Mitigating the Effects of Bulkheads on the Bay Shore of Fire Island National Seashore

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Abstract. The National Park Service is constructing a feeder beach to restore sediment to the eroding bay shore adjacent to a marina bulkhead using sand removed from a navigation channel. An important goal of this project is to evaluate its feasibility in reducing erosion caused by shoreline armoring while ensuring that it does not (1) create an intervening environment between the active beach and upland; (2) result in excessive sedimentation offshore; or (3) result in sediment being re-deposited in the navigation channel. Semi-annual topographic surveys will be made before, during, and after placement of the fill to reveal how the shore evolves through time. A process explanation will be provided in a 28-day instrumented time series study, using sand traps and dyed sand tracer to determine rates and pathways of sediment transport. The results will identify how much fill is needed, how the volume and frequency of emplacement relate to dredging needs, and whether feeder beaches can be used in other bay shore locations.

Introduction

Shore parallel walls, such as bulkheads, are commonly used to protect estuarine shores because they are affordable, provide protection in limited space, and need not alter the bay bottom (Nordstrom, 1992; Shipman and Canning, 1993; Macdonald and others, 1994; Douglass and Pickel, 1999; Taborda and others, 2009). Information about effects of shore parallel structures is based largely on studies on ocean beaches (Plant and Griggs, 1992; Griggs and others, 1994; Kraus and McDougal, 1996; Basco and others, 1997) and reviewed by Kraus (1988) and Kraus and McDougal (1996). In contrast, information about armoring on estuarine beaches is sparse (Jackson and Nordstrom, 1994; Macdonald and others, 1994).

Shore parallel walls alter shore processes and responses in several ways. Vertical structures increase wave reflection (Miles and others, 2001), which can cause greater turbulence and scour seaward and at the ends of the structures. More sediment can be mobilized at vertical structures than on beaches without structures (Silvester, 1977; Griggs and others, 1994; Miles and others, 2001; Jaramillo and others, 2002), but it is not clear whether this mobility is accompanied by increased erosion rates (Kraus, 1988; Basco and others, 1997). Shore parallel structures do contribute to local sand starvation by preventing erosion of the upland that would otherwise provide sediment to the longshore transport system (Kraus, 1988). If placed across the active beach, these structures can become sediment traps and cause local accretion updrift and erosion downdrift (Kraus, 1988). They can alter beach habitat by contributing to changes in sediment size, replacing the beach during construction, or preventing new beach from forming as the shore is displaced landward through erosion and sea-level rise (Canning and Shipman, 1995; Spalding and Jackson, 2001; Dugan and Hubbard, 2008; Dugan and others, 2008). They can also create exotic habitat as newly introduced hard structures in formerly sandy environments (Chapman and Bulleri, 2003), and act as barriers to movement of fauna between water and land. These ecological effects greatly reduce the value of using artificial structures to protect land managed for natural values. As a result, more innovative “soft” solutions to shoreline armoring (beach nourishment, vegetation plantings) are being sought in estuarine environments (Macdonald and others, 1994; Zelo and others, 2000).

The National Park Service is now examining ways to minimize the detrimental effects of shore parallel walls within Fire Island National Seashore (fig. 1), where 17 communities remain as developed enclaves. Nearly all of these locations are protected by shore parallel walls. These walls are primarily bulkheads, so this term is used when referring to them.

