Section 2

Alternatives Analysis

2.0 ALTERNATIVES ANALYSIS

Section 404(b)(1) Guidelines used by the U.S. Army Corps of Engineers (USACE) require an analysis of practicable alternatives before any discharge of dredged or fill material may be permitted (40 CFR 230.10). According to the Guidelines, an alternative is "practicable" if it is *available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes*.

The Alternatives Analysis provided herein has been an integral part of the Project design process. An initial draft of this analysis was prepared in advance of the DEIR and was submitted to the USACE, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA)/National Marine Fisheries Service (NMFS), Massachusetts Coastal Zone Management, Massachusetts Department of Environmental Protection, and Massachusetts Division of Marine Fisheries (DMF) for review through the USACE's Highway Methodology and to provide an opportunity for preliminary regulatory input. That initial analysis was discussed at a meeting held with the USACE and state and federal resource agencies on February 1, 2006. The initial iteration of the analysis was generally well-received, and the agencies requested that the Proponent include an analysis of reef balls and a more thorough cost analysis regarding fisheries impacts. This agency input has been incorporated into this subsequent analysis of Project alternatives (see Sections 2.3.2 and 2.6.2).

The purpose of this Alternatives Analysis is to assess the practicability of various Project alternatives. As detailed herein, this analysis has considered environmental impacts, effectiveness, regulatory considerations, and cost, and has led to the selection of a preferred alternative for the Project. A preliminary Project design, based on the outcomes of this Alternatives Analysis, is presented in Section 3.0; the final Project design will be presented in the FEIR.

Beach nourishment has become a prominent strategy for managing eroding coastlines in the United States, Europe, and Australia. Increasing utilization of this strategy and interest in its benefits and effects led the Marine Board of the National Research Council's (NRC's) Commission on Engineering and Technical Systems to propose a comprehensive study and subsequent report on the engineering, environmental, economic, and public policy aspects of beach nourishment (NRC, 1995). The National Academy of Sciences along with the National Academy of Engineering and the Institute of Medicine approved the study, and the NRC convened the Committee on Beach Nourishment and Protection to carry it out. During preparation of the subsequent report, the committee collaborated with the Federal Emergency Management Agency, NOAA, the U.S. Geological Survey, the Minerals Management Service (MMS), and the USACE. The resulting comprehensive analysis of beach nourishment provides useful data, analyses and discussions that have been used in the development of this Alternatives Analysis.

Specifically, the NRC report identifies several findings with which the proposed Project is aligned (NRC, 1995). These include, among others, that:

- Beach nourishment projects can effectively protect eroding shorelines and restore lost beach assets, and the design of these projects should be dependent upon their specific geographic and geologic settings. The Project is being designed in conjunction with comprehensive monitoring and modeling efforts incorporating considerations of the local geologic setting, wave climate, tides, currents, and sand transport regime.

- Hard (fixed) structures should be allowed by agencies when these elements are appropriately designed to improve the performance of a beach nourishment project and where they will not have substantial negative impacts. The proposed Project incorporates groins and geotextile tubes with nourishment to improve Project longevity and effectiveness in such a way that adjacent beaches are not adversely impacted. In fact, the Project aims to benefit adjacent beaches by adding a large volume of nourishment material to a shoreline which is currently characterized by a deficient sand supply. Furthermore, post-construction monitoring will identify any unexpected effects from the proposed structures and will be used to inform any related maintenance or modifications, should such efforts become necessary (see Section 5.2.2.4).

- Borrow sites should be analyzed to determine whether any alterations to sediment transport or wave dynamics are expected to result from mining activities. Extensive geotechnical analyses coupled with monitoring and modeling efforts are being performed for the nourishment area and borrow site to identify any potential effects from Project activities (including sand mining) on sediment transport, waves, or current dynamics. The Proponent intends to utilize one or more borrow sites, as required, for initial Project nourishment as well as subsequent renourishment events. No adverse or significant impacts to sediment transport, waves, or current dynamics are expected to result from proposed borrow site activities.

- The presence of a beach nourishment project should not be allowed to dictate or relax construction or development policies along the coastline. The proposed Project is not meant to increase the Project area's suitability for future development; rather, the Project is intended to protect a variety of existing resources including public infrastructure, private residences, and historic structures from ongoing, long-term coastal erosion.

- The formulation process for a beach nourishment project should include steps of design, analysis, judgment, and public participation. The design for the proposed Project is the product of a comprehensive, thoughtful, and long-term alternatives analysis that has benefited from intensive stakeholder involvement and peer review by deeply experienced scientific and engineering professionals in addition to consultation with published texts. By welcoming objective participation by outside experts, the Project's design review and analysis has productively informed the Proponent's judgment of Project alternatives.

For the past 15 years, a variety of shore protection alternatives have been evaluated both in concept and in practice at Sconset. Large-scale beach nourishment was first evaluated as an option between 1991 and 1993, when it was concluded that more economical shore protection strategies could be implemented in the short-term to manage erosion and minimize detrimental impacts to the Coastal Beach and Coastal Bank. Various alternatives have been implemented with varying levels of success, including the No Action alternative, managed retreat from the Coastal Bank, beach dewatering, small-scale nourishment, Duneguard, Coastal Bank toe terracing, Coastal Bank terracing and vegetation planting, and drainage wells to drain a perched aquifer that was exacerbating erosion on the bank face. Despite these efforts, the beach and bank have continued to erode, a process exacerbated by recent stormy winters. In addition, many of these alternatives are not preferable or particularly practical due to logistical or technical constraints. For example, areas of landward open space required to continue managed retreat from properties at the top of the Coastal Bank are nearly exhausted, removing that strategy as a viable option.

Five alternative strategies remain: (1) No Action; (2) retreat; (3) structural stabilization; (4) bank stabilization; and (5) large-scale nourishment. Of these alternatives, the No Action strategy is unacceptable given the tremendous public and private resources at risk, and the retreat alternative is unacceptable due to the limited opportunities to relocate these resources. The purely structural alternative is not preferred due to strict regulatory obstacles; furthermore, because this alternative alone does not enhance the beach environment, it does not satisfy all Project objectives (such as providing recreational benefits). Bank stabilization alone would not satisfy Project objectives and would require structural stabilization once the base of the Coastal Bank became undermined. Therefore, large-scale nourishment is the preferred alternative for the Project. Due to the Project site's unique characteristics, which include a convex shoreline, a diverging sediment transport pattern, a steep beach face, and energetic wave and current regimes, the effectiveness and longevity of the nourishment Project's design is enhanced by incorporating components of the various alternative strategies that are not practicable as stand-alone measures. Therefore, to maximize the Project's performance, longevity, and economic viability, nourishment is proposed in conjunction with the following additional components: up to 13 groins in erosion hotspots, up to 6,100 linear feet of geotextile tubes installed at the toe of the Coastal Bank, and Coastal Bank terraces coupled with vegetation plantings. These additional components also help minimize environmental impacts by reducing the required frequency of renourishment events.

The preferred alternative is the product of site-specific experience, sound scientific understanding of coastal processes, responsible engineering design, and stakeholder input. Advisory panels were convened by the Proponent to guide the processes of environmental impact avoidance, minimization, mitigation and design to ensure selection and implementation of the most effective Project. Such advisory groups and associated individuals have included an engineering review panel, expert input on shorebird and fisheries impacts, and industry design input to ensure a viable, practical and realistic Project design.

The following sections provide a thorough review of Project alternatives, their associated environmental impacts, and subsequent conclusions.

2.1 No Action Alternative

The No Action alternative would allow natural processes to occur without any form of human intervention to prevent Coastal Bank erosion. This approach would require structures at the top of the bank, including the Sankaty Head Lighthouse, to be moved as the bank continues to retreat landward, or else they would be lost. Private property values in the Project area total approximately $450 million; therefore, tax revenues and public infrastructure losses to the Town of Nantucket would be substantial if erosion continued unabated, and would include a loss of emergency access and potentially the Town sewer beds. Opportunities for public access could also be expected to diminish as the beach would continue to narrow, public parking at the popular Codfish Park beach area would become more constrained, access stairways would collapse, and remaining portions of the historic bluff walk would disappear.

For the proposed Project, the No Action alternative, while once viable, is no longer feasible. Land use controls are not practicable because the Project is intended to protect existing resources including infrastructure, historic landmarks, and developed residential properties, all of which are increasingly threatened by erosion and storm damage. In addition, one of the Project's objectives is to demonstrate the ability of nourishment to ultimately protect the entire Sconset shorefront, including the heart of Sconset Village. Clearly, the abandonment of hundreds of homes, municipal infrastructure facilities, and the historic Sankaty Head Lighthouse in the face of an ever-receding bank is not a feasible solution. Furthermore, public roads in the Project area currently provide emergency access to more than 100 homes; loss of these roads would constrain access to emergency services.

The fiscal impact from property losses associated with this alternative would be substantial; 2004 property values alone were approximately $450 million in the Project area, comprising nearly 4% of Nantucket's annual property tax revenue. Beyond these economic concerns, the historic value of registered properties and the Sankaty Head Lighthouse is at the core of Nantucket's cultural history. In addition, destruction of the Town Sewer Beds could create adverse environmental impacts and threaten public health and safety, as well as add substantial costs to the Town's capital budget. The Project proposes a proactive, environmentally-sensitive solution to rectify the situation with a minimum level of detrimental impacts.

2.1.1 Environmental Review of the No Action Alternative

The No Action alternative is not practicable because it would not satisfy the Project objectives. By allowing current conditions of erosion to continue, this alternative would place a large amount of personal property, public infrastructure, historic landmarks, and rights of public access at great risk. All of the Project benefits presented in Section 1.0 would be severely threatened or lost if this alternative was selected.

2.2 Retreat Alternative

In cases of shoreline retreat, alternatives sometimes incorporate land use controls and managed retreat policies as strategies to offer long-term solutions to erosion problems. When practicable, such strategies are encouraged by the Office of Ocean and Coastal Resource Management (OCRM) (NOAA[2], 2005). In areas where dense coastal development has not already occurred, land use controls may maintain enough of a buffer between the shoreline and upland structures to weather periods of erosion until the trend shifts. By avoiding development in high-risk coastal areas, the costs, maintenance requirements and potential impacts from beach nourishment and other shoreline management activities can also be avoided.

A retreat strategy, on the other hand, may be an appropriate option where rapid shoreline erosion threatens existing development or areas where property values and other economic considerations are not high (Dean, Davis and Erickson, 2005). If space is available, threatened structures may be moved landward in response to a retreating shoreline; perhaps the best-known example of this occurred when the Cape Hatteras Lighthouse was relocated 1,600 feet inland in the year 2000 (Greene, 2002).

For this Project, continued relocation of threatened structures and infrastructure does not provide a practicable solution, because in most cases landward retreat and relocation is constrained by existing conditions. Over the last fifteen years, several Sconset homes close to the edge of the Coastal Bank have been moved to prevent their loss. These houses were either moved landward on their existing lots or moved to distinct landward lots. Most of the nearby landward lots are now occupied, reducing the feasibility of moving additional homes away from the bank as erosion continues (see Figure 1-2). While relocating threatened homes to lots elsewhere on the island is possible in theory, this action is not practical in logistical terms due to the large size of the structures in question and the various physical limitations and impediments to their relocation (e.g., power lines, etc.).

2.2.1 Environmental Review of Retreat Alternative

This alternative is not practicable because it would not satisfy the Project objectives. Due to existing land uses and the occupation of landward lots, it is not possible to move many of the threatened structures and resources back from the eroding Coastal Bank. As a result of this constraint, continuing erosion of the Coastal Bank would place a large amount of personal property, public infrastructure, historic landmarks, and rights of public access at great risk. All of the Project benefits discussed in Section 1.0 would be severely threatened or lost if this alternative was selected.

2.3 Structural Alternatives

Coastal engineers have historically relied on hard structural alternatives to armor retreating shorelines in efforts to halt erosion and protect landward resources. Examples of such hard structures include seawalls, revetments, and breakwaters. A brief discussion of the design, feasibility, and impacts from these structures is provided here. In the context of this section, structural alternatives are considered alone and absent beach nourishment. For the purposes of this document, beach dewatering is discussed as a soft structural alternative.

2.3.1 Seawalls and Revetments

The Proponent has investigated various shore protection alternatives for the Project area. This investigation encompassed several typical types of structural shore protection that have been permitted elsewhere along the Massachusetts coastline, including seawalls and revetments.

A properly-designed seawall for the Project shoreline would be a massive vertical structure composed of hard, impervious material such as concrete or steel that would be placed on the Coastal Beach at the toe of the Coastal Bank. A revetment is another type of hard structure typically consisting of armor stones that would be placed on the face of the Coastal Bank. These armor stones are often underlain by layers of smaller rocks and filter fabric to create a system that absorbs wave energy, retains landward Coastal Bank sediment, and allows water to drain through the structure without creating erosion channels that could weaken it. Composite seawalls can also be constructed, which might include a seawall fronted by a rubble-mound structure designed to protect the toe of the seawall and dissipate wave energy during storms. Photographic examples of a seawall and a revetment are provided in Figure 2-1.

If constructed, a seawall or revetment would likely extend from below MLW to above the level attained by waves during major storm events. A preliminary analysis of seawall and revetment design for the Project area suggests that in order to withstand long-term erosion pressures, the structure would need to extend from 10 feet below the existing beach face to at least 20 feet up the face of the Coastal Bank.

2.3.2 Breakwaters

In late 1992 and 1993, the Proponent funded studies prepared on behalf of the Town of Nantucket by Coastal Planning & Engineering, Inc. (CP&E) of Boca Raton, Florida to investigate shoreline protection alternatives for the Project area. The first report, prepared in May of 1993, was entitled "An evaluation of alternative technologies for beach erosion control at Sconset, Massachusetts". This report evaluated technologies for shore protection including reef-type breakwaters and submerged barge breakwaters, both of which are constructed in shallow water close to shore. Photographic examples of emergent and submerged breakwaters are provided in Figure 2-2. Since preparation of this report, the Proponent has continued to investigate the practicability of breakwaters.

Manufactured artificial reef breakwaters consist of concrete structural units intended to break wave action and artificially perch the landward beach. They are typically located at water depths of -7 to -9 feet MLW. Two types of artificial reef breakwaters, PEP and Beachsaver, were considered during the studies; these structures are very similar in design and placement, and have similar effects on the beach. Both types of units are narrow-crested relative to wave length and have low profiles, features which inhibit their ability to effectively dissipate wave energy. This is particularly true during storms, when storm surge and wave setup increase the freeboard from the crest of the artificial reef to the water surface, thereby allowing more wave energy to pass by when protection is most needed. Scaled physical modeling of similar narrow-crested submerged breakwaters has shown dissipation of only a small fraction of wave energy even under simulated non-storm conditions. The ability of these structures to dissipate wave energy also decreases as they settle into the sediments, a problem that has been documented with artificial reefs. Examining case studies where these structures have been employed provides valuable insight into their potential performance benefits and limitations.

A PEP artificial reef was constructed offshore of an eroding beach in Palm Beach, Florida. The structure was not able to halt or inhibit erosion of the beach it fronted, and normal coastal conditions and storm-induced wave action significantly impacted the artificial reef and caused problems with settlement. Additional monitoring studies showed that the structure's interaction with local wave and current regimes strengthened the longshore current along the landward shoreline, which contributed to beach erosion by exacerbating sediment loss from the beach in the lee of the reef. Sections of the PEP reef were later removed and used to form a shore-perpendicular groin system. Experiences with PEP reefs elsewhere have included a segmented PEP reef system, such as one constructed at Vero Beach, Florida in September 1996. Segmenting the reef reduced the strength of the longshore current and moderated the exacerbated rate of sediment loss, but ultimately the beach response was not found to be significant. In fact, beaches landward of the segmented system at Vero Beach measured less accretion than control areas (Stauble and Tabar, 2003).

