9.0 Impacts Associated With Beneficial Use Sites

9.1 Wetland Restoration Sites

9.1.1 Shore Erosion

The breakwaters and restored wetlands at Kelly Island will protect about 5,000 feet of severely eroding shoreline; those at Egg Island Point will protect about 10,000 feet. These shorelines have been eroding at the rate of 15 to 30 feet per year. The expected life of the geotextile tubes is estimated to be 30 years, so the Egg Island Point restoration will be afforded protection from erosion for up to that period of time. The Kelly Island wetland restoration will be maintained for the life of the project to insure that the fine grained material will escape.

9.1.2 Water Quality

The results of chemical and biological testing of dredged material that would be used for beneficial use sites are discussed in greater detail under Section 4.0, Sediment Quality Investigations. Sediment testing included bulk analysis and elutriate analyses for heavy metals, pesticides, PCBs, PAHs, phthalates, volatile organics, and semi-volatile organics; bioassays; and bioaccumulation tests. The results of this testing indicates that the dredged material from Reach E is acceptable for beneficial uses such as wetland creation and sand stockpiles for later beach nourishment.

9.1.3 Benthic Communities

Benthic survey results are discussed in greater detail under Section 8.0, Benthic Habitat Investigations. No significant differences were found between any of the beneficial use sites and background conditions in Delaware Bay that would preclude its use. Therefore, no significant impact will occur to benthic resources due the use of any of these sites as either wetland restorations or sand stockpiles.

Approximately 60 acres of mostly subtidal habitat adjacent to Kelly Island and 135 acres of subtidal habitat adjacent to Egg Island Point will be restored to intertidal wetland habitat, consisting of mostly Spartina alternaflora (saltmarsh cordgrass). Prior to the severe erosion that is presently taking place, this area consisted of intertidal marsh. Nevertheless, the benthic community that exists will be replaced by an intertidal marsh community. The benthic communities of these sites, which cover about 195 acres, would be eliminated and the bottom would be changed from subtidal to intertidal wetland, averaging about +5 feet MLW. These sites were among those having the poorest quality benthic communities. They were characterized by a considerably less diverse assemblage than the background benthic communities in Delaware Bay. Compared to other candidate sites, they contained a higher abundance of opportunistic species, which are typical of disturbed environments. LC-9 was characterized by a different species composition between the two years it was sampled, which is a further indication of its unstable benthic community. LC-9 and PN1A also had the lowest percent of equilibrium taxa among all of the candidate sites.

9.1.4 Wetlands

Approximately 60 acres of mostly subtidal habitat adjacent to Kelly Island and 135 acres of subtidal habitat adjacent to Egg Island Point will be restored to intertidal habitat, consisting of mostly Spartina alternaflora (saltmarsh cordgrass). In addition, hundreds of acres of intertidal wetlands that exist behind the restored wetlands will be protected from continued erosion.

9.1.5 Fish and Wildlife Resources

The construction of the wetland restorations will be phased to avoid and/or minimize impacts to fish and wildlife, especially to spawning horseshoe crabs and migrating and feeding shorebirds as described under Section 3.3.4.4. Reconstruction of wetlands at Kelly Island and Egg Island Point will greatly benefit most wildlife species. Although approximately 195 acres of aquatic habitat will be lost, this was formerly intertidal marsh before being destroyed by erosion. The loss of this aquatic habitat is not a significant impact.

9.1.5.1 Kelly Island

The primary species of concern at Kelly Island under its present condition are the horseshoe crabs which spawn at nearby sand beaches, the migrating and feeding shorebirds, waterfowl, and waterbirds in general. The engineering design previously described will enhance habitat for all of these species, and in addition, will provide a sheltered intertidal area for juvenile fish species certain times of the year (See Figure 3-4 and 3-5).

The capability of the Kelly Island site to enhance habitat, and slow erosion losses behind the CDF, will off-set short-term impacts. To minimize the risk of any mishaps taking place during construction, field monitoring will be in place to insure correct filling procedures, dike, and outlet works construction, achievement of marsh elevations, and other aspects of a high quality project.

The sand dike is designed to have slopes and elevations conducive for horseshoe-crab spawning. Erosion of the dike is inevitable, but the quantity of sand placed will allow crab spawning for many years. Maintenance of the dike will extend this time for at least the life of the project (50 years).

9.1.5.2 Southeast Egg Island Point

One of the major considerations for southeast Egg Island Point is the blocking of the tidal channel that was once a tidal pool within the marsh. It has eroded to the point of no longer being a pond, but being part of the Bay, and provides an area of extensive intertidal mud flats. An evaluation conducted by the Corps indicates that there will be tidal access from the other side of Egg Island Point, via Straight Creek. No real blockage of the tidal creek will occur, although its flow direction will be altered. In addition, the blocking of the channel on the southeast side of Egg Island Point should protect the mud flats and adjacent marsh from continued erosion.

Another area of concern is the provision of spawning areas for horseshoe crabs, which use the Egg Island Point area more abundantly than they do the Kelly Island area. Habitat characteristics that crabs require are sandy, aerated, unvegetated beaches. The sand placed in the lee of the breakwater at southeast Egg Island Point will be at an elevation to attract crabs. A greater long-term problem will be the vegetation that may ultimately cover the sand, with a resulting loss of crab spawning habitat. Slopes and elevations will be conducive to both spawning and non-trapping of crabs within the site. This location should provide abundant crab spawning habitat, at least for the short-term.

The danger of crabs being trapped within the fill area is lessened by the broad extent of sandy beach that will be constructed behind the breakwater. The most likely potential for crab trapping will be directly behind the breakwater in pools that may form from overtopping and scour. The natural formation of tidal channels in dredged material sites should accommodate crab movements, but it is likely that some crabs will be trapped.

There are a number of other species that will benefit from protection of the southeast Egg Island Point site, such as waterbirds, shorebirds, and juvenile fish. All of these species will use the low marsh and tidal pools. Since Egg Island Point also has more high marsh and shrubby areas than Kelly Island, any washback of sand into the high marsh zone should serve to enhance that habitat. This would provide both additional crab spawning areas along fringes and potential tern, gull, and other waterbird nesting areas.

Most of the habitat characteristics and considerations for Kelly Island are also part of Egg Island Point, and the same species will benefit from the projects. The protection of the rapidly eroding shoreline marshes, and the resultant additions to habitat at Egg Island Point will more than off-set any detrimental short-term effects from construction activities.