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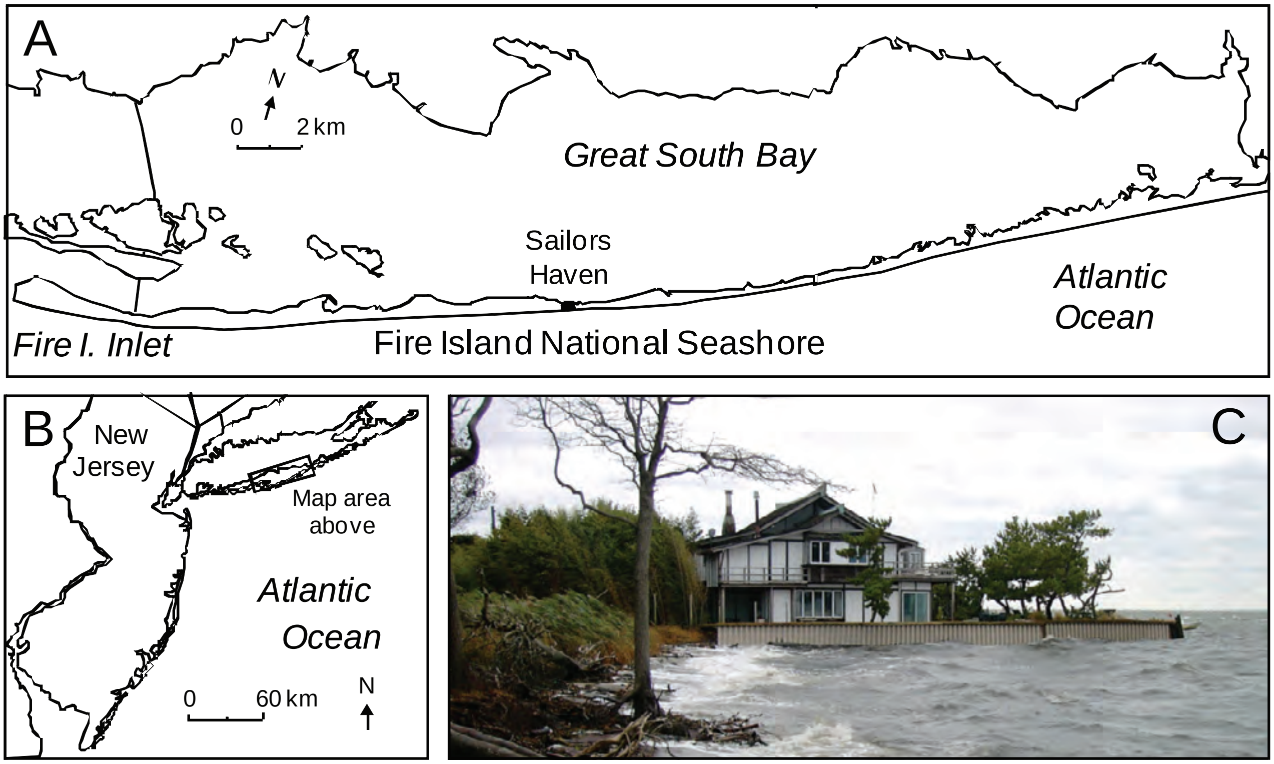

Figure 1. (*A*) and (*B*) are the Fire Island setting. The photograph (*C*) was taken at time of high water on the east side of the community of Cherry Grove, just east of Sailors Haven. The narrow beach and eroding upland are characteristic of much of the bay shore, including sites far from bulkheads.

Bulkheads were often installed prior to the establishment of the national seashore. Others were constructed subsequently, without permission of National Park Service managers or under the issuance of park special use permits, for repair or replacement with little or no change in location, capacity, or appearance. Determining the effect of bulkheads on adjacent unprotected land and identifying alternative strategies for managing these areas are critical research needs for the park.

Many bulkheads have been in place so long that the foreshores fronting them have been eliminated, leaving the structures on the low tide terrace. These structures act as sediment traps for alongshore sediment transport on the foreshore, causing the beach to accrete on the updrift side and erode on the downdrift side. The bulkheads on private land terminate at National Park Service property, resulting in accelerated erosion of park land (fig. 1*C*). Erosion adjacent to some of the bulkheads is threatening fresh water wetland systems as well as beach and upland habitat, and exposing utility lines that service the island.