Beachsaver reefs have been installed along the southern coast of Long Island, New York and in New Jersey in attempts to slow beach erosion. Experience in New Jersey has shown that Beachsaver reefs installed across the seaward ends of groins can be moderately effective at maintaining the beach between the groins; however, the structures were not able to stop beach erosion in the absence of groins. CP&E reported that, in their opinion, Beachsaver installations would not change the natural sand deposition process in the Project area sufficiently to maintain the beach.

Artificial submerged breakwaters are not appropriate for the Sconset Project primarily because of the Project area's steep shore face and dynamic coastal zone. Due to the steep nearshore slope, these structures would need to be located in water depths exceeding -12 feet MLW, and at such depths the structures' low profiles would be ineffective, particularly during storms. Significant settlement would also be expected due to the energetic wave climate and strong tidal currents, both of which would induce scour.

Sunken barges, considered broad-crested breakwaters, are a third type of artificial reef that can be employed in erosion control efforts. As a result of their broad profile, they have a greater effect on waves than their narrow-crested counterparts. CP&E evaluated this alternative assuming the sunken barges would be approximately 195 feet long, 35 feet wide, 12-14 feet deep, and located in approximately 15 feet of water. Several problems were associated with using sunken barges as artificial reefs, including structural deterioration due to corrosion, settlement, and movement along the seafloor due to hydrodynamic forces acting on the bulky structures. Each of these factors adds significantly to cost of this type of structure, which CP&E estimated to be approximately $730 per foot in 1993 dollars.

A fourth type of artificial reef involves reef balls placed offshore of an eroding shoreline. Reef balls are relatively small, dome-shaped concrete structures with holes intended to create structure and habitat for fish. Placed in nearshore areas, these structures are intended to absorb wave energy, reducing the amount of energy impacting the shoreline and thereby moderating erosion. By containing holes, however, the effectiveness of these hollow structures at absorbing wave energy is drastically compromised.

Due to the intense and dynamic waves and currents present in the Project area, installations of these structures may in fact be counterproductive because the reef balls would likely be scattered and crushed in the active coastal zone. Stability, scour, and settlement are all design problems associated with reef balls. It is generally recommended that reef balls be attached to an articulating concrete mat foundation when placed in a sandy substrate. When installed on hard substrate, pilings should be driven through the reef ball units and into the seafloor to enable the structures to resist horizontal and vertical movement (Harris, 2004). Partially due to these requirements, Harris (2004) concludes that "the design of any coastal protection site is extremely site-specific and not all locations are suitable for the use of artificial reef submerged breakwaters for shoreline stabilization."

A reef ball breakwater was constructed for a project in the Dominican Republic where the tidal range was 1.2 feet and water depth was approximately 2.5 feet. In contrast, the environment in the vicinity of the nourishment area exhibits tidal ranges from two to more than four feet, contributing to strong currents (see Section 4.1.2.2.4), and water depths well in excess of those at the Dominican project site. It would not be possible to place reef balls in similarly shallow water in the Project area due to vertical and horizontal changes observed in the beach profile. Furthermore, reef balls employed in the Dominican project and elsewhere have weighed on the order of 2.2 tons; armor stones weighing a minimum of five to seven tons would be required to withstand the high-energy, dynamic conditions present in the nearshore environment of this Project. Placing these structures further offshore, where wave energy may not be as intense, would not be a practicable alternative as the structures' effectiveness would be substantially reduced. The effectiveness of reef balls would be questionable even in a moderate wave climate, and their use is not a practicable concept in the environment offshore of Nantucket.

An effective offshore breakwater design at Sconset would likely require a large emergent rubble-mound breakwater system, which would be extremely costly and occupy a large area of the bottom. A rock revetment or seawall alternative would provide more effective protection at lower cost and with less environmental impact.

2.3.3 Coastal Groins

Coastal groins are concrete, rock and/or timber structures constructed perpendicular to the shoreline and extending seaward of the beach (see Figure 2-3). These structures are designed to retain beach sand along a shoreline or to trap sand being transported in an active littoral system in order to stabilize and build out the beach directly up-drift of the groins (Douglass, 2002). However, groin effectiveness is achieved at the expense of inhibiting longshore transport of sand, which can exacerbate downdrift shoreline erosion. Because they impede longshore sand transport, if traditional coastal groins are installed absent a corresponding nourishment program, they can simply transplant an erosion problem from one area to another. Once a popular response to beach erosion, traditional high-profile and impermeable groins are now considered problematic and even damaging given their consequences for downdrift shorelines (Douglass, 2002). Groins proposed by this Project, however, will be constructed in conjunction with a comprehensive nourishment program which will drastically increase the volume of sediment in the local littoral system. This Project's groins are designed to moderate losses of beach nourishment sand from the design beach profile, thereby increasing the longevity of the Project design and the corresponding intervals between renourishment events. At the same time, by injecting such a large volume of nourishment material into the littoral system, the Project aims to benefit adjacent beaches.

Design improvements to groins have been made to allow more sand to pass to downdrift beaches, which can mitigate sand volume loss and erosion historically associated with these structures. Low-profile and semi-permeable groins are designed to allow some longshore sediment transport to pass over and through the structures to reduce downdrift impacts. Novel designs also include removable members, allowing structural adjustments to optimize performance and minimize adverse impacts. These structures can have tapered offshore profiles designed to act as templates for a desired beach profile, and they can be notched to allow sediment transport in the swash zone. Variations of the semi-permeable groin concept have been successfully employed in projects at Naples Beach, Florida, Port Elizabeth, South Africa, and northern New Jersey, among other locations.

T-head or headland-style groins have also been constructed in conjunction with offshore, connected, or shore-parallel breakwater elements (typically rock or rubble-mound) designed to minimize offshore sand losses around the end of the groin (see Figure 2-4). The T-head also affords added protection to adjacent shorelines by reducing direct wave impacts on the beach.

Groins are usually designed in conjunction with beach nourishment activities and are intended to lengthen the design life of a nourishment project by maintaining the beach design profile in areas of accelerated erosion (i.e., erosion hotspots). The strategy employed in these cases is to maintain the minimum beach profile in these hotspots while allowing some sediment transport to continue over and around the structures toward downdrift beaches. To achieve this objective, properly-designed groins generally extend just into the advance nourishment, or sacrificial, portion of the nourished beach. As the sacrificial beach erodes away, the groins become exposed and begin to moderate the rate of additional sand loss.

When design expectations are satisfied, groins can lengthen the design life of nourishment in erosion hotspots to a temporal scale more consistent with the design life of the comprehensive nourishment project. This not only improves a project's performance and cost-effectiveness, but can also lessen potential environmental impacts by reducing the frequency and/or volumetric requirements of renourishment events. Increasing the number of groins decreases the beach fill volume required to maintain a project's design profile, thus limiting the acreage of submerged area covered by nourishment material. Groin fields installed in a closely-spaced configuration are effective in retaining sediment along a beach in the presence of strong longshore currents and energetic wave activity. Spacing groins at a distance less than or equal to twice the groin length (as measured from berm crest to seaward end) will hold more sand along a given reach than if the structures are more broadly spaced. By reducing the spacing and increasing the number of groins, the beach profile will become steeper and more uniform along the shoreline (see Sections 2.3.5 and 3.2.2).

There are numerous groin designs that can be adopted to achieve various objectives. One such design is for a structure consisting of a marine mattress foundation filled with stone which is then topped with armor stones. Gaps between the large armor stones can be left empty, increasing the structure's porosity. These groins can also be constructed with a tapered profile to template the beach nourishment, extend the Project's longevity in erosion hotspots, and minimize the nourishment footprint and downdrift impacts.

An alternative to a rubble-mound groin is a pile groin, which is constructed by driving a series of pre-stressed reinforced concrete or wooden piles into the beach. Concrete piles are generally preferred to wood, since the latter will deteriorate over time. Permeability can be controlled by altering the number of piles, pile spacing, and the number of rows of piles, but performance of pile groins is difficult to predict. Also, as the beach erodes, more and more of the piles will become exposed, increasing wave loading while simultaneously reducing the embedment depth. In the Project's active and dynamic coastal environment, this could result in structural damage.

A second alternative groin design involves king piles and panels. This type of groin is constructed by inserting concrete or wooden panels into grooves cut into the piles; these panels can be added or removed to alter the structure's height, although such alteration is not easy. King pile and panel groins can also be made semi-permeable by adding spacers between the panels to control porosity. As with pile groins, performance of semi-permeable king pile and panel groins is difficult to predict. The proposed groin design for this Project is a pile and panel groin with a wooden stem and rubble-mound head; the rubble-mound head will minimize scour and wave loading.

The preliminary design for groins proposed as a component of this Project is more comprehensively discussed in Section 3.2.2. This design is being refined, and final specifications will be presented in the FEIR. Although groins are not a viable as a stand-alone alternative for the proposed Project given the sand deficit in the system, they are viable as a Project component in conjunction with beach nourishment. Their potential role as a Project component is discussed in further detail below.

2.3.4 Beach Dewatering Systems

Beach dewatering systems are part of an experimental erosion-control strategy by which water is removed from the beach face to promote accretion of actively-moving sediment in the swash zone. The theory behind the concept is based on the supposition that draining water from the beach face can reduce the local groundwater table, thereby stabilizing the existing beach by reducing the buoyancy forces and lubrication between individual grains of sand on the existing beach. In addition to halting the erosion of existing sediment, beach dewatering systems are also designed to promote deposition of new sediment actively moving through the swash zone, thereby encouraging shoreline accretion. Percolation of swash zone water into the beach results in less seaward drainage across the beach face, thereby encouraging deposition of sediment.

The concept of beach dewatering was first identified in Denmark in 1981 at Hirtshals West, when the North Sea Research Center constructed a pump drainage system designed to filter water through the beach face for use in a saltwater aquarium. After providing high-quality water to the aquarium for approximately six months, flow rates began to decline substantially and local citizens began to observe accumulations of sand in the landward roadways. It was also discovered that the beach had accreted 20-30 meters in the vicinity of the pumping system. Beach accretion had decreased the efficiency of the pumps, thereby compromising the effectiveness of the filtration system for the aquarium. Furthermore, the accreted beach provided a greater source of dry beach sand for aeolian transport onto local roadways. The pump system was lengthened to accommodate the pumping of more water, and a plan was eventually adopted to remove sand from the accreted beach on a regular basis so that sufficient pumping volumes could be achieved for the research center. This prototype provided the template upon which later beach dewatering systems were based. Including three systems that were planned or in progress for construction in 2005, 41 systems are known to exist worldwide.

The performance of beach dewatering systems is the subject of much debate in coastal, scientific, and engineering communities. Key success stories have occurred at Sailfish Point, Florida, and at Thorsminde, Denmark, where installations operated for several years and monitoring data demonstrated meaningful beach accretion that corresponded to system operation. The Danish Coastal Authority observed direct accretion of the beach which corresponded to more than six years of system operation, and the authority observed a reversal to beach erosion when the system was intentionally shut down for experimentation purposes.

There have also been a number of disappointments with beach dewatering systems. Efforts to adopt the systems in Malaysia have met with difficulties, and achieving accurate pipeline installations, effective well configurations, and preventing clogging of shore-parallel beach face filtration pipes have all presented challenges. Many systems have experienced physical damage during storms, and flooding has damaged electrical components.

Although the volume of published research and experience is not sufficient to conclusively demonstrate the effectiveness of beach dewatering systems, it is generally accepted that the technology can be effective along sandy tidal beaches that are exposed to moderate wave climates, have high groundwater tables, and where seasonal beach fluctuations are evident.

Typically, beach dewatering systems are expected to be less effective along chronically-eroding beaches exposed to severe wave and current regimes. What is ambiguous is the apparent effectiveness of the Thorsminde system in promoting beach accretion after extreme storms (including a 100-year storm) along what is a high-energy coastline. A project at Mermoz's Beach along the French Coast also provides an example of the effectiveness of beach dewatering employed in conjunction with shore-perpendicular coastal structures.

There is a significant history with beach dewatering systems at Sconset Beach: four different systems have been installed with mixed levels of performance success, as demonstrated by quarterly data reports published since 1994. Two of the systems, Lighthouse North (LHN) and Lighthouse South (LHS), have been severely damaged and are being removed. Both of these systems were installed along the section of Sconset Beach that has experienced the most severe erosion over the past decade, and have not remained operational due to problems with construction, maintenance, and repeated storm damage. Since becoming defunct, the majority of these two systems have been removed; any components remaining at the time of Project construction will be removed in conjunction with Project activities.

The two remaining systems, Lighthouse South-South (LHS-S) and Codfish Park, currently retain the essential infrastructure to function. The Codfish Park system in particular remains covered by the existing beach. Prior to 1999, Codfish Park was severely eroding and had little active beach fronting the public roadway. Prior to upgrade of the system, the baseline erosion rate in the 600-foot area subject to the beach dewatering system's sphere of influence was a net loss of 3,219 cubic yards per year. Following a system upgrade, the Codfish Park beach accreted at an annual rate of 15,418 cubic yards for the period spanning from December 1999 to July 2002. Once the beach accreted to a point where the system could no longer pump effectively, operations were terminated and the beach responded by eroding at a rate of 5,102 cubic yards per year. This pattern is consistent with the Thorsminde experience, absent a scenario to evaluate whether the beach will recover upon reactivation of system operations. The Codfish Park dewatering system has not yet been reactivated due to problems with the electrical system and concerns regarding the permitting process.

Although the patterns of shoreline erosion and accretion at Codfish Park have not been conclusively linked to operations of the dewatering system, they are evidence of the system's potential effectiveness. The LHS-S system is considered viable since the critical infrastructure for proper operation remains and the requirements to reactive the system are not substantial. Based on performance of the LHN and LHS systems, beach dewatering alone is not considered a viable alternative for satisfying Project objectives. However, monitoring results associated with the Codfish Park system considered in conjunction with beach dewatering systems employed in other locations around the world suggest that this technology may provide some erosion-control benefits. In the context of this Project, beach dewatering offers the potential of reducing the rate of loss of the nourished beach, thereby serving as a demonstration project for improving the functionality of beach nourishment in general.

2.3.5 Environmental Review of Structural Alternatives

Designed to directly prevent erosion from a stretch of protected shoreline, dampen wave energy along the shore, or catch and trap sand being transported downdrift, hard (fixed) structures (i.e., revetments, seawalls, breakwaters or groins) can reduce the sediment supply available to the littoral system. These structures do not add sediment to the littoral system, and hence they do not address the basic problem of depleted sand supplies along eroding shorelines. As a result, hard structures often protect the directly-armored shoreline at the expense of downdrift areas, particularly when structures are constructed absent beach nourishment. By either trapping sand or preventing erosion of upland material, hard structural stabilization measures can potentially exacerbate erosion problems on adjacent, downdrift beaches.

Exceptions involve low-profile or semi-permeable groins which, after filled to entrapment, can help maintain a more natural rate of sand transport from erosion hotspots. These structures slow sediment losses from the design beach profile and enhance the effectiveness of nourishment efforts. Implementing a beach nourishment program in conjunction with the placement of adjustable structural alternatives enhances the sand supply in the littoral system, moderates sediment losses from erosion hotspots, and increases the longevity of the design beach profile. The National Research Council recommends that regulatory agencies consider the use of well-designed structures, when proposed in conjunction with beach nourishment activities, in cases where their use will significantly improve the performance or longevity of shore protection projects without promoting unacceptable adverse effects (NRC, 1995).

Impacts from shoreline armoring absent nourishment are increasingly recognized by coastal engineers and regulatory authorities, and many state and local programs now discourage hard structures or require nourishment as part of their approval to maintain the sand supply in the littoral system. By placing a large volume of nourishment material in the Project area and bolstering the sand supply in the local littoral system, the Project also will benefit adjacent beaches.