There are two areas that are believed to require planting with Spartina alterniflora because of possible scour problems: a 200 foot strip, about 200 feet shoreward of the tubes; and the area near the point. These areas would be subject to greater wave erosion. However, the recommendation to allow natural colonization for at least part of the site comes from both cost-savings and the need at Egg Island Point for more bare sand for both crabs and birds. The situation is different at southeast Egg Island Point than at Kelly Island, where fine-grained material is being placed, and the bare sand is a very important habitat type that fits requirements for several species.

9.1.5.3 Northwest Egg Island Point

The northwest Egg Island Point site will have no fill material placed and is designed to trap sediment to nourish the eroded marshes on that side. Any accumulations of sediment will benefit Egg Island Point wildlife by adding to the existing marsh, providing sand areas for crab spawning, and protecting from beach scour. Some of the area that will be protected by the staggered rows of tubes is presently crab spawning beaches. These should be enhanced, since nearly full tidal access from the Bay to the beaches will be present using the staggered configuration (Figure 3-6). Any high marsh that should accrete as a result of the design will further enhance use by wildlife, especially by crabs and waterbirds.

The staggered row design planned at northwest Egg Island Point is a tested, proven habitat restoration technique for the Gulf Coast. It is expected to provide the same type of benefits in Delaware Bay.

9.2 Sand Stockpiles

9.2.1 Shore Erosion

Studies done by the Corps of Engineers indicate that there will be significant sediment dispersion from the sand stockpiles. Transport rates will be slow, however, so most of the placed material will remain in the stockpiles for decades. The stockpile sand that does leave will move predominately landward, then spread laterally along the shore, thereby providing fill material for nourishment of sand-starved bay beaches.

9.2.2 Water Quality

Temporary water quality degradation is expected due to elevation of suspended sediments. Brief periods of elevated turbidity will occur as a result of sand placement; however, sand is heavy and should settle quickly. Extended periods of elevated turbidity may occur if wind or water currents cause sediments to remain in suspension. Water quality degradation would be more severe and widespread with unconfined open water disposal than if the sand were deposited behind containment devices such as geotextile tubes.

9.2.3 Benthic Communities

No significant differences were found between candidate sand stockpile sites and background conditions in Delaware Bay that preclude selection as beneficial use sites. Therefore, no significant impact will occur to either the diversity or overall populations of benthic resources due to the use of these sites as sand stockpiles.

Benthic survey results are discussed in greater detail under Section 8.0, Benthic Habitat Investigations. Approximately 730 acres (500 acres for MS-19 and 230 acres for LC-5) of subtidal aquatic habitat averaging -8 feet MLW will be covered with approximately 4.7 million cubic yards of sand to a depth of -3.0 feet MLW.

Placement of up to 4.7 million cubic yards of dredged material at the proposed sand stockpile sites would result in burial of the existing benthic community. Benthic recolonization depends upon a number of factors, which include substrate type, distance from similar habitat, and water currents. Recovery of the benthic community would be further hindered by future disturbance as the material is taken from the stockpiles for beach nourishment projects.

Benthic recolonization is dependent upon recruitment from plankton dispersed by water currents. Changes in current patterns and velocities may alter dispersal of benthic larvae. The loss of the benthic community due to dredged material disposal would be expected to be a short-term adverse impact. The Corps has constructed twenty-three underwater berms for storm attenuation or beach nourishment throughout the United States (Landin, 1992). For example, results of detailed studies of benthic recovery and fish use on a berm constructed at Dauphin Island, Alabama, indicated rapid benthic recovery. Fish use of the area also was reported to be greater than in surrounding waters. The benthic recovery and greater fish use are related to slope, configuration, and orientation of the berm in the current (Landin, 1992).

Long-term impacts would likely result from the use of the sites as sand sources for future beach nourishment projects if the area is subjected to repeated disturbances. A regularly disturbed bottom would not necessarily provide the same abundance or species composition as the present site condition. However, these impacts would occur to relatively small portions of the sandpiles at a frequency of every 5 to 10 years.

The beneficial use sites that were selected for sand stockpiles are L-5 and MS-19B. These sites would be covered with sand, changing the average depth from -8.0 feet MLW to about -3.0 feet MLW. The present substrate of L-5 has a significantly greater silt/clay content that MS-19B (39-62% vs. 16%). A change to a total sand substrate at L-5 will have a greater effect to change the benthic community that is present than at MS-19B which presently has essentially a sand substrate. It is likely that both benthic communities will change since they are both less than 6 feet and will be subjected to greater exposure to physical stress caused by waves and surface currents. As mentioned, these effects may be most significant during storms when significant amounts of energy can be transferred from the surface to the sediments. L-5 is similar in quality to LC-9 and PN1A as described above. Site MS-19B had one of the highest quality benthic community among the 12 potential beneficial use sites, and would be expected to sustain greater impacts due to the lower recovery potential of its benthic macroinvertebrate community. Species richness was highest among the candidate sites at MS19B. It contained a higher abundance of equilibrium species, which are typically indicative of a stable, diverse, mature community, than the background benthic communities of the Delaware Bay. Site MS19B also contained the highest frequencies of individuals and the greatest number of species with body length greater than 2 cm, again indicative of a stable, mature assemblage, as well as infaunal species having commercial/recreational value. Although MS-19 has a higher quality benthic community than the other 12 sites that were evaluated, there were no significant differences found between it and the background conditions of the Delaware Bay that would preclude its use.

9.2.4 Fish and Wildlife Resources

The offshore areas in the vicinity of both proposed stockpile sites support important fisheries for weakfish. Additionally, the offshore areas in the vicinity of Sites L-5 and MS-19 support summer flounder, black sea bass, and drum (FWS. 1995b).

The environmental impacts of dredged material disposal in open water are similar in some ways to impacts resulting from sand dredging. Direct impacts include water quality degradation and temporary loss of the benthic community. Benthic community loss will in turn impact finfish species that feed on benthic organisms.

Deposition of large quantities of dredged material in sand stockpiles would decrease water depth at the sites from current depths to approximately -3 feet below MLW. This depth reduction could result in changes in the tidal regime and current patterns, which in turn could impact biological resources. Changes in the tidal regime may have some impact on biological resources associated with nearby rivers as well as resources associated with adjacent beaches.