The purpose of this paper is to identify how beach nourishment can be used as an alternative to construction or extension of bulkheads to protect the eroding bay shore of Fire Island. Nourishment has not been used there in the past, and the acceptability of this option requires conducting a feasibility study to document that a feeder beach can restore the sediment budget interrupted by bulkheads without creating undesirable beach habitat or excessive sedimentation offshore. Documentation of the effects of nourishment will be provided by gathering data in the field over a 2-year period at a demonstration site at Sailors Haven Marina (figs. 1 and 2). The rationale and methods for this data-gathering program are identified here, as well as the perceived benefits of the project in addressing environmental issues.

Characteristics of the Bay Shore of Fire Island

Waves causing beach change on the bay shore are generated in Great South Bay (fig.1*A*). This basin is narrow and shallow, and fetch distances for waves breaking on the middle section of the shoreline are less than 15 km in the direction of the dominant northeasterly and northwesterly winds (Sherman and others, 1994). Wave heights are low (<0.3 m) and wave periods are short (<3 s) during moderately strong onshore winds of 6-7 m s^{-1}. Mean tidal range on the mid-island bay shore is 0.21 m; spring tidal range is 0.24 m (National Oceanic and Atmospheric Administration, 1995). Beaches are low and narrow (fig. 1*C*). Where beaches are

Figure 2. Sailors Haven study area, showing projected location of feeder beach. Source: New York District Engineer photograph taken after Hurricane Isabel in autumn 2003.

limited in size, small changes in sediment input and output can cause high rates of shoreline change (Nordstrom, 1992; Freire and others, 2007). Much of the bay shoreline of Fire Island is eroding, with an average long term rate of about 0.3 m yr^{-1} and a maximum long term rate over 1.0 m yr^{-1} Leatherman and Allen (1985). Rates in a given year can be up to 3 m yr^{-1} (Nordstrom and others, 2009).

The shallow low tide terrace is characterized in many locations by a series of transverse bars that are generally oriented southwest to northeast, indicating that sediments comprising them are driven primarily by northwest winds when water is blown out of the bay and spilling waves break frequently across the low tide terrace. Sediments on the foreshore, in contrast, appear to be driven primarily by northeast winds that are accompanied by raised water levels and plunging waves that break directly on the foreshore, although easterly transport can occur on the foreshores at times of high water during northwest winds as well.

The bay shore of Fire Island consists of numerous segments of land managed by the National Park Service alternating with land in developed communities. About 18 percent of the 67.3 km-long shore is protected by 43 bulkhead segments. Most bulkheads are sheet-pile structures (fig. 1*C*). The longest extent of bulkhead is 1.85 km (Nordstrom and others, 2009). Access to the developed communities and intensively used areas of the Seashore is primarily by ferry, so most communities have a marina and access channel that requires periodic maintenance dredging.

An Alternative to Bulkheads

The existing regulatory framework promotes replacement of existing structures over implementation of alternative designs for erosion mitigation. An owner with an existing bulkhead can easily obtain a permit from the New York State Department of Conservation (NYSDEC) for its replacement. If an owner proposes an alternative method of shoreline protection that requires placing sediment in the intertidal zone, such as beach fill or a vegetated shore, the application is presumptively incompatible with NYSDEC regulations. If a permit could be granted under state regulations, greater review, monitoring, and pre-construction documentation would be required, increasing the time and cost to implement the project or action. The National Research Council (2007) identified regulatory policies as a major impediment to implementing alternatives to shoreline armoring to minimize the negative impacts on coastal resources. That report called for the implementation of demonstration projects to evaluate alternatives and to provide monitoring data that regulatory agencies can use to evaluate these alternatives.

Beach nourishment is the most widely used response to shoreline erosion in the USA (Valverde and others, 1999) and is generally considered more benign than use of hard structures (Speybroek and others, 2006). Vegetation alternatives can be used in estuarine environments but not on sandy substrate subject to reworking by energetic bay waves (Nordstrom, 1992), such as most of the bay shore of Fire Island. By protecting eroding shores, vegetation has the disadvantage of reducing sediment inputs to downdrift areas (Macdonald and others, 1994).