Without accompanying nourishment, seawalls and revetments are not preferred alternatives for the proposed Project primarily due to environmental regulatory constraints stemming from their likely environmental effects. Although seawalls would effectively protect the bank and upland property from erosion, potential issues associated with the interruption of natural sand supply and transport could make timely permitting of the Project problematic. In addition, these structural alternatives are specifically prohibited by the Nantucket Wetlands Bylaw administered by the Nantucket Conservation Commission, and public sentiment in the region is generally in opposition to hard structural alternatives such as seawalls. These structures would also be costly, with a seawall ranging from $2,000-4,000 per linear foot (for an approximate total of $7-14 million) and a revetment providing similar protection for $4,500-7,500 per linear foot. Although confident that an effective structural plan, with appropriate mitigation, could be designed from an engineering perspective, the Proponent has determined that these structures are not preferred, at this time, given the regulatory climate surrounding the Project and the potential detrimental environmental effects from armoring the shoreline if beach nourishment is not a Project component.

Manufactured artificial reef breakwaters are not practicable due to serious questions about their effectiveness. Artificial reefs are generally submerged and have exhibited limited effectiveness at causing waves to break before they impact the shoreline. These structures are generally narrow in width in comparison to wave length, which inhibits their ability to appreciably dampen wave energy. Artificial reef breakwaters are also susceptible to scour and settling, which can allow significant wave energy to pass over them and impact the beach. In addition, as water depth increases over the structure during storm surge, the breakwaters offer the least protection when it is most needed. Costs associated with PEP and Beachsaver structures range from $550-625 per foot (in 1993 dollars). At these costs, protecting 3 miles of shoreline would range from $8.7-9.9 million, with limited effectiveness. More minor artificial submerged breakwater structures such as reef balls would be completely ineffective in an environment as dynamic and active as the one present in the Project area.

Emergent breakwaters could be more effective from an engineering standpoint, but only when constructed in massive rock configurations that are not practicable because of likely environmental impacts and permitting constraints in the Project area. The Project beach slopes steeply offshore; therefore, the breakwater would have to be located in relatively deep water. Consequently, a breakwater would require a large base foundation, which would permanently impact nearshore marine habitat. Particularly for a project of this size, where up to four miles of shoreline would require such protection, this impact would be large. The costs for a project of such scope would be prohibitively high (likely $4,000-6,000 per linear foot).

The feasibility of permitting sunken barge breakwaters for this Project is questionable. The CP&E report cited a 1930s state policy prohibiting the sinking of vessels, apparently out of concern that these structures could become impediments to navigation. Installing a sunken barge breakwater at $730 per foot over a four-mile shoreline would cost nearly $15.5 million (in 1993 dollars). Therefore, these structures are not practicable due to high cost, questions regarding feasibility, limited expected success, and potential permitting problems. If a structural solution was to be pursued, a seawall or revetment would be preferred over any type of submerged or emergent breakwater.

Traditional coastal groins are not a practicable stand-alone alternative for the proposed Project primarily due to environmental regulatory constraints stemming from their likely environmental effects. Furthermore, a groin field absent an accompanying nourishment program would not likely be effective because it would not address the existing sediment deficit in the Project area. Employing groins as a stand-alone measure could potentially shunt erosion problems to downdrift beaches by interrupting natural sand supply and transport.

Adverse downdrift impacts from groins can be largely avoided or minimized when these structures are used in conjunction with nourishment, which increases the sediment supply in the littoral system, and when their placement is based on thorough site-specific analyses. Groins are practicable as one element of the proposed Project's multi-faceted approach to bank stabilization and shoreline nourishment. If installed at nodal points where longshore transport occurs in both directions, these structures can regulate the rate at which beach nourishment sand is lost from these erosion hotspots such that shoreline change is more consistent along the length of the Project. By regulating a more natural rate of sand transport from erosion hotspots, properly-designed groins may increase the longevity of the design beach profile and correspondingly maintain and enhance the success of nourishment efforts (see Section 3.2.2). The proposed groins are intended to help protect the design beach profile within the Project area without relocating erosion's detrimental impacts to adjacent downdrift beaches (NRC, 1995). Inclusion of these structures as a Project component will also minimize environmental impacts by reducing the volume of nourishment fill required to satisfy Project objectives and lengthening the interval between renourishment events. To maximize the effectiveness of groins and minimize the chances for potential associated detrimental impacts, monitoring coupled with a contingency plan to mitigate any adverse effects is generally recommended (NRC, 1995). The alternatives analysis includes an evaluation of thresholds for renourishment, adjustment, or removal to mitigate any observed adverse impacts to beaches outside the immediate Project area, which would be contrary to the Project's objectives. Section 5.2.2.4 discusses monitoring and maintenance activities associated with proposed groins.

2.4 Bank Stabilization

Bank stabilization is an integral component of the Project because in many locations the Coastal Bank is overly steep due to cutting at the toe of bank by storm waves. Bank stabilization techniques proposed as part of this Project include planting vegetation where the bank is not over-steepened and combining temporary bank terracing with a vegetation program and geotextile tubes where over-steepening does threaten landward resources.

Stabilizing the bank solely using vegetation involves planting beach grass and woody vegetation consisting of Black Cherry (*Prunus serotina*), Bayberry (*Myrica pensylvanica*) and Viburnum (*Viburnum spp.*). Bank stabilization through a combination of bank terracing and vegetation plantings involves constructing a series of terraces on the bank face using biodegradable coconut fiber mats (see Section 3.2.5). The mats are layered with sand, after which American beach grass (*Ammophila breviligulata*) or other indigenous vegetation is planted to stabilize the terraces. Since portions of the existing Coastal Bank are over-steepened, recession at the top of the bank may occur even following completion of nourishment activities. Therefore, bank stabilization via terracing and vegetation planting is an important facet of this Project. This combination of bank stabilization methods has been implemented in several locations along Sconset's shoreline, and has been successful at preventing further bank retreat (see Figure 2-5). Installing coconut fiber toe terraces would provide some level of protection for the bank until the comprehensive nourishment Project could be completed.

In an effort to adequately protect landward resources during the permitting phase of this Project, the Proponent proposes to utilize and expand the existing efforts at bank stabilization prior to conducting nourishment. This will afford interim storm damage protection to landward resources until the comprehensive nourishment Project is permitted and constructed. As explained in Section 6.1, the Proponent is seeking a Notice of Project Change/Phase One Waiver from MEPA to allow bank terracing and vegetation efforts to proceed immediately. Upon completion of the Project and until they have biodegraded, the terraces are intended to provide protection to the bank from water and wind-induced erosion.

2.4.1 Geotextile Tubes

Geotextile tubes consist of fabricated geotextile cloth sheets sewn together into a tube shape typically 30 to 60 feet in circumference. These tubes are then filled with sand pumped from the nearshore beach or deposited from an overhead gravity hopper into ports located on the top of the tube. A scour apron with an anchor tube is typically connected to the seaward edge of the geotextile tube to minimize undercutting by wave scour. Buried near the toe of the Coastal Bank, geotextile tubes promote bank stability by protecting the toe from erosion and defending the bank against storm damage. These structures are intended to afford protection to the bank under extreme circumstances, and are not designed to be exposed to wave action except in the case of a severe storm or a rapid series of smaller storms occurring at a time in the Project's design life when renourishment is required (see Section 3.2.3). Absent this scenario, scheduled renourishment events coinciding with erosion of the advance nourishment fill will maintain the fill around and above the geotextile tubes (for a discussion regarding renourishment triggers, see Section 5.2.2.3).

The proposed geotextile tubes will be installed at the toe of the Coastal Bank. A timely renourishment schedule is essential to properly maintain these structures. Geotextile tubes will degrade after prolonged exposure to UV light, and they are not designed to withstand the energy of routine wave impacts and surfzone activity. The design life of these structures may be extended by applying a polyurea coating. Absent the ability to properly maintain these structures, the alternatives analysis includes a consideration of removal threshold criteria. See Section 5.2.2.4 for discussions regarding geotextile tube monitoring and maintenance efforts.

Geotextile tubes can be paired with bank terracing and vegetation plantings as part of a combined approach to achieve bank stabilization. However, this combination of components will in no way supplement the sand supply in the beach system; rather, the geotextile tubes will prevent erosion of the toe of bank during strong storms while terracing and vegetation plantings will help prevent material losses from the bank face and retain wind-blown sand. Neither of these bank stabilization methods can substitute for the protection provided by a properly-designed and constructed nourishment project, however. In fact, it could be argued that these components actually reduce sand inputs to the littoral system by maintaining the Coastal Bank, potentially exacerbating the local sediment deficit. However, by incorporating geotextile tubes and other bank stabilization measures into a comprehensive nourishment effort that will drastically increase sediment in the littoral system, the Project seeks to improve the local sediment budget while simultaneously stabilizing the Coastal Bank to protect landward resources. Therefore, the combination of geotextile tubes, terracing and vegetation plantings should be incorporated into the full Project, but cannot be considered as a substitute for nourishment efforts. While these components will enhance the Project's design and effectiveness, they will not reduce the design volume of the proposed nourishment.

2.4.2 Environmental Review of Bank Stabilization Alternative

On its own, a strategy of bank stabilization through temporary terracing, vegetation plantings, and/or installation of geotextile tubes would not provide adequate storm damage protection for upland resources in the Project area, and hence is not a practicable alternative. While vegetation helps prevent wind, rain, and runoff-induced erosion from destabilizing the Coastal Bank, the primary cause of bank retreat is wave-induced erosion or scarping of the toe of the Coastal Bank. This toe erosion destabilizes the bank, resulting in bank slumping and upper slope failure. Coconut fiber mat terraces can prevent runoff-induced erosion while also providing a measure of protection near the toe of the Coastal Bank under normal and moderate storm conditions; however, during major storm events these terraces do not provide sufficient protection against wave-induced scarping at the toe of the bank. The coconut fiber toe terraces are also biodegradable and do not offer an effective long-term solution by themselves, but could be effective as temporary impediments to erosion until the comprehensive nourishment Project is completed. Hence, the Proponent is seeking a Notice of Project Change and Phase One Waiver from MEPA to allow construction of the proposed terraces and associated vegetation plantings while the remaining portions of the Project proceed through the permitting process (see Section 6.1).

The only way to avert long-term retreat of the Coastal Bank is to prevent erosion at its toe and to stabilize the upper slope with terraces and/or vegetation plantings. This could be achieved with structural alternatives such as a seawall or revetment, or by employing a multi-faceted strategy of nourishment and bank stabilization measures to stabilize over-steepened portions of the bank, maintain a beach of sufficient width to protect against day-to-day wave action, and prevent erosion at the toe of bank during larger storm events. Bank terracing, vegetation plantings, and geotextile tubes can be components of a successful shoreline stabilization strategy if used in conjunction with nourishment, but would not provide sufficient protection to satisfy Project objectives as stand-alone measures. Furthermore, while stand-alone bank stabilization measures may reduce inputs of sediment to the beach environment by removing the Coastal Bank as a source of material, the proposed Project intends to stabilize the bank while dramatically increasing the volume of material on the beach; this will benefit both the Project shoreline as well as adjacent beaches. While not as effective as a hard structure, a properly-managed bank stabilization and nourishment strategy can effectively manage erosion of upland property. While not the primary solution, bank stabilization is an important component of the overall Project design given the need to manage an over-steepened Coastal Bank and associated erosion caused by wind, rain, and runoff common in the Project area.

2.5 Beach Nourishment Alternatives

As the engineering community, regulatory authorities, and resource agencies have become increasingly sensitive to detrimental effects stemming from hard stabilization structures, soft stabilization strategies have becoming increasingly favored where landward interests are threatened by shoreline retreat or storm damage. Beach nourishment is perhaps the most well-known and intensively studied method of soft shoreline stabilization (see Section 1.6), and it is the only shoreline management strategy that addresses the basic problem of sand supply shortages along eroding coastlines (NRC, 1995). The National Research Council recommends that local, state and federal agencies consider beach nourishment as a "viable alternative" for protecting eroding shorelines and restoring or enhancing beach assets (NRC, 1995).

One of the driving forces behind beach nourishment projects is the protection of infrastructure, property and development from erosion and storm damage. Although nourishment requires maintenance in order to be effective as a long-term management strategy, in dynamic coastal environments it can provide sufficient protection from erosion to minimize property losses without heavily armoring the coast with structures. By widening the beach, nourishment creates a wider swath of sand across which wave energy is absorbed and dissipated, and can also prevent waves from directly impacting structures, Coastal Bank, or Coastal Dune.

In the United States, the predominant methodology for nourishment includes placing sand into a construction beach profile. Natural coastal processes interact with this construction beach profile and rework the nourishment material to create an equilibrated beach profile (NRC, 1995). This latter profile can be approximated based on coastal conditions at the project site and characteristics of the nourishment material. If the nourishment material is sufficiently similar in grain size to the native beach sand, and the native beach does not contain exposed rock or other erosion-resistant features, then the equilibrated (or equilibrium) profile can be expected to be roughly the same as the natural beach, only displaced seaward (NRC, 1995).

Beach nourishment can be performed alone or in concert with other shore protection measures such as structural or bank stabilization alternatives, sand retention devices, and beach dewatering systems. These alternatives may include seawalls, geotextile tubes, sculpted berms, groins, breakwaters, or a combination of multiple measures. Various beach nourishment alternatives are evaluated below. In each case, nourishment for this Project would consist of building a wide, high beach by placing a substantial volume of clean, beach-compatible sand on Sconset Beach as well as Coastal Dune to protect the eroding Coastal Bank as well as upland property and structures.

The Project's proposed beach nourishment envelope spans almost three miles from its northern limit near Sesachacha Pond, past the Sankaty Head Lighthouse and south to Codfish Park (see Figure 1-1). Almost an additional mile of shoreline extending south of Codfish Park to the Town Sewer Beds is proposed to receive berm and dune nourishment.

2.5.1 Stand-Alone Beach Nourishment

2.5.1.1 Description of Stand-Alone Beach Nourishment

If nourishment was adopted as the sole shoreline management strategy employed in this Project, then Sconset Beach would be nourished as described above with no additional measures undertaken to prolong the design life of the nourished shoreline. A cross-section of a generalized schematic nourishment design beach profile is shown in Figure 2-6. The berm height for this Project is expected to be 12 feet above MLW in areas of beach and dune nourishment and 16 feet above MLW where only dune nourishment is proposed; initial design calculations suggest that a minimum beach width of 100 feet is required to provide adequate protection during storms (see Section 3.2.1). These specifications define the "design beach", which is intended to be maintained at all times. This design beach is the minimum beach profile that yields benefits prior to renourishment (NRC, 1995). Seaward of the design beach is the "advance renourishment" sand, which is sacrificial and is expected to erode as the beach equilibrates and longshore sediment transport continues. Although the volume of required nourishment varies along the coast, the typical template includes 150-200 cubic yards of sand per linear foot of beach. Coastal erosion and sand transport along the coast would occur naturally and in response to coastal storms.

The total beach nourishment Project, including the advance nourishment profile, proposes to widen the beach berm by approximately 200 feet (see Section 3.2.1). Preliminary erosion and beach performance modeling for the Project, which does not propose nourishment as a stand-alone measure but rather as an integral part of a multi-faceted shoreline management approach, has indicated that such a profile design will require up to 2.6 million cubic yards of nourishment sand and will have a design life of approximately five years (assuming average conditions).

2.5.1.1.1 Beach Nourishment Schedule

Project construction is proposed to occur between the end of May and November based on a number of considerations including meteorological conditions, wave and current climates, safety, and time-of-year restrictions related to biological resources. This construction schedule will allow the Proponent to achieve the goal of planning and implementing a feasible Project that provides safe and reasonable working conditions while still respecting and protecting various environmental resources. To this end, the Proponent has invested extensive effort in refining the Project's design and methodological approach with regard to construction, monitoring, and mitigation activities.

As presented in Section 4.1, the Project's setting along the east coast of Nantucket and offshore in the Atlantic Ocean is a harsh, unforgiving, and hazardous environment due to highly-dynamic weather, water circulation, and wave conditions. To assess these conditions, 23 years of monitoring data were obtained from NOAA Buoy 44008, which is located approximately 55 nautical miles southeast of Nantucket. This buoy collects 20 minutes of wave data every hour, from which a single significant wave height value is resolved. These data were divided into two subsets, one for the summer months (May through October) and one for the winter months (November through April), which correspond to the two most likely Project construction windows. Data were analyzed to determine the number of hourly readings collected, minimum significant wave height, maximum significant wave height, average significant wave height, the number of hours that the significant wave height exceeded six feet, and the percentage of time that the significant wave height exceeded six feet for each 6-month period (see Table 2-1). These values were averaged for the 23 years data.