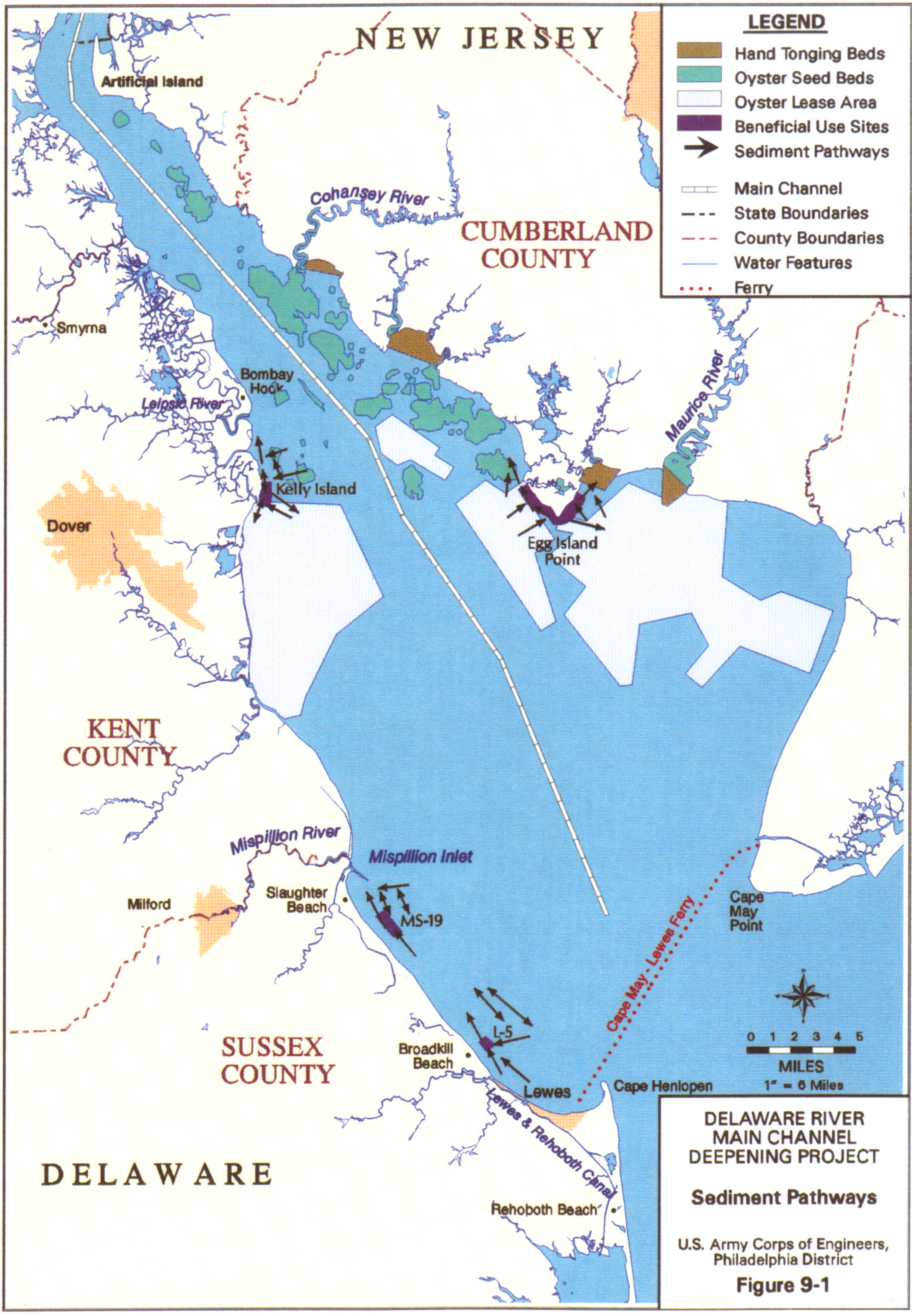
Placement of dredged material would result in some loss of finfish nursery and feeding areas. The loss of the food source would be expected to result in a temporary and localized reduction in recreationally and commercially important finfish species. As with effects to the benthic community, the repeated disturbance of the sand stockpile sites for future beach nourishment projects would likely result in long-term adverse impacts to local fisheries. However, these impacts would occur to relatively small portions of the sandpiles at a frequency of every 5 to 10 years.

9.3 Sediment Transport/Oyster Impact Investigations

Commercially important oyster lease beds are located throughout the offshore area around Egg Island Point. Most of these lease beds are located 500 to 800 feet offshore; but in some cases lease beds are located within close proximity to the shoreline. Oyster seed beds occur to the northwest of Straight Creek and this area also supports a commercially important blue crab fishery (USFWS. 1995b). In Delaware, commercially important oyster seed beds exist in the area offshore of Kent Island and Kelly Island (Figure 9-1). There are also oyster beds inside the mouth of the Leipsic River. Additionally, hard clams and blue crabs are distributed throughout the Kelly Island area. Blue crabs in this area are commercially important.

Concern was expressed by the resource agencies about potential impacts that may occur to oysters due to movement of sand used to build the wetland restorations at Egg Island Point and Kelly Island. In addition, concern was expressed about the fate of fine grained material that will be confined behind the sand berms and geotextile tubes at Kelly Island if there was a catastrophic failure of this structure. Concern was also expressed about the possible fate of the sand placed in the sand stockpiles.

In order to address these concerns, the four Delaware Bay beneficial use sites were evaluated for potential sediment transport impacts resulting from their placement. Two independent investigations were performed to address sediment transport impacts from these sites. The first investigation was conducted by Offshore and Coastal Technology, Inc. and included the development and application of a fine-scale numerical model of all four sites which simulated wave and current energy under a range of scenarios. The results of the wave and current energy modeling were then applied to estimate rates and pathways of potential sediment transport at the four sites under both "normal" and storm conditions. The results were also used to assess potential impacts of suspended sediment dispersal on nearby oyster beds using an oyster impact model developed by the Haskin Shellfish Research Laboratory of Rutgers University. A second analysis was performed specifically to address the relative stability/mobility of sediment to be placed at the two sand stockpile sites. This effort was based on application of the Corps of Engineers EBERM (Empirical BERM fate) methodology. EBERM utilizes site-specific wave data and stockpile geometry for the proposed project in comparison with similar data obtained from prototype, monitored stockpile sites in a variety of hydraulic environments. The methods and results of the fine-scale numerical hydraulic model of all four sites will be presented first, followed by discussion of the EBERM


LEGEND
Hand Tonging Beds
Oyster Seed Beds
Oyster Lease Area
Beneficial Use Sites
Sediment Pathways
Main Channel
State Boundaries
County Boundaries
Water Features
Ferry
NEW JERSEY
Artificial Island
Cohansey River
CUMBERLAND COUNTY
Smyrna
Bombay Hook
Leipsic River
Kelly Island
Egg Island Point
Maurice River
Dover
KENT COUNTY
Mispillion River
Mispillion Inlet
Milford
Slaughter Beach
MS-19
Cape May Point
Cape May - Lewes Ferry
L-5
Broadkill Beach
SUSSEX COUNTY
Lewes
Cape Henlopen
Lewes & Rehoboth Canal
DELAWARE
Rehoboth Beach
0 1 2 3 4 5
MILES
1" = 6 Miles
DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT
Sediment Pathways
U.S. Army Corps of Engineers, Philadelphia District
Figure 9-1

investigation.