Placing beach fill on the low tide terrace would cover benthic habitat. This is a special concern on estuarine beaches, where fauna are not acclimated to the rapid surface change and burial occurring on ocean beaches. The perceived losses are often cited as the primary reason for lack of acceptability of nourishment projects in estuaries (U.S. Army Corps of Engineers Baltimore, 1980; U.S. Army Corps of Engineers Seattle, 1986; Nordstrom, 1992; Shipman, 2001). The NYSDEC policy against use of beach fill on the low tide terrace has contributed to the lack of impetus to use nourishment projects on Fire Island. Another problem is that the State requires that shore protection efforts attempt to achieve a permanent solution to local erosion.

The Feeder Beach Concept as a Form of Restoration

The inherent dynamic nature of beach systems and the adaptation of species to geomorphic change prevent the possibility of finding a permanent solution by restoring landforms or habitats to specific target states and maintaining existing inventories in a stable shoreline condition in perpetuity, but the processes whereby these resources evolve can be maintained. The term “restoration” can be applied to a process, such as sediment transport, just as it can to a stage in landform evolution (for example, a marsh or upland). Thus reestablishing the sediment budget using a feeder beach (to protect the upland next to a bulkhead and supply sediment to the system in a natural way) can be considered restoration, and the concept of permanence transfers to the issue of maintaining sediment inputs.

Introducing sediment at the eroding ends of bulkheads would help overcome the site-specific impacts of these structures while allowing adjacent natural areas to be nourished at a rate corresponding to natural sediment transport rates. Large-scale nourishment projects, while economically efficient, may be less desirable than small projects on estuarine shorelines because they would bury too much existing habitat and create an intervening environment between the active beach and upland. Use of sediment dredged from nearby navigation channels provides suitable source materials that can be delivered relatively cheaply and at a rate that can more nearly approximate natural losses.

The demonstration project at Sailors Haven Marina (fig. 2) will provide an initial template for restoring sediment to the transport system at hard structures interrupting longshore transport at other locations on Fire Island. The plan is to place sand dredged from the navigation channel over a portion of the low tide terrace and foreshore west of the marina to protect the upland and create a feeder beach that will supply sediment to the longshore transport system and compensate for the losses caused by the marina bulkhead. Long-term success of a feeder beach requires periodic renourishment. At Sailors Haven Marina, this will be done in conjunction with dredging of the navigation channel, where dredging is required every 2 to 4 years.

The project is not intended to totally prevent coastal erosion. The National Park Service policy is to allow natural processes to occur to the extent possible and only intervene to redress accelerated erosion caused by human actions (National Park Service, 2006). Evolution of estuarine beaches in areas subject to human alterations is now often related mainly to human activity (Taborda and others, 2009), and it seems appropriate to use human action to restore sand to the system where human actions accelerated past losses.

NYSDEC has agreed to the demonstration project and has issued a permit for construction and monitoring. Results of the project will allow NYSDEC to determine if this is an appropriate technique for application at other hard structures. Dredging within the Seashore requires issuance of a Special Use Permit. Pending successful completion of this demonstration project and NYSDEC approval of the technique, park managers can use this permit process to require communities to beneficially use sand from channel dredging to construct and periodically create feeder beaches where appropriate. In December 2005, park managers implemented new polices for the issuance of Special Use Permits for private bulkheads that are designed to minimize impacts from replacement of existing bulkheads and facilitate implementation of more ecologically sensitive designs in the future.

The beach fill should mimic the natural configuration of the shore by being at the height of the natural formations and relatively narrow, and it should be close to the bulkhead ends (fig. 2) to compensate for the sediment deficit at the location most adversely affected. The width of the fill must reflect a compromise between the need to minimize the footprint of the fill on the landscape and the need to prevent the upland from eroding at an accelerated rate. On an ocean shore, a wide fill is desirable to provide space for new dunes with complete environmental gradients to form, but the natural profile along most of the Fire Island bay shore consists of an eroding foreshore in direct contact with the upland or marsh. One purpose of the study is to determine a design height and width for the fill that will not create an intervening sub-environment. Periodic wave overwash of the fill and delivery of wrack to the wider backshore created by the fill are important in providing the habitat and nutrients representative of a natural estuarine backshore. Evaluation of the naturalization process requires examining effects of specific storms and longer term changes in topography related to cumulative storm effects as identified below.