During the summer, the average minimum significant wave height was approximately 1.1 feet while the average maximum significant wave height was approximately 20.5 feet, yielding an overall average significant wave height for the summer period of approximately 4.3 feet. The average number of hours that the significant wave height exceeded six feet during the summer was approximately 675 hours (16.77% of the total time monitored).

During the winter, the average minimum significant wave height was approximately 1.5 feet while the average maximum significant wave height was approximately 25.4 feet, yielding an average significant wave height of approximately 7.0 feet. The average number of hours that the significant wave height exceeded six feet during the winter period was approximately 1,847 hours (51.59% of the total time monitored). This is a significant increase over the summer monitoring period (see Table 2-1).

Performing dredging and nourishment operations in seas over six feet is not possible. Figure 2-7 illustrates the significantly greater average wave heights in winter compared to summer between 1983 and 2005, and Figure 2-8 illustrates the annual percentage of time when significant wave height exceeded six feet, broken out by season over this same period of time. Sea conditions in excess of six feet occur more than half of the time during the six-month winter period. Based on these data, it would be impossible to complete Project construction during the six-month winter period. In addition, if the Proponent attempted to adopt such a schedule, it is possible that dredging contractors would consider the Project infeasible and not worth the risk, thereby opting out of the bidding process. The 1983-2005 data portrayed in Figures 2-7 and 2-8 clearly reveal that the best window of opportunity to perform dredging and beach nourishment operations is during the summer (May through November), when sea conditions are more suitable for construction.

Table 2-1 Wave data from NOAA Buoy 44008 (1983-2005)

Year	# Hourly Wave Readings	Minimum SWH*	Maximum SWH	Average SWH	# Hours SWH>6′	% Readings>6′
SUMMER (May through October)						
1983	2875	1.0	15.7	3.9	503	17.50
1984	4250	1.0	20.0	4.2	723	17.01
1985	2893	1.0	17.1	3.9	265	9.16
1986	4285	1.0	20.3	4.4	860	20.07
1987	4130	1.0	15.4	3.7	335	8.11
1988	4258	1.3	21.0	4.2	630	14.80
1989	4321	1.0	14.1	4.3	822	19.02
1990	4368	1.3	22.6	4.5	797	18.25
1991	4365	1.0	37.4	4.1	457	10.47
1992	4385	1.3	11.5	4.0	568	12.95
1993	4359	1.0	17.4	3.8	457	10.48
1994	4329	1.0	16.7	4.1	751	17.35
1995	4297	1.3	17.4	5.1	1156	26.90
1996	2752	0.1	30.7	4.8	646	23.47
1997	2436	1.3	25.4	4.3	370	15.19
1998	4376	1.2	17.7	4.4	875	20.00
1999	4383	1.3	37.6	4.5	912	20.81
2000	4349	1.2	15.0	4.2	586	13.47
2001	2992	1.4	9.7	3.9	321	10.73
2002	4385	1.3	18.5	4.4	802	18.29
2003	4351	1.2	22.1	4.8	1009	23.19
2004	4396	1.1	20.0	4.4	770	17.52
2005	4387	1.2	27.6	4.8	920	20.97
AVERAGE	**3997**	**1.1**	**20.5**	**4.3**	**675**	**16.77**
WINTER (November through April)						
1982-1983	3967	1.0	25.6	7.5	2310	58.23
1983-1984	3318	1.0	26.2	7.4	1986	59.86
1984-1985	3538	1.3	18.4	6.5	1755	49.60
1985-1986	3071	1.3	21.3	6.7	1521	49.53
1986-1987	3597	1.3	26.6	7.3	1798	49.99
1987-1988	1710	2.0	15.7	6.1	787	46.02
1988-1989	4270	1.3	21.3	6.5	1953	45.74
1989-1990	4251	1.6	22.0	6.4	1840	43.28
1990-1991	4099	1.6	23.0	6.6	1850	45.13
1991-1992	4296	1.3	24.0	6.7	1969	45.83
1992-1993	1164	2.0	16.4	6.1	421	36.17
1993-1994	4235	1.0	25.6	6.9	1956	46.19
1994-1995	4200	1.3	35.1	7.2	2173	51.74
1995-1996	1997	1.7	28.5	8.1	1259	63.04
1996-1997	3613	1.5	25.7	7.3	2082	57.63
1997-1998	2492	1.4	30.1	7.1	1286	51.61
1998-1999	4118	1.0	26.1	6.8	2067	50.19

1999-2000	4300	1.5	31.9	7.5	2335	54.30
2000-2001	4229	1.5	30.2	7.1	2152	50.89
2001-2002	3528	1.7	24.7	6.9	1866	52.89
2002-2003	4319	1.7	28.5	7.9	27.8	62.70
2003-2004	3199	1.5	28.3	7.4	1776	55.52
2004-2005	4330	1.7	29.8	7.7	2620	60.51
AVERAGE	**3558**	**1.5**	**25.4**	**7.0**	**1847**	**51.59**

SWH = Significant Wave Height

Scheduling Project construction during the summer and fall will avoid impacts to winter flounder spawning. Winter flounder is a commercially-important flatfish species whose populations have declined dramatically over the past two decades due to a variety of pressures including overharvest, habitat degradation, and entrainment and impingement in power plant cooling systems. In an attempt to protect winter flounder spawning grounds, regulatory agencies have instituted restrictions on in-water construction activities between February and the end of May in areas where spawning occurs. The proposed Project will avoid construction during this period, as detailed in Sections 3.4 and 5.1.2.

In addition to the considerations listed above, Project construction between the end of May and November can be accomplished without significant adverse impacts to nesting shorebirds. From April 1 through Labor Day, Piping Plovers and Least Terns have historically nested at the northern end (near Sesachacha Pond) and southern end (near Low Beach) of the proposed beach nourishment template (see Section 4.7). Impacts to nesting shorebirds will be avoided by prohibiting construction activities within specified buffer zones designated around nesting areas until after Labor Day. In the middle portion of the Project area, where no nesting has historically occurred, shorebird monitoring will be conducted to ensure there are no adverse impacts to nesting shorebirds. Finally, a shorebird management plan for the entire Project area has been developed in accordance with state guidelines. Sections 4.7 and 5.4 provide additional details regarding avian populations in the Project area and the Project's related monitoring and mitigation efforts. While the Project must be careful not to impact shorebirds or their habitat during construction, the Project activities will provide long-term benefits to shorebird habitat (see Section 4.7).

Furthermore, performing Project construction between the end of May and November will avoid winter months when these offshore areas are used by waterbirds; by planning and performing dredging outside these months, the Project's potential impacts will be avoided or minimized (see Section 4.7).

2.5.1.1.2 Cost Analysis of Beach Nourishment

Beach nourishment is a viable alternative for shoreline maintenance and storm protection. Cost estimates for construction of the design template, including dredge equipment mobilization, sand placement, and grading, typically range from $5-10 per cubic yard. However, even if environmental conditions made it feasible to perform Project construction during the winter months, costs would be substantially greater due to high demand for dredging equipment in the southeastern part of the country, where winter is the prime season for dredging. Key variables factoring into construction costs include timing within the calendar year, project design characteristics, weather conditions, dredge equipment supply and demand, fuel prices, labor, and other direct costs.

Construction timing is the primary governing factor for the cost of the Sconset Project. If construction occurs between the end of May and November, the cost is significantly reduced for two reasons: (1) more dredging equipment is available because of dredging restrictions in the southeastern United States due to turtle nesting season; and (2) prevailing wind, wave and current conditions are more favorable, reducing down time for the dredging operator. During the winter months, storms coupled with the severe wave and current regimes offshore from Sconset would make dredging and construction costs substantially higher, and equipment demands related to Florida's dredging season (which is at its peak from November to March) would not only drive up Project costs but would add additional uncertainty to the Project's ability to obtain the necessary dredging equipment. Due to these factors, bids from dredging contractors for winter work would be prohibitively high, if any bids could be secured at all.

Nourishment costs for construction between the end of May and November are estimated at $8-10 per cubic yard, whereas winter costs are estimated at $12-16 per cubic yard or more, depending on equipment demand and operating conditions. Using these estimates, the seasonal cost differential for the Project is $10 million, where winter construction would cost 50% more than summer construction. Furthermore, consultations with the peer review panels and other professionals have suggested that winter construction may not be practical or even feasible for the Project due to extreme weather and associated marine conditions. Attempting construction in the Project's dynamic and potentially dangerous environment during the winter would incur substantial costs relating to equipment downtime and could threaten the safety of construction crews.

2.5.1.2 Environmental Review of Stand-Alone Beach Nourishment

Large-scale nourishment is a practicable alternative for this Project based on considerations of effectiveness, feasibility, permitting, and environmental impacts. This alternative fundamentally restores and enhances natural coastal processes while protecting the Coastal Bank and upland properties, providing public benefits, and expanding Coastal Beach resources and functions.

Proposed nourishment fill will restore the depleted supply of sediment on the beach and improve performance standards of the Coastal Beach, Coastal Bank and Coastal Dune resource areas. In addition to enhancing storm protection and providing a wider beach (which will protect landward resources while also benefiting recreational interests), nourishment provides other important benefits. These include maintaining options for additional shoreline management strategies (whereas hard structural stabilization can eliminate future options) and potentially providing protection and/or enhanced habitat for plants, sea turtles, shorebirds (including listed species), and other organisms (some of which may be listed species) (Greene, 2002; NRC 1995). In addition, since beach nourishment does not create a barrier to longshore sand transport but rather increases the sand supply available to the littoral system, this management strategy can provide measurable benefits to downdrift beaches. For these reasons, beach nourishment is often defined and/or required as appropriate mitigation for shoreline development, and is the preferred use for disposal of clean dredged material of compatible grain size.

In spite of the tremendous benefits associated with beach nourishment, there are potential adverse impacts that must be carefully minimized and/or mitigated. For example, the placement of nourishment fill covers existing supra-, inter-, and subtidal habitats with borrowed sand. Organisms using or residing in the sand can be affected depending on where and when nourishment is conducted and where the sand will be transported. Careful planning is required to minimize impacts in the nourishment area (see Section 5.0). Previous project experiences indicate that nourishment activities can be planned and executed in a manner that achieves Project objectives while resulting in a minimal level of environmental impact (see Section 1.6).

In addition to impacts along the nourished shoreline, the potential for adverse physical impacts at the offshore borrow site have been assessed. (For a full discussion of sand source alternatives, see Section 2.6.) Existing marine fisheries, shellfish, benthic organisms and habitat must be carefully evaluated so that potential impacts to these resources can be assessed and subsequently avoided or minimized. Dredging projects can potentially modify water circulation, sediment transport, and wave patterns that may affect evolution of the seafloor and erosion of landward beaches (e.g., due to wave focusing or interruptions in sediment transport patterns). The dredging activity proposed by this Project will be limited to a relatively shallow excavation on the landward side of a sand ridge located 2.5-3 miles offshore from the nourishment area. Mining of material from the lee side of the sand ridge will not significantly impact ridge morphology and will therefore have little to no impact on local water circulation patterns or wave climate. Since dredging will occur 2.5-3 miles offshore, impacts to nearshore sediment transport caused by wave focusing will not be significant. There are other potential impacts to offshore birds, including food sources and feeding patterns.

According to preliminary beach performance modeling, beach nourishment performed at the Project site as a stand-alone shoreline management measure would have a design life of approximately 5 years, based on average environmental conditions for the area. The inclusion of additional shoreline management strategies as complementary Project components would potentially enhance the longevity of the design beach profile and subsequently reduce the frequency of required renourishment events. Less frequent renourishment would potentially decrease impacts in both the nourishment area and borrow site by resulting in less frequent disturbance; benthic communities would be granted more time to recover before subsequent disturbance.

The following sub-sections provide summaries of key environmental issues and analysis related to impacts which must be considered during review of beach nourishment as a viable Project component.

2.5.1.2.1 Nearshore Sediment Transport

The proposed nourishment will add a significant volume of sand to the Project shoreline. This nourishment fill will supplement the local sediment deficit, serving to satisfy Project objectives by protecting the Coastal Bank and threatened upland resources while also benefiting adjacent downdrift beaches. The National Research Council recognizes that beach nourishment can significantly benefit adjacent beaches by increasing the sand supply available for longshore transport (NRC, 1995). Based on analyses to date, the Project is expected to supply the littoral system with more than 25 years of the sediment quantity naturally supplied by the eroding Coastal Bank, Coastal Beach, and Coastal Dune systems; the addition of this material will make up for historic losses along the Project shoreline. It is estimated that the life expectancy of the proposed nourishment will be approximately five years, after which erosion will likely encroach into the design beach profile and potentially threaten the Project's ability to satisfy its objectives; at this point in time a renourishment event will be needed to build the beach out from its design profile. Nourishment fill naturally entrained in local longshore transport will nourish adjacent beaches, providing benefits beyond those to the immediate Project area. Cross-shore sand transport will equilibrate the existing over-steepened beach profile in the Project area, which will provide additional shoreline protection by reducing the seafloor slope in nearshore areas; sand in the seaward portion of the nourished beach profile will dissipate wave energy before it reaches more landward sections of the shoreline.

Detailed sediment transport models are being applied to optimize the Project's design. Modeling results are also being applied to quantify the Project's effects on the regional sand supply and transport patterns.

2.5.1.2.2 Nearshore Benthic Habitat

Nearshore areas where local fishermen have reported bottom characteristics suitable for fisheries habitat (e.g., rocks and shoals) have been preliminarily investigated and confirmed using bathymetric and sidescan sonar surveys as well as underwater video. Geophysical and remote sensing surveys were conducted in spring 2006 to provide data for high-resolution benthic mapping of the nearshore Project area and the Primary Study Area being investigated for borrow site suitability (see Figure 1-4). Results from these surveys are being utilized to more accurately evaluate the Project's potential effects on significant marine resources.

Results from sediment transport models are being evaluated to identify areas that may be impacted by the footprints of either the initial nourishment envelope or the equilibrated beach profile. These areas are being compared to nearshore fisheries habitat surveys to determine the potential for overlap. Nourishment material placed on the beach will match or be slightly coarser than the native beach material to optimize the Project design's performance and to retain similar habitat characteristics (see Section 3.3.1).

Reconnaissance and design-level field investigations have been conducted in the nearshore zone and in the Primary Study Area. Geophysical remote sensing surveys and data from vibracores are being used to supplement existing data and evaluate previously-unexplored sand source areas. These surveys include bathymetry, sub-bottom profiling, sidescan sonar, and magnetometer investigations. A comprehensive analysis of all survey results will be available in the FEIR.

A Differential Global Positioning System (GPS) was used during the surveys to facilitate navigation and accurate positioning. A Pro Beacon receiver provided differential GPS correction from the U.S. Coast Guard Navigational Beacon located in Acushnet, Massachusetts. GPS accuracy, with the differential correction used for these surveys, was one to four feet, adequately satisfying requirements for geotechnical investigations of sediment sources.

Navigational, magnetometer, and depth sounder systems were interfaced with an onboard computer, and data were integrated in real-time using a state-of-the-art navigation and hydrographic surveying system. Graphic displays included pre-plotted survey lines, an updated vessel track across the survey area, adjustable left/right indicators, as well as other positioning information pertaining to vessel speed, quality of fix, and line bearing. All data were recorded on the computer's hard drive and transferred to a USB memory stick each day during the survey to ensure adequate back-up of the raw survey data. After post-processing, navigation data were exported to ArcGIS8 to utilize Geographic Information Systems (GIS) technology for analysis and report preparation. Detailed descriptions of each remote sensing survey or data collection effort are provided below.