9.3.1 Fine-Scale Numerical Hydrodynamic and Sediment Transport Modeling

The numerical simulation of currents was performed with a two-dimensional finite difference model of Delaware Bay with 0.25 minute grid resolution in latitude and longitude. The tidal boundary for both normal and storm conditions was the Delaware Bay mouth. The current model was validated with prototype current data collected at the four sites in June and July 1995. The wave modeling utilized the directional spectral steady state model STWAVE. Wave data for the model were obtained from previous work, which developed hindcast data for a six-year "normal" period (1987-1993) and for historical severe storm events, including 15 hurricanes and 15 northeasters. The two models were exercised independently for both storm and normal condition simulations.

Current velocity output from the current model was used to develop estimates of shear stress on the sediment bed. Sediment transport is assumed to take place when the shear stress from the current flow exceeds the threshold of shear stress for the sediment. As long as the current-generated shear stress exceeds the critical shear stress for the sediment, the material can be transported with the ambient current. Sediment transport in the wave model is simulated through several mechanisms. Wave-induced orbital bottom velocities can generate sufficient shear stress at the bed to mobilize sediment. Waves can also generate residual currents which transport sediment in the direction of wave propagation, and longshore currents which transport material in the longshore direction of wave propagation.

The numerical models were used to generate conditions under which sediment is expected to be transported at each of the project disposal sites. At Egg Island Point and Kelly Island, the models were used to develop potential pathways of sediment that may move along the foundation of the geotextile tubes, or in the vicinity of the project area if the containment tubes were to be compromised. The sediment will be transported under normal tide and wave conditions at a long term rate, and will be transported under storm tide and wave conditions at more extreme rates that could be of concern to shellfish grounds. In addition, the Kelly Island area will contain a large amount of silt material that may move out into the bay under a catastrophic failure of the containment system. That case is assumed to be long term leaching of material into the bay under primarily normal tidal conditions. At the stockpile sites, LC-5 and MS-19, long term transport rates are of primary concern, in addition to the potential pathways of sediment toward and along adjacent shorelines.

9.3.1.1 Model Results

Egg Island Point, NJ, Wetland Restoration Site

Based upon the results of the wave and current simulations for Egg Island Point and adjacent areas, sedimentation rates and pathways were delineated. Figure 9-1 also presents the sediment pathways determined for the area.

To the west of the point, transport along the shoreline and the immediate offshore area was found to be dominated by tidal currents with the net tidal and storm transport directed to the north. Wave-driven sediment transport is generally onshore. The models do not indicate a significant mechanism that would transport sediment toward the shellfish areas to the west. With current speeds peaking at 40-45 centimeters per second (cm/s) during typical tidal conditions and 80 cm/s during extreme storm conditions, scour of sand similar in size to that planned for placement here can occur and current-driven longshore transport potential is calculated to be on the order of 5000 cubic yards per year (net). In an extreme storm (2-year and higher), current-driven transport potential along the shoreline is calculated to be on the order of 500 cubic yards per day of storm, and approximately 36,000 cubic yards of material per year potentially transported along the project's perimeter and from its external foundation to the northwest due to storms.

At locations to the east of the point, lower typical and storm current speeds of 30-40 cm/s and 85 cm/s, respectively, induce slightly lower potential sediment transport rates. Current-driven transport along the shoreline is directed along shore toward the NE at a rate of approximately 3500 cubic yards per year (net), including toward the east and possibly southeast of Egg Island Point. Annually, approximately 32,000 cubic yards of material can be potentially transported by currents in these same directions due to storms. Wave-driven transport is directed onshore. Wave-driven longshore potential transport rates are calculated to be 75,000-150,000 cubic yards (net) to the northeast on the eastern side of the point and the northwest on the western side of the point. Storm erosion analysis indicates that offshore-directed sediment transport is not likely due to the extremely flat offshore bottom slopes. The simulations do indicate, however, a potential material pathway is toward the east and possibly toward the southeast where shellfish lease areas exist.

Potential transport rates are an indication of possible rates of natural removal of placed material from the area. With containment systems in place, only exposed sand will be subject to scouring at approximately the rates given above. However, if containment systems fail, transport to the NE, E, and NW will proceed at approximately those rates and shoreline recession will also proceed at rates similar to or slightly faster than recent historical shoreline recession.

Impacts on Shellfish

The sedimentation rates induced by sand placement in the Egg Island Point area could have an impact on neighboring shellfish beds. Impacts are primarily due to an interruption in filter-feeding by the shellfish, which could cause a long-term reduction in health or population depending upon the length and severity of the interruption. Interruption in this project is considered to be due to an increase in suspended sediment concentration in the water column over the shellfish areas due the newly-available sediment material in the containment site.

The primary effect on shellfish will take place during storms when the greatest potential for mobilization of sediment occurs. At Egg Island Point, a review of the hindcasted storm simulations and calculations of transport rates yields the following:

Recurrence	Peak Bottom Current (cm/s)	Duration (hours)	Potential Transport Conc. (mg/l)	
			Ambient (Silt)	Proposed Fill (Sand)
1yr	50	36-48	250	15
10yr	60	48-60	500	30
20yr	65	48-60	700	45
50yr	75	24-72	1200	75
100yr	85	24-48	2000	125

In the table provided above, an estimate of extreme peak hourly storm bottom current speeds was estimated from the hindcasted population of storms, which yielded 10 events exhibiting a storm-generated component over and above the normal astronomical tidal current. Also provided is a storm duration associated with each particular storm frequency, which indicates that storms of the 1yr to 50 yr range are northeasters, while hurricanes become significant at the 50yr-100yr level. Ambient sediment transport concentrations are presented for each storm frequency, based upon a review of typical and annual sediment loadings provided by the Haskin Shellfish Laboratory, taken continually over a year's time. Based upon a general mean sediment concentration of 40 mg/l in normal tidal currents peaking at 40 cm/s, storm values were determined by scaling to more extreme conditions based upon a velocity to the fourth power ratio, the accepted functionality for total sediment load. This is likely a conservative assumption given that the supply of sediment to the water column is not unlimited. Finally, an estimate of potential sediment transport concentrations is provided given an unlimited supply of material from the Egg Island Point fill.