Characteristics of the Demonstration Project

Sand for the demonstration project will be available from maintenance dredging that will occur in 2011–2012 (estimated to yield 2,500 m^3). It is assumed that the length of the initial fill will be at least 200 m, the backshore width no greater than 4 m and the height no greater than 1.5 m above the height of the low tide terrace. Placement of fill must occur between November 2011 and January 2012 to avoid impacts on sea turtles, essential fish habitat, and breeding birds and avoid interference with park visitation.

Studies of beach processes in low-microtidal estuaries and studies of bulkheads and nourishment projects in these environments are underrepresented in the scientific and management literature (Nordstrom and others, 2009; Jackson and others, 2010). Accordingly, a major portion of the evaluation will be devoted to a field study of the evolution of the fill. Steps will include identifying (1) the rate of sediment transport alongshore and the likelihood that sediment will move out of the fill area and nourish downdrift areas; (2) the likelihood that sediment will move from the foreshore to the bars on the low tide terrace and then to the navigation channel; (3) the likelihood that periodic nourishment will re-establish the sediment budget altered by the marina; and (4) the impacts on biota. These study components require evaluation of beach processes and shoreline changes in the short term (daily and storm-related cycles) and medium term (seasonal and annual effects).

Rate of Transport Alongshore

A feeder beach is not like a traditional beach nourishment project in that it is designed to allow sediment to leave the fill area to nourish adjacent beaches. Peat outcrops, fallen trees and root masses protruding from uplands protect the shore in places and create sediment traps. These features, and breaks in shoreline orientation, may create isolated longshore drift cells, so it is important to identify the extent to which sediment can bypass them. Longshore transport rates should be determined by conducting sediment tracer and sand-trapping experiments and using beach volume changes revealed in topographic differences in the fill area and downdrift.

Movement of Sediment to the Bars and Navigation Channel

A previous tracer study of the inner transverse bars west of the marina (Nordstrom and others, 1996) indicates that the bars provide a mechanism for movement of sediment offshore. The amount of sediment delivered appears small under natural conditions, but the amounts that would be delivered from a newly placed fill are unknown. Topographic profiles must extend offshore and onto the bars to identify changes in sediment volume, and a tracer study should include sampling offshore to determine pathways of sediment from the foreshore to the bars and intervening portions of the low tide terrace. The apparent eastward movement of the bars indicates the potential for delivery of sediment to the navigation channel. Sediments on the low tide terrace are similar to sediments in the eroding formations, the foreshore and the navigation channel (Nordstrom and others, 2009), indicating that these environments may not be mutually exclusive in terms of sediment exchange. The dredged sediment is compatible with placement on the beach, but there is the potential for this sediment to be recycled to the navigation channel.

Implications for the Sediment Budget

The optimum way to determine the amount of sediment required in the feeder beach is to (1) determine the rate of erosion of a natural headland uninterrupted by shoreline armoring; (2) determine how the marina alters that rate; (3) determine the rate that sediment from the feeder beach is delivered to downdrift beaches; and (4) evaluate whether the rate of transport from the feeder beach is compatible with the natural rate in the absence of the structure. The natural rate cannot be determined because of lack of data collection before the structure was built and lack of a control site in a different location that is assumed to be affected by the same processes. A practical estimate of the role of the feeder beach in reestablishing the sediment budget is the degree to which the volume of sediment moving out of the fill area matches the volume emplaced during renourishment intervals without increasing beach width in the long term, while allowing for some interaction between the waves and wave formed features on the beach and upland or marsh on the landward side. The landforms in the fill area and downdrift of it should mimic the form and function of the presently eroding segments along the bay shore removed from the bulkheads.