- ♦ Seismic-Reflection Sub-Bottom Profile Survey

  Full-spectrum "chirp sonar" instrumentation was used to acquire shallow sub-bottom data. This technology has been successfully utilized for beach nourishment projects in Florida, Louisiana, and North Carolina in 2005 alone. The system often shows a distinct reflector at the boundary of sand deposits and accumulations of silt, clay, gravel, and peat.

  The sonar is a versatile wideband FM sub-bottom profiler that collects digital normal incidence reflection data over many frequency ranges and generates cross-sectional images of the seabed. The system transmits an FM pulse that is linearly swept over a full-spectrum frequency range (also called a "chirp pulse"), and the tapered waveform spectrum results in images that have virtually constant resolution with depth. All sub-bottom data were recorded on the computer's hard drive and transferred to a USB memory stick and/or portable hard drive at the end of each survey day to ensure proper back-up of raw data.

♦ Sidescan Sonar Survey

(1) *Borrow Site:* A sidescan sonar system was employed to identify seafloor composition and to map bottom characteristics such as significant marine resources, underwater wrecks, submerged hazards, and other features that would affect borrow site delineation and dredging activities. This survey occurred within the Primary Study Area being investigated for borrow site suitability (see Figure 1-4). Not all geophysical track lines shown on Figure 1-4 were performed; rather, surveys initially focused in a 1,500-acre area and, after sand was deemed too fine-grained, proceeded into a 1,000-acre area. Results from these investigations led to the identification of the Northern Borrow Site as the preferred offshore sand source (see Section 2.6.2). Survey results are discussed in Sections 2.7 and 3.3.

(2) *Nearshore Zone:* Previously-existing sidescan sonar surveys of the Project's nearshore area, although helpful, were of marginal quality and limited the Proponent's ability to accurately interpret existing marine habitats in sufficient resolution. Therefore, understanding that accurate identification of nearshore marine habitats is important to avoiding and minimizing Project impacts, the Proponent conducted an additional sidescan sonar survey of the nearshore zone along the Project shoreline. Results from this survey provided two sidescan mosaics of varying frequencies and resolutions, enabling the Proponent to accurately map nearshore marine habitats.

A series of shore-parallel survey track lines were run to collect these data. During sidescan data acquisition, geologists performed in-the-field interpretations so bottom grab samples could be collected from select areas. Such samples enabled the Proponent to ground-truth sidescan data and verify seafloor composition in a geological context. Sidescan results have been used to delineate zones of nearshore cobble bottom and glacial boulders; Section 4.3.6 provides a discussion of the sidescan survey and resulting delineations. A dive survey was conducted in June 2006 to assess the characteristics and habitat value of the nearshore cobble and boulders; results from this survey are presented in Sections 4.3.6 and 4.5.5, and potential mitigation relating to habitat conversion in the nearshore is discussed in Section 5.2.3.3.1.

♦ Bathymetric Survey

A bathymetric survey was conducted simultaneously with the sub-bottom survey described above to map seabed topography and identify sediment ridges and troughs. During performance of the survey, navigational and depth-sounder systems were interfaced with an onboard computer, and data were integrated into the navigation software. Soundings data were recorded continuously in raw digital format on each profile line at intervals of one to two feet along with information such as the date, time, northing/easting, latitude/longitude, and a summary of all navigational parameters.

Vertical and horizontal data were recorded and presented in feet based on the North American Vertical Datum of 1988 (NAVD 88) and Massachusetts State Plane – Island Coordinate System, North American Datum of 1983/1990 (NAD 83/90). All work was conducted in compliance with the USACE *Technical Requirements for Hydrographic and Topographic Surveying* for Class III Hydrographic Surveys.

- Magnetometer Survey

  A magnetometer survey will be conducted to meet cultural resource protection requirements and to locate objects that could be obstacles to dredging. A Digital Cesium Marine Magnetometer will be used to perform a cursory investigation of magnetic anomalies within the proposed borrow site. Results from the magnetometer survey will be used to establish exclusion zones around any underwater wrecks, submerged hazards, or other features that could affect borrow site delineation and dredging activities.

2.5.1.2.3 Nearshore Benthic Invertebrates

The proposed nourishment envelope will cover more than 125 acres of beach, inter-tidal, and sub-tidal habitat. Direct mortality to the benthic community, including invertebrates and shellfish, will be unavoidable. However, as with the offshore communities, nearshore benthic organisms are expected to begin recolonizing the area within months of Project completion, and full recovery is expected within one to three years. Section 4.5.4 contains a thorough discussion of potential Project impacts to benthic resources.

2.5.1.2.4 Nesting Shorebirds

The Project will provide substantial benefits to listed species of nesting shorebirds such as the Piping Plover and Least Tern. Beach habitat in the majority of the Project area (from Hoick's Hollow to Codfish Park) is currently unsuitable for nesting shorebirds because it is too narrow, is frequently overwashed by high tides and storm waters, and is abutted by a steep Coastal Bank. Beach nourishment will create a wider, higher beach area that will provide favorable habitat for nesting shorebirds, which prefer to nest in sandy areas above the reach of the tide. Nourishment projects in other locations, including several projects along the shoreline from Manasquan Inlet to Asbury Park in northern New Jersey, have demonstrated that shorebirds will utilize nourished beaches for nesting. Furthermore, Massachusetts state guidelines for listed shorebird management specifically state that Piping Plovers "may also nest where sandy dredged material has been deposited" (NHESP, 1993).

Potential construction-related impacts to shorebirds will be avoided or minimized by monitoring the site during the potential nesting season (April 1 to Labor Day). The

Proponent will require a cessation of Project activities in localized areas if nesting is documented. Shorebird monitoring and mitigation activities specifically relating to this Project are presented in Section 5.4. On April 20, 2006, a draft Shorebird Management Plan was submitted to the Massachusetts Natural Heritage and Endangered Species Program, USFWS, Nantucket Marine and Coastal Resources Department, and Nantucket Conservation Commission outlining the Project's anticipated effects on shorebirds and presenting relating monitoring and mitigation efforts. The Proponent will work to incorporate any feedback from these agencies and will prepare a final Shorebird Management Plan.

During beach equilibration, a scarp may develop that could impede movements of unfledged (flightless) chicks; however, such a scenario would not necessarily be directly related to nourishment activities (NRC, 1995). Scarps develop naturally on beaches in response to coastal conditions, so it is not anticipated that development of such a feature on the Project beach would introduce shorebirds to an unnatural condition. For example, a coastal storm in May of 2005 eroded the beach at Sconset and produced a one-meter-high scarp in the upper beach which extended from north of Hoick's Hollow to Low Beach.[1] Furthermore, scarping of the nourished beach tends to be most pronounced immediately following placement of the nourishment fill; performing beach nourishment in the summer and fall will allow the beach profile ample time to adjust before Piping Plover chicks are present the following spring.

In addition, the dredging contractor will be required to grade the seaward face of the nourished beach to provide a gradual seaward-sloping surface. A typical construction slope for beach nourishment projects constructed with medium- to coarse-grained sand is 1V:10H. However, initial indications for this Project are that a construction template slope of 1V:8H may be achievable. The contractor will be able to control the beach slope above MHW but will have limited control of the beach fill below this line due to the dynamic sediment transport processes present in the Project area. Seaward of MHW, the nourishment material will follow the natural angle of repose. It is possible to specify different construction slopes above and below MHW; however, this requires additional grading work and is typically avoided. More gradual construction slopes may reduce scarping, but coastal processes will reshape the beach to its natural equilibrium slope regardless of the initial slope. Due to this beach equilibration process, the nourished beach is typically constructed at the most economical slope. Depending on weather conditions and sea state following placement of nourishment fill, it is anticipated that the nourished shoreline will take approximately one to two years to reach an equilibration profile.

---

[1] Dr. Robert Kennedy, ornithologist, made this observation of beach scarping during his plover monitoring walk between Hoick's Hollow and Codfish Park.

Finally, the type of storm that would create scarps would certainly impact a swath of beach larger than just the Project area. Ultimately, the benefits of beach nourishment in terms of creating more suitable shorebird habitat are significantly greater than any impacts from potential scarp development.

2.5.2 Nourishment with Creation of a Vegetated Dune

2.5.2.1 Description of Nourishment with Creation of a Vegetated Dune

Nourishment of the Project shoreline could be performed in combination with construction of a vegetated dune or berm along the back of the beach near the toe of Coastal Bank. This combination of shore protection measures could more effectively achieve Project objectives than a stand-alone nourishment Project. A dune would effectively add an extra volume of sand to the landward portion of the design beach, and established dune vegetation would stabilize the feature, making it less susceptible to erosion. Construction of a vegetated dune, therefore, may slightly increase longevity of the design beach and would provide the toe of Coastal Bank with a level of protection greater than that achieved through nourishment alone. Additional analyses are being performed to quantify the relative costs, benefits, and environmental impacts of adding a vegetated dune to the Project design.

2.5.2.2 Environmental Review of Nourishment with Creation of a Vegetated Dune

Environmental benefits of adding a vegetated dune include increasing the sand supply in the littoral system, improving storm damage protection for the Coastal Bank and upland areas, and providing additional wildlife habitat. Including such a feature in the nourished shoreline design may, however, reduce the area of suitable habitat created for nesting shorebirds, which tend to prefer un-vegetated beaches. All of the environmental considerations presented for the stand-alone nourishment alternative are applicable to this alternative as well (see Section 2.5.1.2).

2.5.3 Beach Nourishment with Groins

2.5.3.1 Description of Beach Nourishment with Groins

In this alternative, nourishment would be performed in a manner consistent with the alternatives described above and up to 13 groins would be constructed in select locations of accelerated erosion in order to improve the Project's longevity. As described in Section 2.3.3, groins are shore-perpendicular structures designed to retain beach nourishment sand on the beach and/or capture longshore sediment transport. The Massachusetts Division of Marine Fisheries specifically requested that the Proponent analyze groins as a potential Project component that could increase the longevity of the nourishment and hence decrease the frequency of renourishment events. The groins for the Project have been designed primarily to retain beach nourishment sand. By moderating the rate of sand losses from erosion hotspots so that sediment transport rates are more consistent along the Project shoreline, groins may increase the longevity of nourishment and hence delay the need for renourishment events.

The proposed groin design is a pile and panel groin with a rubble-mound head. The rubble-mound groin head will be constructed of armor stone, and the crest will be at Mean Low Water, a design which reduces the size and number of stones required for the structure while still providing protection to the end of the wooden groin stem. The armor stone will be supported on a marine mattress foundation. These structures are proposed to be spaced at approximately 500-foot intervals and will be roughly 270 feet long. Section 3.2.2 contains a more detailed description of the proposed groins.

The inclusion of groins in the Project design is intended to maintain a minimum beach profile in erosion hotspots occurring at nodal points along the Project shoreline where longshore sediment transport occurs in both directions. Up to 13 groins are proposed; the exact number, locations and dimensions of these structures will depend on modeling results related to the longshore sediment transport rate, plan view beach geometry, and nodal point positions. The Project's preliminary design for the groins calls for these structures to template the design beach profile and extend approximately 270 feet seaward from the toe of the Coastal Bank (see Section 3.2.2). Landward portions will have an elevation approximately two feet below the nourished berm, and the structures will taper down to the elevation of MLW at the seaward ends. Computer modeling will be used to optimize the size, length, number and location of the groins for the intended storm protection and to minimize the required sand nourishment volume; final design specifications will be presented in the FEIR.

The design expectation is to utilize groins to lengthen the design life for nourishment within traditional erosion hotspots to a time period that is more consistent with the design life of the surrounding large-scale nourishment. Such an effect would not only improve Project performance and cost-effectiveness, but could also lessen environmental impacts by reducing the frequency of renourishment events. The incremental cost of groins is expected to be approximately $4.5 million; based on early cost and performance analyses, groins are cost-effective. Adding these structures also provides for design flexibility such that a design life of five years may be achieved with a lower nourishment volume than the stand-alone nourishment alternative would require.

2.5.3.2 Environmental Review of Beach Nourishment with Groins

Groins are practicable as a complementary element to beach nourishment. If installed in erosion hotspots, these structures could promote a more consistent rate of longshore sand transport within the Project area and hence increase the longevity of the design beach profile. By moderating the rate of sand transport from nodal points where littoral drift occurs in both directions along the shoreline, groins can be incorporated into the Project to maintain and enhance the success of nourishment efforts without necessarily projecting detrimental impacts onto downdrift beaches. The proposed groins will achieve this purpose because they will not interfere with the general overarching sediment transport regime in the Project area; furthermore, the nourishment with which these structures are associated will dramatically increase the volume of sand in the local littoral system.

Based on the increased nourishment longevity achieved with use of the proposed groins, the frequency of renourishment events will be reduced, thereby minimizing associated environmental impacts when compared with the stand-alone beach nourishment alternative (see Section 2.5.1). Adding a rubble-mound component at the seaward limit of the Project also has the potential to provide structure for marine wildlife habitat (see Section 5.2.3.3.1).

2.5.4 Beach Nourishment with Geotextile Tubes

2.5.4.1 Description of Beach Nourishment with Geotextile Tubes

Beach nourishment can also be performed in conjunction with placement of geotextile tubes along the base of the Coastal Bank. As described in Sections 2.4.1 and 3.2.3, geotextile tubes are sand-filled fabric structures that include a scour apron with anchor tube connected to the seaward edge to minimize undercutting by wave scour. Including geotextile tubes as a Project component would not affect erosion rates or alter patterns of sediment transport along the Project shoreline from what would occur in the stand-alone beach nourishment. Instead, when buried near the toe of a Coastal Bank, geotextile tubes enhance bank stability by defending the toe of bank against storm-induced wave scour. In this Project, the geotextile tubes are proposed at the toe of Coastal Bank where erosion is occurring and threatening landward resources.

The incremental cost of the geotextile tubes is expected to be approximately $1.125 million, which by the assumptions incorporated into initial cost estimates correlates to an increase of 5% for the total Project (see Section 2.5.1).

2.5.4.2 Environmental Review of Beach Nourishment with Geotextile Tubes

Geotextile tubes are practicable as a complementary element to beach nourishment. The only way to avert long-term retreat of the Coastal Bank is to prevent erosion at its toe. In this alternative, beach nourishment would provide a wide beach along which wave energy would dissipate before detrimentally impacting landward interests, while geotextile tubes would reduce erosion and undercutting at the toe of bank during larger storm events. Section 3.2.3 provides a thorough discussion of geotextile tube design and performance. Bank stabilization in conjunction with beach nourishment provides a natural protective storm buffer for upland resources along the entire Project area.

For this Project, the proposed geotextile tubes will only be exposed in the case of a severe storm or a rapid series of smaller storms occurring after significant depletion of the design berm has already occurred. Other than in this extreme scenario, the geotextile tubes will remain buried in the nourished beach at the toe of Coastal Bank. Therefore, these structures will be protected from the elements until they are required to protect the toe of bank under severe storm conditions or in the event of the rapid loss of the design berm. This is important, since geotextile tubes could become a source of debris should a tube fail due to repeated wave action; if a geotextile tube is subjected to repeated wave action, localized scouring is also likely. These potential adverse effects can be avoided by committing to timely renourishment if the structures become exposed. Section 5.2.2.4 discusses monitoring and maintenance efforts related to geotextile tubes.

2.5.5 Beach Nourishment with Groins and Geotextile Tubes

2.5.5.1 Description of Beach Nourishment with Groins and Geotextile Tubes

An additional Project alternative includes a combination of beach nourishment, groins, and geotextile tubes. This alternative would effectively manage the shoreline and protect landward resources by (1) creating a wider beach to dissipate wave energy and provide a buffer for Coastal Bank and Coastal Dune, (2) mitigating the rate of loss of nourishment sand from erosion hotspots, and (3) protecting the toe of bank against damage and scour from extreme (e.g. 50-year) storms or a rapid series of smaller storms occurring at a time in the Project cycle when renourishment is required. By employing this innovative combination of management strategies, the Project can effectively achieve its objectives while enhancing the longevity of its design and preventing detrimental effects on downdrift shorelines.