The table provided above indicates that storm-induced sediment transport of new material potentially is much less than the ambient sediment loading in the water column during most storm events. The Haskin Shellfish Laboratory investigation of the conditions required for impact on oyster survivability indicates that any 4-day event with the combined effect of ambient material plus the new source of material will have no observable effect on shellfish. The longest extreme storm event found in the historical record and included in the hindcast was the March 1962 storm which lasted approximately 60 hours, but caused relatively low current speed increases at Egg Island Point (about 50 cm/s). The peak current speed event was found to be the 1944 hurricane, but that event caused increased current speeds for less that 24 hours which is typical of a summer/fall hurricane. The shellfish survivability model indicated that an August storm event of greater than 4 days and less than 30 days duration would be required for a significant impact on the population. Again, extreme events of record in that time of year are rare hurricanes which typically last no longer than 48 hours.

Kelly Island, DE, Wetland Restoration Site

Based upon the results of the wave and current simulations for Kelly Island and adjacent areas, sedimentation rates and pathways were delineated. Figure 9-1 presents the sediment pathways determined for the area.

Numerical flow modeling indicates that typical tidal current speeds decrease from south-to-north along the Kelly Island area, peaking at 50 cm/s at the southern end (Port Mahon), to 40 cm/s along the central section of the island, and 35 (ebb)- 55 (flood) cm/s at the northern end. The storm currents peak at approximately 80 cm/s along the entire area. Typical current-driven transport rates are on the order of 5000 cubic yards per year alongshore (net to south). In an extreme storm (2-year and higher), current-driven transport along the shoreline is calculated to be potentially on the order of 500 cubic yards per day during a 2-year event, and potentially approximately 29,000 cubic yards of material per year transported annually along the project's perimeter and potentially from its external foundation to the north and south due to storms. All model runs indicate a strong sediment pathway in the north-south direction along all of Kelly Island, and sand transport should feed neighboring beaches or shoal the Port Mahon channel unless measures are taken to prevent shoaling. Wave transport is primarily onshore and alongshore at a potential annual rate of approximately 25,000-50,000 cubic yards (net) to the north. The sediment pathways discerned from the model results indicate that shellfish lease areas to the east should not be significantly impacted by sand placed at this project site. Although predominant winds are directed to the east during normal conditions, the corresponding wind-driven currents are not calculated to be sufficient to carry material offshore nor to significantly change the north-south direction of tidal currents. Storm wind-driven currents during both hurricanes and northeasters are onshore-directed (i.e. from the easterly quadrants), and are thereby expected to keep sediments moving close to the shoreline. Strong winter northwesterly winds may induce some offshore-directed sediment motion; however, this generally occurs during the months when shellfish are virtually dormant.

As in the Egg Island Point case and barring erosion of upland silt disposal areas, the potential rate of sediment transport will remain the same, but the amount of readily available material for transport could increase if containment systems fail.

