C. *Sand Backpassing at Brigantine*

This strategy involves extracting sediment from an area approximately 13,500 ft south of the nourishment area where substantial sediment accretes. The sediment backpassing strategy would recycle a portion of this material back to the Brigantine nourishment area. Complete details on this strategy are presented in the Brigantine Island section of the Authorized Shore Protection projects (Strategy F).

The existing authorization for this project does not include specific authority to backpass sand. However, the Corps' value engineering authority could be used to determine the effectiveness of backpassing at reducing the long term nourishment costs compared to its implementation cost. The need to develop benefit numbers is also reduced by this approach; the benefits are in the form of the reduced nourishment costs. Appropriate environmental clearances would also be required.

Sand back passing involves the more efficient use of the sand resource within a given project area. This is not an authority question, but a question of the ability of a project to utilize new information to provide the project's outputs at a lower cost. This is a value engineering question since value engineering is designed to allow the Corps to provide the same outputs of a project more efficiently. The Corps should initiate a value engineering assessment wherever it feels that periodic nourishment requirements are greater than the cost to back pass. The value engineering procedure is clearly spelled out in Corps regulations.

In addition to performing the value engineering, there are other actions which should be moved forward simultaneously:

1. The environmental requirements to implement the sand backpassing should be initiated at the time the value engineering process has recommended a specific action.
2. Potential changes to the non-federal sponsor's required contribution should be identified and agreed to by the sponsor.
3. A decision as to the need to modify the PCA should be made with a goal to change it in under the District' authority.

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