2.5.5.2 Environmental Review of Beach Nourishment with Groins and Geotextile Tubes

By employing a combination of shoreline management strategies, this alternative reduces the initial volume of nourishment required for the Project and decreases the frequency of renourishment events. By moderating the rate at which beach nourishment sand is lost from erosion hotspots, the proposed groins will foster more consistent rates of sediment transport across the entire Project area, thus reducing the frequency of renourishment events. Geotextile tubes, on the other hand, will provide an additional level of storm damage protection for the toe of Coastal Bank. Potential adverse effects from groins and/or geotextile tubes can be avoided through proper monitoring and maintenance efforts coupled with timely renourishment events. Thorough monitoring plans will enable the Proponent to maintain the structural integrity of these Project components, identify any related impacts, and perform any modifications necessary to alter their effects (see Section 5.2.2.4).

2.6 Sand Source Alternatives

Beach nourishment projects require large volumes of sand from appropriate borrow sites, and identifying potential sites with adequate sources of accessible sand is challenging. Nourishment material must be compatible with the sediment native to the receiving system, the borrow site should ideally contain a sufficient quantity of sand for initial nourishment and also a renourishment event, and the site must be located to avoid and/or minimize impacts.

When selecting an appropriate sand source, color and composition of the sediment are two additional factors that must be considered, particularly given their importance to residents and beach users. However, grain size is the most important characteristic of the borrow material when evaluating the potential effectiveness and viability of a project's design. To maximize the longevity of nourishment, borrow sediment must be at least as coarse as the native material in the nourishment area; if the material is finer in texture, it will erode more quickly and reduce the effectiveness and design life of nourishment efforts (Dean, Davis and Erickson, 2005). In some cases, when the only sand available for a nourishment project is finer than the native beach sand, a larger effective quantity can be added to the beach to ensure lasting performance. In the case of the proposed Project, nourishment sand of a grain size roughly equivalent to the native beach sand will be utilized or, if slightly finer material is used as nourishment fill, a wider design template will be constructed to achieve the desired design life of the Project. In addition, mud layers and bedrock fragments or cobbles must be avoided.

Due to the large volume of borrow sediment required and the considerations inherent in evaluating such sediment, the location of a potential borrow site is of utmost importance when evaluating the cost and viability of any nourishment project. Costs incurred while dredging and transporting borrow sediment to the nourishment area command the largest share of overall project costs (Dean, Davis and Erickson, 2005). Dredging costs can vary widely depending on the proximity of the borrow site to the nourishment area, project design, prevailing weather and wave conditions during dredging (which affects dredge down time), the season when work occurs, fuel and labor costs, and other market factors.

2.6.1 Upland Sand Sources

2.6.1.1 Description of Upland Sand Sources

The Proponent has used on-island and off-island sand sources to build Coastal Bank terraces at Sconset Beach as part of other projects intended to protect landward resources from erosion and storm damage. The cost of these upland sand sources has typically been $15-20 per cubic yard. On-island upland sand sources have been depleted to the point where the local sand supply is no longer sufficient for terraces, let alone the dramatically higher sand volumes required for the nourishment proposed by this Project. Off-island sand sources are dramatically more expensive than from offshore borrow sources.

The Proponent has also used upland sand from off-island sources for terrace projects. Utilizing these sources requires transporting sand via barge to Nantucket Harbor, where it is loaded onto trucks, transported to Sconset and delivered over the Coastal Bank to construction locations. The cost of sand delivered by this method is typically $25-30 per cubic yard.

In an effort to reduce costs and minimize impacts associated with truck transport over the streets of Nantucket, the Proponent pursued and obtained approval from the Nantucket Conservation Commission for direct sand delivery from off-island upland sand sources to the beach via barge. This delivery method, however, is still quite costly and has not yet been implemented for any construction activities in the Project area. To date, it remains less expensive to barge sand to Nantucket Harbor and transport the material by truck to the Project site. Current estimates for direct barge delivery of sand put the cost at more than $40 per cubic yard. Investigations into how the cost of a direct-barging operation might be reduced are underway; however, downtime and associated cost implications are inflated by risks associated with using the relatively small barges typically available in the northeast in the open Atlantic Ocean with the severe conditions that are often present offshore from the Project site.

After considering that the cost of offshore dredging and nourishment is on the order of $10 per cubic yard, the off-island upland sand source alternative is clearly not practicable. Section 4.8 contains a more thorough discussion of Project-related costs, and socioeconomic impacts. In addition, the quantity and rate of sand delivery from off-island upland sources would not be sufficient to effectively build and maintain the design beach during construction. Overall, the lack of a local upland sand source and the extremely high costs associated with off-island upland sources make it impractical, as well as infeasible from a logistical perspective, to use an upland sand source for the large-scale nourishment Project.

2.6.1.2 Environmental Review of Upland Sand Sources

Due to operations related to sand excavation, an array of environmental considerations must be analyzed and addressed at any potential upland borrow site. These considerations include impacts to surface vegetation, generation of airborne particles, noise issues, odor generation, and transportation impacts to surrounding communities and infrastructure stemming from heavy trucking demands.

In the Project area, the use of an upland sand source is not optimal for several reasons. First, upland sand sources on the island have become depleted and are not able to provide a sufficient volume of sand for the proposed Project. Second, using upland sand from off-island sources is not a preferred alternative since transportation costs would be prohibitively expensive for such a large nourishment Project (see Section 2.6.1.1). Third, the amount of time required to deliver the required volume of sediment from an off-island source would make it impossible to complete the Project in a single season. Nourishment projects typically perform best when the entire project is built before any significant erosion occurs. With the slower delivery of nourishment material to the Project area from upland sources, portions of the Project could erode before the remainder has been constructed.

In addition to these constraints, upland quarry sources often contain a large fraction of fine-grained material, which could exacerbate short-term turbidity impacts during placement of nourishment fill and would not be optimally compatible with native sediment in the Project area. Furthermore, frequent truck trips over the streets of Nantucket would be required to deliver nourishment material from the Harbor to the Project area. Even if sand could be barged directly to the Project site (to avoid docking in Nantucket Harbor), the cost associated with purchasing approximately 2.6 million cubic yards of sediment, plus maintenance materials, eliminates the feasibility of any upland sand source.

2.6.2 Offshore Sand Sources

Offshore deposits have been the predominant sources of sand for large-scale beach nourishment projects in the United States over the past three decades, and they currently supply as much as 95% of the sand used in these projects (NRC, 1995). The identification of suitable borrow sites can be challenging and is dependent upon field investigations and accurate marine substrate mapping. Finkl, Andrews and Benedet (2005) suggest that the classification of potential borrow sites should evolve to include a quantification of uncertainty inherent in such mapping activities. Navigation dredging projects can sometimes provide sediment for nourishment projects, but no dredging projects of sufficient size and proper sediment compatibility are present within a reasonable distance of the proposed Project site. In addition to not containing sufficient material for this Project, communications with the USACE have confirmed that sand dredged from the Cape Cod Canal project is utilized to nourish adjacent beaches and has been utilized by the Town of Sandwich in the past; thus, material from this navigation dredging project is unsuitable and unavailable for this Project. The USACE does not have any other dredging projects nearby which contain sand volumes sufficient to provide material amounts for the proposed Project.

Substrate mapping has revealed that the region offshore from Nantucket is generally characterized by a series of large sandy shoals. In particular, there is an abundant supply of sand offshore from the Project site in Sconset. Despite the abundance of sand, selecting the appropriate borrow site is challenging. A preferred borrow site is one that has the necessary physical sediment characteristics (i.e., volume and grain size) and is located where mining activities will produce minimal impacts on existing offshore geomorphology, wave focusing, longshore sediment transport patterns, and biological communities and habitat. A borrow site must also satisfy operational parameters for dredging equipment, which include considerations of proximity to the nourishment area, wave and current conditions, and water depth. The goal of the borrow site selection process for this Project is to identify an offshore borrow site that meets the design needs of the proposed nourishment template, avoids or minimizes adverse environmental impacts, and accommodates dredging methodologies and equipment to result in a cost-effective Project.

Based on a summer dredging schedule, recent estimates for the cost of offshore dredging and beach nourishment are on the order of $5-8 per cubic yard, which reflects the operational and logistical components of the dredging operation. Offshore dredging will inevitably affect marine organisms and their habitat to varying degrees, and the financial ramifications of these impacts can in some cases be quantified. The initial analysis of the Project's economic impact on fisheries is provided in Section 4.8.1. Section 4.8 provides an accounting of socioeconomic resources and impacts related to fisheries, property values and infrastructure, as well as navigation. In general, financial impacts to commercial and recreational components of the fishing industry will be minimal.

Biological impacts stemming from sand mining of an offshore borrow site include the excavation of habitat present along the seafloor and entrainment of organisms unable to escape the dredge. Project-related impacts to biological resources and habitat are comprehensively addressed in Section 4.0. Effects stemming from the temporary loss of habitat for spawning and feeding can be buffered by habitat of the same value located adjacent to the area of excavation. As addressed in Section 4.5, since excavation activities at the borrow site are not anticipated to significantly change the physical composition of the seafloor, it is anticipated that the benthic habitat and related organisms will recover relatively rapidly after dredging is complete. Furthermore, the controlling factor for species abundance in the Project area is commercial harvesting of groundfish, not habitat availability, so the temporary loss of habitat is expected to have little or no effect on adult survivorship. Entrainment of eggs and larvae in the dredge may somewhat reduce adult populations, but the Proponent contends that results from an upcoming Equivalent Adult (EA) analysis will show that this potential impact will apply to a small number of fish, which will not affect overall populations. The EA analysis requires site-specific measurements of eggs and larvae, which are currently being collected under the Fisheries Sampling Plan; therefore results will be presented in the FEIR.

Sampling scheduled for the summer of 2006 as part of the Fisheries Sampling Plan will help quantify the standing crop of surfclams in the area being investigated as a potential sand source (see Section 4.4); results will be presented in the FEIR. Project activities may impact the population of legal-size surfclams, and the Applicant is proposing to conduct pre-dredge collections of surfclams to avoid such impacts. The collection will allow harvesting of legal-size clams and reseeding of undersized individuals in nearby suitable habitats.

2.6.2.1 Description of Potential Borrow Site(s)

As mentioned in Section 1.2.2, preliminary borrow site investigations were conducted in areas south of Great Point, off the east coast of Nantucket, and within Nantucket Sound (see Figure 1-3). Preliminary investigations focused on the capacity of these sites to provide beach-compatible material for the Project and to act as control sites for environmental analyses and comparisons to the preferred borrow site, once identified.

The Proponent has continued to conduct extensive research involving monitoring, modeling, and outreach with local fishermen to identify and evaluate potential sand sources while avoiding popular fishing locations. Potential borrow sites east of Nantucket near Bass Rip and Great Point shoals were included in early sand source investigations based on preliminary indications of adequate sediment volumes, beach-compatible sediment characteristics, and operational dredging requirements such as water depth and distance from the nourishment area. The characteristics of these areas included in initial investigations are described below.

- Bass Rip Shoal and Trough (Area 1)

  The majority of preliminary, reconnaissance-level data was collected at the Bass Rip shoal and trough. Results based on limited vibracoring information indicated the presence of medium-grained sand on the shoal surface and coarse-grained sand and gravel in the trough. Concerns in the local fishing community indicated that the shallowest portions of Bass Rip, along with Quidnet Rip (bordering the northwestern edge of this study area) should be avoided. In addition, preliminary anecdotal evidence indicated the existence of surfclams in the Bass Rip trough; this characteristic warrants further evaluation to determine the area's feasibility as an appropriate sand source.

  Following preliminary sand source investigations, additional monitoring and modeling efforts enabled the Proponent to identify a Primary Study Area just west of Bass Rip, but not on the shoal itself, within which borrow site investigations consisting of geotechnical investigations were performed in the spring of 2006 (see Section 2.6.2.1.1 and Figure 1-4). This Primary Study Area initially encompassed approximately 2,500 acres of Massachusetts' state waters (see Figure 1-4). The Proponent has focused investigations in state waters partly in an effort to identify a borrow site close enough to the nourishment area to maintain hydraulic dredging as an operationally feasible option; this will enable the Proponent to seek bids from both hopper and hydraulic dredging contractors. Geophysical data and deeper vibracores were collected in spring 2006 to more fully characterize the physical environment and environmental resources in this area in an attempt to more thoroughly assess its potential as a borrow site (see Section 2.6.2.1.1). Results from these investigations have identified a 345-acre Northern Borrow Site on the landward slope of Bass Rip in the northeastern part of the Primary Study Area as the Project's preferred offshore sand source (see Section 2.6.2).

- Sand Waves on Southeastern Great Point Shoal (Area 2)

  This potential sand source, located one to two miles east of Sesachacha Pond, consists of four sand waves trending southeast-northwest near the southeastern edge of Great Point Shoal. Sand waves have historically been known to contain beach-compatible sediment. There are no existing data available that would indicate the probability of finding beach-compatible sediment on these particular sand waves, but their geologic setting within the high-energy oceanographic regime creates the potential for suitable material that is sufficient to merit further exploration. Additionally, representatives of the fishing community have suggested that proposed dredging in this area, if selected as the borrow site, would incur no opposition from local recreational or commercial fishermen.

A Secondary Study Area for borrow site investigations has been identified that encompasses an area near Great Point Shoal, although geotechnical investigations and survey results in the Primary Study Area have led to the identification of a preferred borrow site (see Section 2.6.2). If it becomes necessary to further evaluate the Secondary Study Area, investigations would include reconnaissance-level geophysical surveys (i.e., seismic survey, etc.) followed by at least one vibracore to ground-truth the sub-bottom record.

- Eastern Edge of Great Point Shoal (Area 3)

  Early investigations along the eastern edge of Great Point Shoal, located two to three miles northeast of Sesachacha Pond, indicated that the area could be suitable for sand source investigations. The seaward edge of shoals may contain beach-compatible sand. Five surface samples were collected during preliminary investigations for the Project; these samples, along with one historic United States Geological Survey sample, indicated that medium-grained sand exists at the surface in this study area. No subsurface data currently exist. Based on the geologic setting of this shoal within the high-energy oceanographic regime, however, the potential for beach-compatible sand may merit further exploration.

  The local fishing community does not appear to be in opposition to use of this area as a borrow site. Similar to Area 2, members of the fishing community have suggested that use of this area would not pose problems to local recreational or commercial fishermen. This area of Great Point Shoal is also encompassed by the Secondary Study Area.

Data collection efforts performed to inform the borrow site delineation process included geophysical surveys, sediment coring, and benthic/fisheries surveys. Results were compiled and analyzed to verify and quantify the volume of clean, beach-compatible sediment available within the Primary Study Area to adequately assess its feasibility as a sand source for the Project. The geophysical survey track lines and vibracore locations are shown on Figure 1-4; not all track lines shown on the figure were performed, but rather initial surveys focused on a 1,500-acre area (the Primary Survey Area) and, after sand was found to be too fine-grained, proceeded into a 1,000-acre area (the Secondary Survey Area). As presented in Section 2.6.2.1.1, a preferred borrow site has been delineated in the northern portion of this Secondary Survey Area. This 345-acre Northern Borrow Site is located on the landward slope of Bass Rip (see Figure 1-5). If further analyses of survey results indicates that the preferred borrow site cannot supply a sufficient quantity or quality of sand to satisfy Project requirements for the initial nourishment and a renourishment event, or if the associated environmental impacts are deemed unacceptable, then other areas of investigation will be pursued.

2.6.2.1.1 Primary Study Area and the Northern Borrow Site

Investigations of offshore sand sources are ongoing; however, monitoring efforts coupled with preliminary surveys and data collection activities enabled the Proponent to identify a Primary Study Area which was subjected to geotechnical surveys in the spring of 2006 to assess its suitability to provide a borrow site for the Project. This Primary Study Area was initially identified as a 2,500-acre area entirely within state waters west of Bass Rip; geotechnical surveys were conducted within Primary and Secondary Survey Areas shown on Figure 1-4. Results from these investigations enabled the Proponent to identify a Northern Borrow Site as the preferred sand source for the Project (see Figure 1-5).