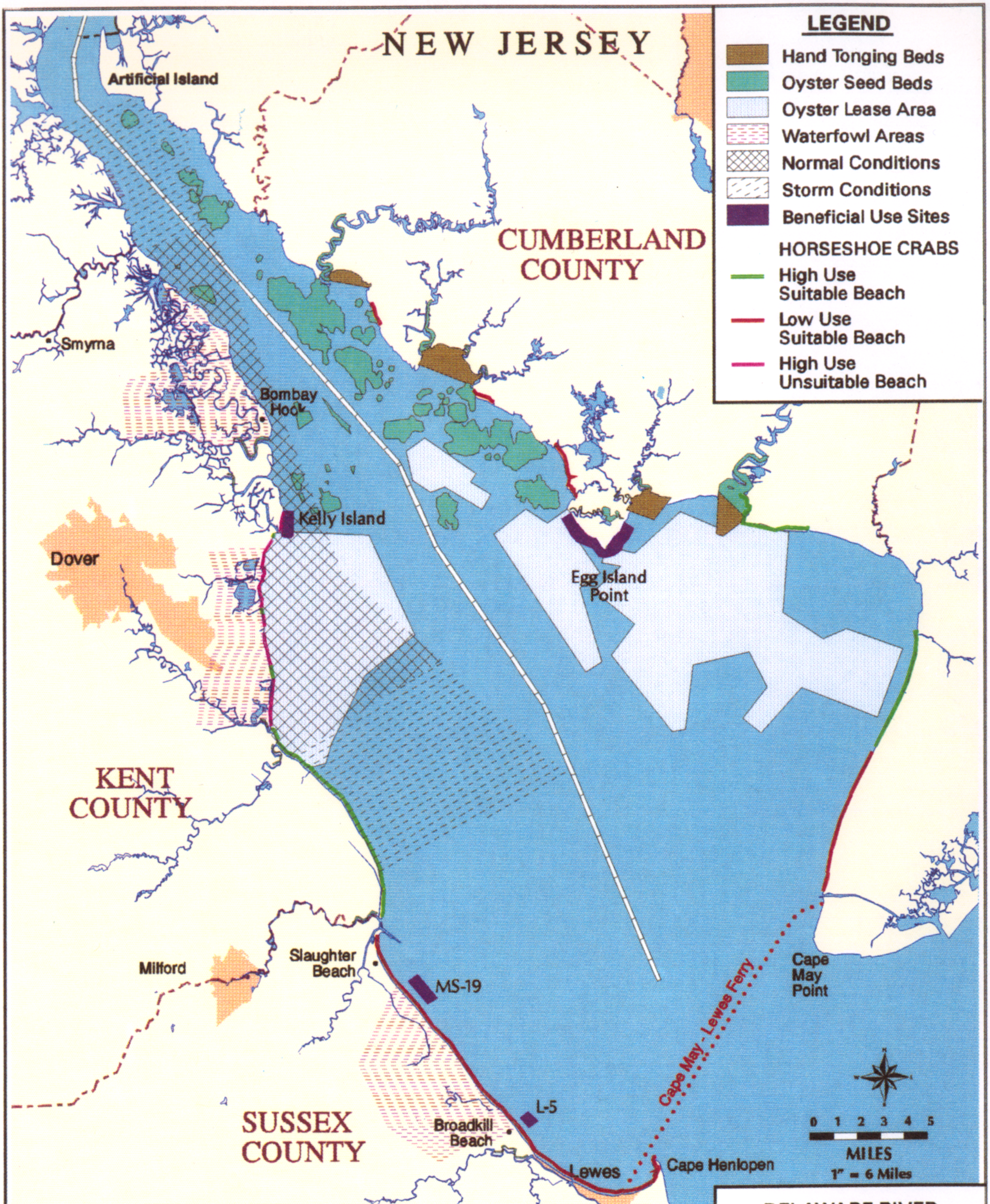
Kelly Island Silt Dispersion

Possible release of silt from the Kelly Island upland containment area is analyzed by assessing the fall velocity of 0.05mm material and its transport characteristics. Silt will generally be eroded from an area when flow velocities exceed approximately 30 cm/s and deposit only at slack tide. During a typical tidal cycle, silt material is calculated to have the potential to travel a maximum of approximately 3.6 nautical miles to the northern quadrant and southern quadrant from Kelly Island. Assuming that material will be transported along Kelly Island in a 100-foot wide swath (about 1/2 a normal-condition wavelength), the potential total sediment loading (or erosion) rate is calculated to be about 45 cubic yards per hour of normal-condition tide.

A more catastrophic assumption would be failure of containment structures and release of material during a storm. Following the same reasoning during an extreme storm, the material would travel approximately 7 nautical miles toward the northerly and southerly quadrants. In the storm case, the potential average total sediment loading (or erosion) rate is calculated to be approximately 1500 cubic yards per hour of storm tide condition, with rates peaking at 3500 cubic yards per hour at the peak of a major storm event. During a 100-year event, storm flows are estimated to have the approximate potential to transport a total of 100,000 cubic yards of silt material from the site split to the northerly and southerly quadrants. This approximately equates to 66 hours of erosive currents during the event. Conservatively assuming this material to cover 7 square nautical miles of seafloor, this equates to an average covering of approximately 1/8 inch of silt. The projected area of coverage based upon this analysis just barely overlaps the western edge of leased oyster bottoms to the southeast of Kelly Island. The anticipated silt dispersion is conservatively shown in Figure 9-2. The offshore extent of the sediment coverage area shown in the figure is considered to be a most-likely boundary for sediment deposition based upon the modeling results, but could easily vary by 25-50% due to variability in specific storm characteristics and site-specific details of the bathymetry.

Impacts on Shellfish

The sedimentation rates induced by sand placement in the Kelly



DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT

Areas Potentially Impacted By Silt If Breach Occurs at Kelly Island

U.S. Army Corps of Engineers, Philadelphia District

Figure 9-2

Island site could have an impact on neighboring shellfish beds. Impacts are again primarily due to an interruption in filter-feeding by shellfish, which could cause a long-term reduction in health or population depending upon the length and severity of the interruption. Interruption in this project is considered to be due to an increase in suspended sediment concentration in the water column over the shellfish areas due the newly-available sediment material in the containment site.

As at Egg Island Point, the primary effect on shellfish will take place during storms when the greatest potential for mobilization of sediment occurs. At Kelly Island, a review of the hindcasted storm simulations and calculations of transport rates yields the following:

Recurrence	Peak Bottom Current (cm/s)	Duration (hours)	Potential Transport Conc. (mg/l)	
			Ambient (Silt)	Proposed Fill (Sand)
1yr	70	36-48	120	60
10yr	90	48-60	325	160
20yr	110	48-60	730	350
50yr	135	24-72	1650	800
100yr	150	24-48	2530	1215

In the table provided above, an estimate of extreme peak hourly storm bottom current speeds was estimated from the hindcasted population of storms, which yielded 10 events exhibiting a storm-generated component over and above the normal astronomical tidal current. Also provided is a storm duration associated with each particular storm frequency as explained for Egg Island Point. Ambient sediment transport concentrations are presented for each storm frequency based upon the data provided by Haskin Shellfish Laboratory. Again, scaling to more extreme conditions was performed for the listed recurrence levels. This is likely a conservative assumption given that the supply of sediment to the water column is not unlimited. Finally, an estimate of potential sediment transport concentrations is provided given an unlimited supply of material from the Kelly Island sand fill.

The table provided above indicates that storm-induced sediment transport of new material is again potentially significantly less than background levels of turbidity in the water column during most storm events. Again, the Haskin Shellfish Laboratory investigation of the conditions required for impact on oyster survivability indicates that only a 4-day event will have an observable effect on the shellfish and only if that event occurs in August. The longest extreme storm event found in the historical record was the March 1962 storm which lasted approximately 60 hours with a peak flow speed of about 100 cm/s. The peak current speed event was found to be the 1944 hurricane (139 cm/s), but that event caused increased current speeds for less that 24 hours which is typical of a summer/fall hurricane.

For the silt material (diameter of 0.05mm), the potential peak transport concentration during typical tide conditions adjacent to Kelly Island is calculated to be approximately 90 mg/l which is approximately 30% higher than the highest turbidity levels reported in historic data. During extreme events, the concentrations are calculated to be approximately the following:

Recurrence	Peak Bottom Current (cm/s)	Duration (hours)	Potential Transport Conc. (mg/l)	
			Ambient (Silt)	Proposed Fill (Sand)
1yr	70	36-48	120	850
10yr	90	48-60	325	2300
20yr	110	48-60	730	5150
50yr	135	24-72	1650	11000
100yr	150	24-48	2530	18000

It should be noted that the extremely high concentrations during the very extreme events are theoretical in nature and are probably beyond conditions for which sediment transport relationships are valid. However, the values indicate that during a long term leaching process (say 30 days), the concentrations of sediment in the water column may increase to the daily range of 90-100 mg/l, which is well-below levels modeled by the Haskin Shellfish Laboratory that have an adverse effect on the oyster beds. However, at the 10yr event and higher, a catastrophic failure of the containment structures will bring concentrations above levels of adverse effect, but the durations of the storms are relatively short and will limit or prevent adverse effects on the oyster beds.