Impacts on Biota

The shallow waters of Great South Bay have been designated essential fish habitat because of their high productivity and regional significance for marine finfish, shellfish and wildlife. The Sailors Haven area serves as potential spawning and nursery grounds for many finfish species that are estuarine dependent during at least one life stage. Species include weakfish (*Cynoscion regalis*), winter flounder (*Pseudopleuronectes americanus*), summer flounder (*Paralichthys dentatus*), and blackfish (*Tautoga onitis*). The benthic community serves as an essential part of the food chain for local fish populations. The structure of the benthic community is determined in part by the frequency and intensity of physical disturbance (Thistle, 1981). Scheduling of dredging and construction activities has been limited to the late fall and winter to minimize impacts on wildlife. Ecological monitoring, including that for finfish, invertebrates, and water quality, will be conducted to evaluate the ecological effects of the project on benthic and pelagic species.

Methods for Evaluating Impacts in the Field

Short-term changes in physical conditions will be evaluated by identifying the controlling wind and wave processes and changes in topography and surface characteristics (sediments and wrack) in a 28-day (lunar cycle) time series in the winter storm season that will include effects of individual storms. Medium-term changes will be evaluated by measuring topography related to cumulative storm effects and movement of pulses of sediment alongshore. During the 28-day time series, wind speed and direction, wave heights, water levels, and current velocities will be monitored (1) on the foreshore and low tide terrace near the bulkhead; (2) near the western end of the fill to provide information on end effects; and (3) bayward of the bulkhead to determine the potential for sediment transport seaward of the structure. Measurement of the quantity of sediment in transport over swash cycles will be made using total load streamer traps. Dyed sand tracers will be injected into the swash zone to identify the relative proportion of sediment moved alongshore and offshore to the bars. A micro-topographic grid will be established near the middle of the fill segment to evaluate the elevation changes that occur over daily and tidal cycles and will be monitored before and after at least four relatively high energy events that occur during the 28 day deployment.

Topography will be mapped semi-annually at 1-m intervals at low tide along cross-shore transects. Sand samples will be taken to confirm that the fill is consistent with the native materials through time and that the movement of sediment from the fill does not change the grain size statistics in adjacent environments. These samples will be taken on the foreshore, transverse bars and low tide terrace environments prior to the fill operation, just after the fill is emplaced, and following the first winter storm season after the fill has been reworked.

Species composition and abundance (expressed in catch per unit effort) of nekton will be determined by analyses of seine samples collected monthly from March to November. Species composition and abundance for benthic infauna will be evaluated in the spring (June) and fall (October) by collecting, sieving, and processing infauna cores. Water-quality parameters, including dissolved oxygen, temperature and salinity, will be measured with an YSI-850 meter prior to the start of each seine haul. All ecological sampling will be conducted one year prior to initial project construction and a minimum of three years post-construction. Sampling in subsequent years will be determined using an adaptive management approach.

Benefits of Project

The results of this project will identify the rate of sediment transport out of the fill area, the kinds of events moving the sediment (episodic or chronic) and the way the beaches in the fill area and downdrift evolve. These characteristics will then be used to identify how much fill is needed and whether the volume and frequency of emplacement required are related to sediment volumes provided by maintenance dredging. The study will also identify how sediment bypasses low headlands to determine whether isolated fill areas placed next to bulkheads allow for sediment transfers alongshore or whether longer fills farther from structures are required. Identification of the pathways of sediment movement and locations where the sediment is deposited will determine whether the fill is moved to areas beneficial to the natural environment.

The need to restore natural functions while allowing for some stability using a strategy of controlled dynamism is becoming a new goal in managing shorelines altered by human use. This strategy is a way of incorporating traditional shore protection methods, such as beach fill, in a new context in locations where static structures were deployed (Nordstrom and others, 2007). This project will provide information about how the feeder beach concept can be implemented adjacent to bulkheads as a means of reducing the excessive local rate of erosion caused by the structures and should have application at other armored segments on the bay shore of Fire Island.

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