This Northern Borrow Site is an approximately 345-acre area located in the northern portion of the Secondary Survey Area. It is located entirely within Massachusetts' state waters west of Bass Rip. Only a portion of the borrow site will be excavated; assuming an average 10-foot dredge cut thickness, approximately 161 acres of the borrow site will be dredged for the initial Project nourishment. A general description of the oceanographic setting and characteristics of the offshore environment near the Project, which includes the area surrounding Bass Rip, is provided in Section 4.1.2. Section 3.3 presents data and interpretations regarding the water depths, seafloor attributes, bathymetry and grain size characteristics of the Northern Borrow Site.

Surveys revealed that southern and western portions of the Secondary Survey Area contained finer-grained sediments (i.e., fine to medium sand 0.2-0.6 mm in diameter) with some interbedded fine sand and silt, and were therefore excluded from the borrow site. Central and northern portions of the study area contained beach-compatible sediments, with the upper layers of vibracores revealing material 0.5-1.5 mm in diameter. Summary results (composites) indicate that the Northern Borrow Site contains approximately 8.3 million cubic yards of sand with a mean grain size of 0.83 mm (medium sand). Grain size compatibility between nourishment sand and native beach material is discussed in Section 3.3.1.

A comprehensive review of the borrow site ultimately delineated for the Project will be presented in the FEIR.

2.6.2.1.2 Preliminary Sand Source Investigations

Preliminary surveys of potential sand sources conducted in November 2005 focused on primary and secondary areas of interest east of Nantucket (see Figure 2-9). These included a northern site approximately 2.7 miles east-northeast of Sankaty Head Lighthouse and a southern site approximately five miles southeast of Codfish Park.

The northern survey area initially covered approximately 380 acres just north and west of the offshore shoal system known as Bass Rip, where water depths are -20 to -50 feet MLW (see Figure 2-9). This preliminary site was encompassed by the Primary Study Area where additional geotechnical investigations were conducted in spring 2006 (see Figure 1-4).

Preliminary investigations indicated that the northern survey area could provide approximately three million cubic yards of sand to a depth of 10 feet below the seafloor. Strong tidal currents in the area dictate an active sediment transport regime which has formed relatively large sand waves (or ridges). Sand ridges are generally associated with modern physical processes on the continental shelf involving interactions between waves, currents, sediments and differential feedback mechanisms. Finkl, Andrews and Benedet (2005) refer to the interactions between these systems as morphodynamics.

Sand ridges formed through these processes can be utilized for sand mining by modern hopper dredges, which can efficiently excavate sand along ridges that are only one to two meters thick by performing long, shallow dredge cuts (Finkl, Andrews and Benedet, 2005). Preliminary geophysical surveys conducted over the northern survey area detected sand waves approximately 15 feet in height where coarse sand (0.8 mm in diameter) is present in crests with finer material (0.2 mm in diameter) at depth. Native beach sand in the Project area has an average diameter of approximately 0.4 mm. Relatively coarse material appears to be moving along landward portions of Bass Rip in large quantities, suggesting that sand removed from this area to nourish the Project shoreline would be replaced by natural processes.

The southern survey area, a secondary area of interest during preliminary investigations, was located solely in federal waters and covered approximately 200 acres where water depths averaged -20 feet MLW (see Figure 2-9). This southern area was located approximately five miles southeast of Codfish Park and one mile north of the Nantucket Lightship Essential Fish Habitat closure area. Mean grain sizes at this offshore site range in size from 0.51-1.20 mm.

2.6.2.2 Evaluation Criteria for Offshore Sand Sources

The evaluation of alternatives for offshore sand sources is guided by the physical, environmental, and operational parameters presented in the following sub-sections. The ultimate goal of the alternatives analysis and site selection process is to identify an offshore borrow site that satisfies design criteria for the beach, minimizes environmental impacts, and accommodates proposed dredging methodologies and equipment to result in a successful, cost-effective Project. While this DEIR contains data and analyses regarding preliminary sand source investigations, efforts to investigate the suitability of the Primary Study Area to provide nourishment material, and delineation of the Northern Borrow Site as the preferred offshore sand source, the FEIR will contain a comprehensive and detailed analysis of the final preferred borrow site.

2.6.2.2.1 Physical Parameters

The borrow site will ideally contain a volume of sand sufficient to supply the initial Project nourishment plus a future renourishment event. Borrow sediment must be compatible with the receiving beach, particularly with regard to grain size. The ideal grain size spectrum of offshore sediment mined for the proposed nourishment would be slightly coarser than the native beach sand to optimize performance of the nourishment template; if this is not possible, the design template will be adjusted accordingly. Grain size analyses have been performed for the Project shoreline, and the results are critical to the selection of a preferred borrow site; grain size compatibility is further discussed in Section 3.3.1.

2.6.2.2.2 Environmental Parameters

Environmental concerns regarding borrow site selection involve considerations of physical processes and biological factors. An offshore borrow site must be delineated where excavation activities will not materially alter patterns of wave transformation, wave energy and sediment transport along the shoreline, or sediment transport patterns in the vicinity of the excavation. Such dredging-induced changes could potentially cause wave focusing along the shoreline and subsequent development of erosion hotspots (NRC, 1995). Potential Project-related impacts to physical processes at the borrow site are discussed in Section 4.2.2. In general, marine habitats within the various potential borrow sites investigated for this Project have been relatively similar to one another. This is because benthic habitat is primarily a function of sediment type, and the Project is targeting medium-grained sand as a nourishment material. Therefore, Project-related impacts to benthic habitat at each of the borrow sites under consideration will essentially be the same. Fish species and their various lifestages are also linked to distinct suitable habitats. Therefore, efforts to characterize marine ecology at the potential offshore borrow sites are focused in the Primary Study Area, which encompasses the preferred borrow site known as the Northern Borrow Site (see Figure 1-5). Biological resources and potential Project-related impacts are discussed in Sections 4.3 and 4.5, respectively.

2.6.2.2.3 Operational Parameters

Offshore borrow sites must be compatible with dredging methodologies and equipment proposed for use. A thorough analysis of a borrow site's suitability for a given project must consider the site's distance from the nourishment area, water depth, and dimensions of the borrow pit. In addition, any relevant time-of-year restrictions relating to marine organisms must be considered. Construction methodology and schedule are discussed in Section 3.4; time-of-year restrictions to avoid winter flounder impacts are discussed in Sections 4.5.1.1 and 5.1.2.

An offshore borrow site's distance from its related nourishment area has direct implications for what dredging methodologies may be successfully employed. Hopper dredges are able to perform borrow site operations far offshore, though costs increase significantly with increased distance from the nourishment area, while hydraulic dredges must be closer to the receiving beach in order to be effectively employed. As presented in Section 2.6.2.1.1, the Proponent has focused spring 2006 geotechnical investigations within a Primary Study Area located entirely within Massachusetts' state waters; results from these efforts have led to the delineation of a preferred Northern Borrow Site (see Figure 1-5). State waters have been the focus of borrow site investigations partly in an attempt to identify a suitable sand source close enough to the nourishment area that hydraulic dredging remains a viable option. Shifting borrow site investigations farther offshore into federal waters may constrain the Project's dredging options. Furthermore, utilizing a borrow site close to shore will shorten the Project construction schedule, increasing the efficiency of design template construction and lowering overall costs.

It is the Proponent's intent to maintain both hopper and hydraulic dredging as operationally-viable options so that construction bids can be sought from the greatest number of potential contractors, hopefully increasing the likelihood of a cost-effective bid. In addition, a hydraulic dredge may be able to perform complete Project operations in only three months, while such operations may require upwards of six months with a hopper dredge. Considering the restricted construction window resulting from challenging environmental conditions and time-of-year restrictions, use of a hydraulic dredge would provide the Proponent with a wider margin of error for completing Project activities.

2.6.2.3 Environmental Review of Offshore Sand Sources

Physical and biological resources in the Primary Study Area, as well as potential Project-related impacts, are discussed in detail in Section 4.0. Overall, activities proposed at the borrow site are designed to avoid and minimize impacts while achieving Project objectives. Rigorous data collection, analyses, and modeling are underway, all of which suggest the level of environmental impact will be low and manageable with appropriate precautions and operational methodologies, and that unavoidable impacts can be successfully mitigated. Existing data and long-term studies from similar projects such as the USACE's Asbury Park – Manasquan Inlet Project are plentiful; data and insight collected from other projects have and will continue to inform the Project design, environmental assessments, and measures to avoid, minimize and mitigate for impacts to the maximum extent practicable while satisfying Project objectives. Many potential adverse impacts can be completely avoided through careful design and Project planning, and Table 5-1 describes some projects that have been analyzed with regard to mitigation efforts (see Section 5.3.3.4). Some environmental impacts are unavoidable, but in these cases recovery is either expected to occur rapidly and/or mitigation will be performed. Aside from potential impacts, the Project promises to achieve substantial environmental benefits. These benefits are primarily related to increasing sand supplies in the littoral system, promoting positive performance of the coastal wetlands, supporting enhanced recreational activities, and providing improved habitat for nesting shorebirds.

The following sub-sections summarize the key environmental issues and resources related to an environmental review of an offshore sand source. Sampling plans, surveys, and the scope of environmental analyses were designed and refined in cooperation with stakeholders and environmental regulatory agencies.

2.6.2.3.1 Offshore Currents and Sediment Transport

Dredging at the offshore borrow site will create a depression in the seafloor which could potentially alter local hydrodynamics. However, the Project environment is characterized by dynamic, active currents and the related sediment transport regime, and the excavated depression will fill in over time.

Historical charts and bathymetric surveys of the region are being analyzed to characterize natural variability in adjacent shoals and to understand the relative magnitude of natural sedimentation as compared to potential effects from offshore dredging. To date, analyses suggest that the offshore shoal complex is highly dynamic and that the proposed dredging represents a relatively small fraction of sand compared to the regional sand morphology. Natural bathymetric changes related to tidal currents and storm wave action measured in the Project area are more substantial than the changes that will occur as a result of the proposed dredging. Therefore, the borrow site is expected to shoal relatively rapidly with no detrimental impacts to adjacent morphological features such as Bass Rip. In addition, the active sediment transport regime in the vicinity is expected to maintain a relatively coarse-grained substrate. Discussions of regional geography and oceanographic setting are provided in Section 4.1. No adverse impacts to offshore currents or sediment transport are expected to result from the Project (see Section 4.2).

2.6.2.3.2 Wave Focusing

Localized changes in water depths induced by dredging can modify nearshore wave transformation processes such as wave refraction, diffraction, and breaking, which can induce variations in nearshore wave energy distribution patterns. Modifications to nearshore waves can potentially cause wave focusing zones (i.e., the focusing of wave energy along certain portions of the shoreline) and wave shadow zones (i.e., zones with reduced wave energy due to divergence of wave rays). The formation of wave focusing and shadow zones may, in turn, affect patterns of erosion and deposition along a given shoreline.

Numerical wave modeling is commonly used to evaluate potential impacts on the nearshore wave climate from sand mining activities at proposed borrow sites. Several wave models are commercially available; these include: (1) STWAVE, developed by the USACE; (2) MIKE21NSW, OMS and Boussinesq, developed by the Danish Hydraulic Institute; (3) RefDifs, developed by the University of Delaware; and (4) SWAN, developed by the Delft University of Technology in the Netherlands. The proposed Project utilized SWAN

(Simulating Waves Nearshore) to evaluate potential impacts to nearshore waves from proposed sand mining offshore from Nantucket.

SWAN is one of the most advanced, widely-used and validated models worldwide. As a non-stationary third-generation wave model, SWAN incorporates all physical phenomena of wave transformation relevant to the evaluation of potential borrow site impacts to the wave climate (Holthuijsen, Booij and Ris, 1993; Ris, 1997). These phenomena include wave propagation in time and space, shoaling and refraction due to water depth and currents, diffraction, wave generation by wind, nonlinear wave-wave interactions (both quadruplets and triads), whitecapping, bottom friction, depth-induced breaking, etc. The model was run for two representative wave cases: (1) average wave conditions with significant wave height (Hs) of 4.2 feet, peak period (Tp) of 5.7 seconds and 93° direction; and (2) a representative storm event with significant wave height of 11.5 feet, peak period of 11.5 seconds and 45° direction. Data records obtained from USACE WIS Station 73 for the previous 20 years were used to calculate the parameters of the representative wave conditions.

Results from analyses to date suggest that excavation of an 18-foot dredge cut (which is significantly thicker than the dredge cut proposed by this Project) will not induce any significant changes to nearshore waves during average wave conditions or during a representative storm. Figure 2-10 illustrates propagation of the average wave condition as well as the location of grid line #50 which was used to quantitatively compare variations in wave height due to excavation activities at the borrow site dredging. Figures 2-11 and 2-12 contain cross-section plots comparing pre- and post-dredging wave heights along nearshore grid line #50; as illustrated in these plots, no significant dredging-induced changes to wave height are expected. Figures 2-13 and 2-14 illustrate pre- and post-dredging results from the wave model simulation conducted for average wave conditions; Figures 2-15 and 2-16 show results during the representative storm event. These model outputs reveal no significant changes in the wave climate associated with an 18-foot excavation of the proposed borrow site.

There are several explanations for why excavation of the borrow site will not significantly alter nearshore waves, including:

- Most of the wave energy dissipation occurs amongst sand ridges located seaward of the borrow site;
- The proposed borrow site (the Northern Borrow Site) is located on the landward slope of a sand ridge (Bass Rip), and the ridge integrity and crest elevations will be preserved after dredging; and
- The borrow site is located 2.5-3 miles from shore, which is a sufficient distance for the combination of wave diffraction and non-linear wave-wave interactions to cancel out any changes in waves induced by dredging before they reach the shore.

The numerical model results indicate that the 18-foot dredge cut modeled at the borrow site by SWAN will not cause significant effects on nearshore waves and will not negatively impact patterns of beach erosion or accretion.

Physical processes in the Project area are discussed in further detail in Section 4.2.

2.6.2.3.3 Offshore Benthic Habitat

The proposed dredging will directly impact offshore benthic habitat within the borrow site, which is currently proposed to be the 345-acre Northern Borrow Site. Based on a series of preliminary bottom grabs, side-scan sonar data, and video surveys, the seafloor within the Primary Study Area and proposed borrow site is characterized by sandy conditions with active sand waves. Material in the troughs between sand waves will be fully characterized by sidescan sonar and other more detailed survey results; the FEIR will contain a thorough presentation of survey results and their implications. Preliminary vibracores and deeper cores collected during spring 2006 revealed sub-seafloor sediment characteristics that are relatively consistent within the depth of the proposed dredging. The proposed borrow site is predominantly composed of sand, with some variability in grain size (see Section 3.3.1). Based on preliminary data, impacts to habitat are expected to be minimal, as the post-dredging seafloor will resemble the existing sandy seafloor conditions.

Recovery periods for benthic populations at borrow sites have been found to vary from a few months to several years, depending on the pre- and post-dredging habitat conditions (NRC, 1995). Conclusions from past studies coupled with the fact that the post-dredging seafloor will resemble existing conditions make it likely that the abundance, diversity, and composition of the benthos will recover relatively rapidly (perhaps within one year) after Project dredging (NRC, 1995). Habitat and potential Project-related impacts are discussed in detail in Sections 4.3 and 4.5, respectively.

2.6.2.3.4 Benthic Invertebrates and Shellfish

Proposed dredging will cause direct mortality to benthic invertebrates and shellfish within the excavation footprint. Impacts among the potential borrow sites currently under consideration will be similar. A series of benthic grab samples were collected in the summer of 2005 to characterize the benthic community, and a Fisheries Sampling Plan which includes efforts to identify seasonal changes in benthic populations commenced in the spring of 2006 (see Section 4.4). Although grab samples were helpful in identifying shellfish populations (including juveniles), focused surveys targeting commercially-important shellfish species are being conducted to quantify harvestable populations. These surveys will be completed and analyzed once the borrow site location is refined.