LC-5 and MS-19 Stockpile Sites

The two stockpile sites MS-19 and LC-5 were modeled together in the same wave model and current model grids and simulations because of their proximity. In both cases, it was found that the sediment pathways were similar, i.e. net wave-driven mass transport is potentially onshore, and the longshore potential net transport is to the northwest. Sediment pathways are illustrated in Figure 9-1. Net wave-driven potential transport is found to be approximately 15000 cubic yards per year in the onshore direction at MS-19 and 5000 cubic yards per year at LC-5. These values indicate that the stockpiles are expected to migrate slowly onshore; however, major 2- to 5-year storms can potentially transport 40,000 cubic yards in a single event in the onshore direction. Mean current-driven velocities along the coast due to astronomical tidal action were found to be about 30-40 cm/s flows at MS-19 and 40-60 cm/s at LC-5. The net transport potential due to these flows are calculated to be approximately 10,000 cubic yards per year at MS-19 and 5,000 cubic yards per year at LC-5 to the south. Again, these transports indicate slow movement of material to the northwest and southeast, forcing the stockpiles to spread laterally.

A significant transport component is the wave-induced longshore transport potential at these sites. At Broadkill Beach (LC-5) average net transport potential is calculated to be about 230,000 cubic yards per year to the northwest (left), and at Slaughter Beach (MS-19) net transport potential is calculated to be approximately 260,000 cubic yards per year in the same direction.

No change in longshore transport along the coast is calculated for the stockpiles with a crest elevation of -3 feet MLW, or for either stockpile with a crest elevation of 0 feet MLW if the stockpiles are kept a minimum of 1500-2000 feet from shore.

Since there are no oyster resources near the sand stockpiles, there will be no impacts. Impacts to other benthic resources are discussed in Section 8.0.

9.3.1.2 Summary and Conclusions

A sediment transport and shellfish survivability study was performed for four sites on the Delaware Bay. The objectives of the study were (1) to map potential sediment transport rates and pathways due to planned projects at Egg Island Point, Kelly Island, MS-19 and LC-5 and (2) to assess potential impacts on neighboring shellfish areas.

In order to perform the study, numerical current and wave models were employed to aid in defining sediment transport mechanisms. Tidal current data was collected in summer 1995 at each location during typical daily conditions to define ambient conditions and to provide some model calibration data. To aid in calibrating sediment transport estimates, suspended solids data collected over several years was supplied by the Haskin Shellfish Research Laboratory. Based upon the models and data, calculations of current-driven and wave-driven sediment transport were made for both storm and normal conditions, which were then used in a shellfish survivability computer model to assess potential impacts on neighboring shellfish beds.

The modeling studies indicated sediment transport characteristics as shown in Table 9-1 for the wetland restoration sites and in Table 9-2 for the sand stockpile sites.

Shellfish survivability modeling was performed for the wetland restoration sites by examining the effect of a 4-day and a 30-day high-turbidity event in each season of the year with a turbidity level of 2 g/l, which was found to be approximately the maximum expected concentration during an extreme storm. The 4-day storm event was selected because it is longer than the extreme storms of record. The 30-day case was selected because it could be typical of the time required to detect and address a sediment leak from the containment areas and to provide information on the variation in impacts with the duration of turbidity.

The results of the shellfish survivability calculations show that there are no expected impacts on oyster survivability or growth

Table 9-1. Sediment Transport Findings at Wetland Restoration Sties (Sand 0.30mm)

	Egg Island Point, NJ	Kelly Island, DE
Normal Current-Driven Transport Potential	5,000 cu yd/yr (net to southeast)	5,000 cu yd/yr (net to south)
Normal Wave-Driven Longshore Transport Potential	75-150,000 cu yd/yr (net to north)	25-50,000 cu yd/yr (net to north)
Storm Current-Driven Transport Potential	30-40,000 cu yd/yr (net to north)	30,000 cu yd/yr (net to south)
Dominant Sediment Pathways	Onshore and alongshore to the north on both sides of the point; slight easterly-driven sediment to the east of the point	Onshore and alongshore to the north and south; slight southeasterly-driven transport to the south of Port Mahon
Silt (0.05mm) Dispersion Potential	not applicable	Normal Tide Transport Potential: 45 cy/hr Normal Tide Travel Distance: 3.5nm Mean Storm Transport Potential: 1500 cy/hr Storm Transport Travel Distance: 7 nautical mi.

Table 9-2. Sediment Transport Findings at Stockpile Sites (Sand 0.30mm)

	L-5	MS-19
Net Wave-Driven Mass Transport Potential	Normal: 5,000 cy/yr (net onshore) Storm: 40,000 cy/yr (net onshore)	Normal: 15,000 cy/yr (net to south) Storm: 40,000 cy/yr (net onshore)
Net Current Driven Transport Potential	5,000 cy/yr (net to south)	10,000 cy/yr (net to south)
Wave-Driven Longshore Transport Potential	175-300,000 yd/yr (net to north)	200-350,000 cy/yr (net to north)
Dominant Sediment Pathways	Onshore and alongshore to the north	Onshore and alongshore to the north
Impact of Stockpile Crest Elevation	Crest at -3'MLW appears to have minimal effect on nearshore transport processes	Crest at -3'MLW appears to have minimal effect on nearshore transport processes

due to the events considered except at Kelly Island in August. Because August storm events are much shorter than the 4-day event considered, insignificant impacts are expected on oysters during real storm events at that time of year. The 30-day event, although also potentially causing an impact at Kelly Island in August, is most likely to be prevented in August because that time of the year is best for performing repair work on the containment system. In addition, any 30-day event in August will exhibit turbidity concentrations that are much less than 2 g/l and more likely 150 mg/l. Similar 30-day simulations with turbidity levels of approximately 150 mg/l in August show much less impact, with the entire spawn not being lost, and no increase in mortality over ambient conditions.

The sand and geotextile tube dredged material containment facility at Kelly Island has been analyzed and designed to prevent the discharge of fine grained material into Delaware Bay. The design minimizes the risk to oyster resources due to catastrophic failure of the structure. Worst case scenarios have been utilized to model foundation and geotextile tube stability, settlement and bearing capacity, and erosional failure. Protection against scour is being provided by protective blankets. In addition, several other geotextile tube projects are being monitored to gain additional knowledge that will insure that this project will succeed. An operation and maintenance manual will be developed for this site, which will include a monitoring plan providing for periodic observation of the Kelly Island structure, especially during the critical late summer period.

9.3.1.3 Operation and Maintenance of Kelly Island

An operation and maintenance plan will be developed that will include repairs to prevent any breach or potential breach from occuring. The innovative design of this facility will ensure that this area will successfully provide for the restoration of valuable wetland resources.