Data and analyses from borrow site investigations have revealed the effects of the highly-dynamic sediment transport regime on the benthic community. Samples included small polychaetes, bivalves, gastropods, amphipods, and other crustaceans, but the density of organisms was relatively low due to the high-energy environment. Organisms present in the area are generally either mobile or have the ability to respond to actively migrating sand substrates. Organisms that require a stable bottom habitat to establish themselves, such as large polychaetes, are nearly absent. Overall, dredging-related impacts to benthic invertebrates are not expected to differ substantially from natural impacts related to storms, active tidal currents, and the vigorous sediment transport regime.

Due to its adaptive nature, the benthic community is expected to recover rapidly from dredging activities associated with the Project. Substantial biomass is expected to recolonize within months of dredging, and species diversity is expected to return to pre-dredging conditions within one to three years (see Section 4.5). These estimates are consistent with findings from offshore dredge monitoring activities in other areas. Unavoidable impacts to shellfish, particularly surfclams, are expected to be mitigated through pre-dredge harvesting and/or reseeding. No significant impacts to lobsters are expected due to a lack of suitable habitat; the presence or absence of lobsters will be confirmed through the trawl surveys. Consultations are being held with DMF and NMFS to discuss whether a potential operating restriction applicable in the months of April and November is needed to avoid impacting seasonal onshore/offshore lobster migration.

Existing benthic and shellfish resources and potential Project-related impacts are discussed in Sections 4.3 and 4.5, respectively.

2.6.2.3.5 Demersal Fish

The proposed dredging will impact an area where bottom-dwelling fish including flounder, cod, and monkfish potentially reside. Impacts among the potential borrow sites currently under consideration will be similar. Section 4.3 contains a thorough discussion of existing finfish resources, while Section 4.5 addresses potential Project-related impacts.

A detailed review and analysis of 20 years of seasonal trawl data obtained from the Massachusetts DMF has been performed to evaluate potential impacts. This data analysis supplements landings data from the NOAA Fisheries Service and reports from local fishermen. A survey of local fishermen has also been conducted, and a year of monthly trawl surveys is being performed to evaluate potential impacts to demersal fish. To place local data into context, comparisons with monitoring and impact assessment studies for other offshore sand mining projects in the mid-Atlantic and northeast have been undertaken. Furthermore, a comprehensive and detailed Fisheries Sampling Plan formulated in consultation with the Massachusetts DMF and USACE commenced in the spring of 2006 (see Section 4.4).

Based on analyses to date, impacts to demersal fish are expected to be of short duration during construction, and will include temporary displacement and disruption of feeding patterns (see Section 4.5). Minimal direct impacts and associated mortality are expected. Due to coarse nourishment sediment and appropriately-selected dredging methodologies, no significant adverse impacts from turbidity are expected (see Section 4.6.2). Demersal fish populations at the borrow site primarily consist of adult individuals and are expected to avoid the dredging activities; bottom-dwelling fish are expected to reoccupy excavated areas soon after dredging has ceased. Fish dependent on local benthic invertebrates for a food source will temporarily relocate to adjacent areas until the benthic community recovers. As discussed above, no lasting impacts to offshore benthic habitat are expected that would differ from impacts occurring naturally in this dynamic environment; therefore, long-term effects on fish resulting from habitat impacts are not expected.

2.6.2.3.6 Pelagic Fish

Dredging is proposed in an area utilized by transient and migratory pelagic fish including striped bass, bluefish, butterfish, sea bass, and sea herring. Existing information documents the presence of pelagic fish in the area and includes data regarding regional population variations over time and seasonal population fluctuations. Landings data from the NMFS and Massachusetts DMF are valuable in this regard, and a survey of local fishermen is being performed to document trends in the catch. Furthermore, a comprehensive and detailed Fisheries Sampling Plan formulated in consultation with the Massachusetts DMF and USACE commenced in the spring of 2006 (see Section 4.4).

Pelagic species are active, generally present as adults, and are expected to avoid dredging activities. Potential impacts will be limited to the period of direct Project activities, and will include displacement and disruption of feeding patterns. No lasting impacts are expected. Impacts among the potential borrow sites currently under consideration will be similar.

2.6.2.3.7 Fishing

Dredging has the potential to affect fishing activities at the borrow site; these activities include limited commercial fishing, frequent charter fishing, and an active recreational fishery. A survey of the fishing community is being conducted to quantify the frequency and location of fishing activities as a basis for characterizing and minimizing impacts. Socioeconomic impacts related to fisheries are addressed in Section 4.8.

Based on information gathered thus far from the local fishing community, limited fishing occurs in the Primary Study Area in which borrow site investigations have been focused and in the northeastern portion of this area where the Northern Borrow Site is located; this is one of the reasons the area was selected as a potential offshore sand source. Communications with the fishing community that utilizes the area near the Northern Borrow Site indicate that strong tidal currents interact with the morphology of Bass Rip to produce strong upwelling along the shoal. This upwelling is vital to the fishing community, as large fish congregate in the upwelling zone to feed on smaller organisms swept by in the current. While no direct modeling of dredging's effects on the upwelling have been conducted, wave modeling results described in Section 2.6.2.3.2 indicate that excavation of a borrow site larger than the Northern Borrow Site would have little to no effect on the wave climate and resulting currents. The primary explanation for this lack of impact is that the borrow site is located on the landward slope of a large sand ridge, the integrity and crest elevation of which will be preserved throughout and following the proposed dredging activities.

More productive fishing grounds are found along Old Man Shoal, Great Point, on Bass Rip itself, in the nearshore, and in certain locations between Bass Rip and the shoreline. Nearshore fishing and surfcasting will be temporarily impacted during Project activities, primarily due to construction activities limiting access to the beach. The wider beach will improve opportunities for surf fishing and will enhance public beach access.

Nearshore turbidity will be generated by nourishment pump-out operations; however, turbidity is expected to be minimal due to the coarse grain size and low silt/clay component of the borrow material coupled with the proposed construction methods (see Sections 3.4 and 4.6.2). Such nearshore turbidity during construction is expected to be similar to turbidity levels generated naturally during storms. Water quality and potential Project-related impacts are discussed in Section 4.6.

2.6.2.3.8 Offshore Avian Impacts

Marine birds utilize offshore areas including the Primary Study Area and Northern Borrow Site primarily for feeding purposes (see Section 4.7). These birds typically feed on the surface or dive to depths of 10 meters or greater; certain species (e.g., White-winged Scoters and Long-tailed Ducks) can dive up to 60 feet. The birds typically feed on mollusks and crustaceans on or near the seafloor or fish and amphipods living near the surface.

Primary impacts to birds at the borrow site will stem from the removal of bottom-dwelling food sources (such as mollusks and crustaceans) and lowering of the seafloor elevation. These impacts will moderate over time as the borrow site naturally fills in and as the seafloor is recolonized. Birds will be unimpeded from traveling to nearby areas providing similar habitat, and a review of nearby waters reveals ample areas with similar habitat values. Accordingly, no major impacts to birds at the offshore borrow site are anticipated.

Avian resources and potential Project-related impacts are discussed in Section 4.7.

2.6.2.3.9 Marine Mammals

Marine mammals are present seasonally along the Project shoreline and in the nearshore waters of Nantucket Shoals (including the Primary Study Area). Sections 4.3.7 and 4.5.5 provide detailed discussions of marine mammals and potential Project-related impacts, respectively.

A number of cetaceans occur in the Project area, and their migratory and feeding patterns vary significantly. Several porpoise and dolphin species (including pilot whales) occur seasonally in the waters of southern New England and may occasionally be present in the vicinity of the borrow site (Reaves et al., 2002). Harbor porpoises are the most common of these species in New England waters, and are particularly conspicuous due to their preference for coastal habitats.

Harbor and gray seals are the two most abundant seal species near Nantucket. Both species typically use Monomoy Island (in northern Nantucket Sound) and Muskeget Island (west of Nantucket) for haul-out. Between September and May, harbor seals disperse as far south as Nantucket from their northern breeding grounds. Gray seals may be found in the area year-round, and the small breeding colonies near Nantucket are the most southerly in the world (NHESP, 2002).

2.7 Selection of the Preferred Alternative

Large-scale beach nourishment is the primary component of the preferred alternative for this Project because it fundamentally serves to restore and support natural coastal processes, protect the Coastal Bank and upland property, and enhance public benefits. Nourishment has had proven success in New England and has been widely used to protect beaches along the Atlantic and Gulf Coasts of the United States (see Section 1.6). The preferred alternative also involves the following components: (1) installation of 6,100 linear feet of geotextile tubes at the toe of Coastal Bank to enhance bank stability in areas of erosion and provide storm protection; (2) construction of up to 13 groins to slow the loss of beach nourishment sand from erosion hotspots; and (3) bank stabilization through terracing and vegetation plantings. If these additional measures were employed absent the proposed nourishment, the Project's objectives would not be satisfied; however, as components of a multi-faceted shoreline management strategy, they provide enhanced protection from storms and help increase the longevity of the nourishment template.

The nourishment proposed by this Project will restore the depleted supply of sand on the beach and improve the performance standards of the Coastal Beach, Coastal Bank and Coastal Dune wetland resource areas. Benefits to the resource areas will include (among others) increased storm protection, enhanced sand supply in the littoral system for transport to adjacent beaches, and restoration of habitat including that for listed species of shorebirds. For these reasons, beach nourishment is often defined and/or required as an appropriate mitigation measure for shoreline development, and it is the preferred use for clean dredged material of compatible grain size.

Along with the tremendous benefits associated with nourishment, there are some adverse impacts that will be unavoidable. For example, the proposed nourishment will cover existing supra-, inter-, and subtidal habitats with borrow material. Organisms that use or reside in the sand will be affected depending on when and where nourishment fill is placed. As such, careful planning is required to minimize impacts when possible. Potential Project impacts are discussed in Section 4.0.

Due to limitations regarding upland and dredging-related sand sources described above, the large-scale nourishment Project proposed at Sconset will require mining sand from an offshore borrow site (see Section 2.6). The rate of sand delivery from upland sources would not be sufficient to effectively build and maintain the design beach berm during construction, and the logistical requirements of coordinating delivery, processing, and stockpiling would likely add significantly to the Project schedule and cost. The cost estimate for transporting and placing nourishment material from an upland sand source to the Project shoreline is $15-25 per cubic yard; assuming a nourishment volume of 2.6 million cubic yards, the low end of this estimate would result in a $39 million cost for sediment placement alone. This cost estimate does not consider the impacts to infrastructure from the great number of dump trucks which would be required to access the beach if nourishment material were trucked to the Project area. Comparatively, the cost estimate for placing 2.6 million cubic yards of nourishment material in the Project area using a dredge is $22.8-28 million. Overall, it has been determined that use of an upland sand source for this large-scale nourishment Project is not feasible due to the lack of a local upland sand source, the slower rate of delivery to the nourishment area, and extremely high costs associated with off-island upland sources. Figure 1-5 identifies the Northern Borrow Site, which has been identified as the preferred offshore sand source.

The Proponent intends to use either a hydraulic or hopper dredge to perform the proposed sand excavation. The production rate of a hydraulic cutterhead dredge is primarily dependent on the distance from the borrow site to the end of the Project area, although grain size of the borrow material and the dredge cut thickness must also be considered. Production rates of 700-1,200 cubic yards per hour may be expected in the Project area while using a hydraulic cutterhead dredge, while production from a hopper dredge would be on the order of 600 cubic yards per hour (see Section 3.4). A typical dump truck is capable of carrying 20 cubic yards of material; therefore, approximately 30 dump trucks per hour would be required to match output from a hopper dredge. Once again, this comparison illustrates the impracticality of trucking sand to the nourishment area.

To understand and avoid potential Project impacts in the nourishment area and at the borrow site, thorough planning and design of the Project must include an analysis of experiences from similar projects and an extensive assessment of Project-specific local conditions. Fortunately, there is an extensive network of experience with beach nourishment projects in Massachusetts, around the country, and worldwide. Previous experience indicates that beach nourishment can be planned and executed in a manner that achieves Project objectives while resulting in an acceptable level of environmental impact (see Section 1.6).

The preferred alternative was also derived as a result of a series of peer review proceedings and panel discussions. A coastal engineering peer review was conducted to garner comments and guidance from experts with a number of coastal engineering companies, municipalities with active beach nourishment programs, and leading coastal engineering academic institutions on the conceptual design and design process for the Project. Unanimous conclusions included support for regional beach nourishment, use of an offshore borrow site, protection for the toe of Coastal Bank in the form of a seawall or other bank stabilization measure such as geotextile tubes, and installation of sand transport control devices such as groins. An additional unanimous recommendation critical to the Project was to select a construction schedule at a time of year when sea conditions would be expected to be most favorable; the peer review participants acknowledged that the construction schedule must also depend on other considerations such as fisheries. There was general consensus that construction between May and October would be most practical given concerns with winter storms, hurricanes, and peak demand for dredging equipment in the southeast from November to April.

An additional panel review and consultation process was conducted with representatives from the dredging industry, specifically from companies actively involved in offshore dredging for purposes of nourishment. Representatives from three major dredging companies were consulted to ensure the Project design was consistent with available construction equipment and techniques. Given the energetic wave climate and tidal current regime in the Project area, input from the dredging companies was considered essential to ensure a viable Project design, interest in bidding the Project, availability of construction equipment, and favorable pricing.

The dredging industry review panel also unanimously recommended scheduling Project construction in non-winter months (i.e., May through October) to ensure availability of equipment for the Project, which is otherwise committed to projects primarily on the mid-Atlantic, southeast, and Gulf coasts. This schedule would also provide the most favorable conditions for building and achieving the proposed design profile while minimizing sand losses during construction, and would allow the Proponent to seek cost-effective bids. Winter costs, for example, are expected to be 50-100% higher than non-winter costs.

A more extensive discussion of the preferred alternative is provided in Section 3.0.

2.8 Conclusions of the Alternatives Analysis

The initial screening of alternatives has led to the emergence of nourishment coupled with groins, geotextile tubes, and bank stabilization through terracing and vegetation plantings as the preferred alternative. Other alternatives investigated included the No Action, managed retreat, several structural alternatives, bank stabilization, and beach nourishment as a stand-alone measure.

The No Action and retreat alternatives would not achieve Project objectives and would lead to the loss of public infrastructure, the historic bluff walk, many homes and historic properties, and the loss or relocation of the Sankaty Head Lighthouse. Additionally, use of Sconset and Codfish Park beaches would be diminished. For these reasons, the No Action and retreat alternatives were determined not practicable. Seawalls and revetments were determined not practicable due to regulatory constraints and permitting challenges; breakwaters were determined not practicable due to serious questions about their effectiveness in the Project's high-energy environment where the beach face is quite steep. The bank stabilization alternative was determined not practicable as a stand-alone strategy because it would not provide adequate storm damage protection. This alternative cannot prevent wave-induced scarping at the toe of the bank, which in turn causes slumping and failure. However, bank terracing and vegetation plantings are proposed as components of the comprehensive Project to protect resources landward of over-steepened portions of the Coastal Bank. Accordingly, a Notice of Project Change/Phase One Waiver is being requested from MEPA to allow these bank stabilization measures to be implemented for interim protection while the Project proceeds through the permitting process.

When utilized alone, nourishment would achieve Project objectives by creating a wider beach to dissipate wave energy and protect landward resources. Most beach nourishment projects constructed throughout the United States utilize beach nourishment alone to accomplish shoreline management goals; the primary purposes of these projects are coastal protection, restoration of beach habitat, and reestablishment of a recreational beach for residential and/or tourist use. However, additional investigations and considerations of Project design have indicated that the proposed nourishment's effectiveness will be enhanced by incorporating groins, geotextile tubes, and bank stabilization through terracing and vegetation plantings as additional Project elements. This combination has been determined most practicable in terms of effectiveness, feasibility, environmental benefits and impacts, costs, and ability to achieve Project objectives.