In light of the sensitivity of the oyster resources of the Kelly Island area certain contingency measures will be planned in the extremely unlikely event a breach occurs. These seed beds, existing under inherently low food supplies, do not have the reserves required to easily withstand increased turbidity levels that may result. Before the construction of the Kelly Island wetland restoration site, oyster populations will be measured to determine the status quo so that a comparison can be made in the unlikely event of a breach. Parameters to be measured include abundance, size (biomass) frequency, disease infection intensity, reproductive state, and recent mortality. If a breach occurs, the same parameters would be measured to determine the extent of impacts. If the impacts were significant, restoration of the bottom that was damaged by the release of silt would be done.

Maintenance

Three areas of maintenance may be necessary at the Kelly Island Wetlands Restoration Project. One area of maintenance includes project structures such as the geotextile tube groins, geotextile tube armor on the southern spit of the island, drop inlets and outlet pipes, weirs, offshore and cross-shore sand dikes, and the geotextile tube cores in those sand dikes. Another area of maintenance is the Mahon River channel to ensure that material eroding from the Kelly Island wetland restoration is not impacting the navigation channel. The third area of maintenance is needed for development of the marsh to create tidal connections to stagnant pools, increase (or decrease) tidal flushing, encourage propagation of desirable plant species, and eradicate undesirable species. The Corps of Engineers will be responsible for maintenance of the structure and the DNREC will manage the site for wetland, wildlife, and fisheries values.

Project Structure Maintenance

The offshore sand dike was designed by assuming that up to 35,000 yd^3 of material per year would be removed from the structure over a 10 year period (plus a factor of safety).

Plans will be made to replenish the volume of sand lost from the structure over the first 10 years of the project. To be consistent with the design approach, it was be assumed that 350,000 yd^3 of sand will be required after 10 years. Prior to maintenance a hydrographic survey would be conducted to determine the actual volume of sand required. If it is less than 350,000 cy, maintenance could be postponed or a replacement volume of sand provided.

Annual inspections of the structure will be made to ensure its integrity. Of particular concern is damage due to overtopping that may occur during an extreme event (e.g. water level with 10-25 year expected return interval). If a breach forms in the structure, the geotextile tube core will limit the damage, but the problem will be repaired. In this case, repair could probably be accomplished with earth moving equipment using existing sand in the structure. If the geotextile tube in a breach is damaged, a determination will be made as to whether it should be repaired or replaced. In general, any breach should have only local effects and so repair may not be necessary. The breach could simply be filled.

Wind transport from the crest of the structure may be a problem. If necessary, it will be reduced or eliminated by planting suitable vegetation or by using a sand fence.

The cross-shore dike is not expected to lose any sand to transport processes. However, if the structure is overtopped during severe weather, a breach may form through its cross-section. If a breach forms in the structure, the geotextile tube core should limit the damage, but the problem will be repaired. In this case, repair could be accomplished with earth moving equipment using existing sand in the structure.

Annual inspections of the cross-shore dike be conducted to determine the condition of the dike and the outlet works. Likely problems with the outlet works will include clogging of the outlet pipes with sand and deterioration of timber weir boards, or mechanical components.

The geotextile tube groins should be considered temporary. The only way that they should be considered permanent is if they are regularly inspected and maintained. The cross-shore orientation of a groin makes it susceptible to damaging waves, erosion and undermining. The seaward end of the tube groin will not be prevented from lateral motion very well and so may be moved by large waves. Accumulation of sand is expected on the updrift side of the tube with sediment losses on the downdrift side. This will tend to destabilize the tube and cause it to roll slightly in the downdrift direction. As with any exposed geotextile tube, the fabric is always susceptible to damage by abrasion and punctures. Tube groins are even more susceptible to damage because of their orientation. They tend to intercept debris being transported longshore.

The groins will be inspected annually. The groins will be inspected after the winter season and, when possible, in the fall. A complete failure of the groins is not expected, though some damage may occur. The tube groins should continue to function for several years. Replacement of failed tubes will only be done if it is clear that loss of sand through longshore transport (especially in the southerly direction) is a problem. Otherwise, replacement of the tubes will be foregone and replacement of sediment lost to longshore transport at some future time will be considered. (See discussion of maintenance of the offshore dike above.) If southerly transport is evident and threatens navigation in the Mahon River channel, a determination of the rate of transport will be made. It may be more cost effective to dredge the river channel than to replace the geotextile tube groins. However, it may also be reasonable to dredge the channel and use the material to fill new geotextile tube groins.

The tube recommended for protection of the southern spit of Kelly Island is considered temporary. The tube will be inspected annually for damage. If the tube is damaged, a determination will be made regarding repair or replacement with another tube or other material. The structure is important because it limits wave propagation directly into that portion of the Mahon River leading to the boat launch.

Mahon River Navigation Channel Impacts From Kelly Island

The amount of sand that may be transported into the Mahon River navigation channel is very difficult to estimate. The net transport is expected to be 35,000 yd^3/yr to the north. Tidal currents and waves out of the north will tend to move some material south, but the volume is uncertain. Further, sand that does move south may not enter the navigation channel. Therefore, the channel will be surveyed annually to determine whether shoaling in the channel is a problem. Channel maintenance will be planned for every three years. However, annual surveys (at least for the first 5 years) will indicate whether this is a reasonable estimate for maintenance.

If dredging is required due to sand accumulation, the sandy material removed from the channel could be placed on the offshore sand dike to postpone its maintenance requirements (as discussed above).

Habitat Maintenance

During the development of the marsh after placement of the dredged material, some topographic shaping and active management may be necessary to ensure the marsh develops as anticipated by all parties. This work may require cutting new tidal channels to stagnant pools, increasing or decreasing the amount of water allowed to flow through structures, developing new inlet structures, creating high marsh zones or open water pools, vegetating areas that have not vegetated naturally, eradicating nuisance plant species (e.g. *phragmites*), and other similar maintenance work. Most of the evolution of the marsh can occur naturally, however some aspects may require active management.

Other habitats such as those for horseshoe crabs, migratory birds, and shore birds will be monitored for functional development, colonization, and other life requirement aspects. If the development of the habitats is inadequate, then modification or maintenance will be required.

In general annual or more frequent inspections should be conducted to observe and document the development of all of the ecological characteristics of the project.

9.3.2 EBERM Analysis

The EBERM analysis evaluated the long-term potential for stability/mobility of sediments to be placed at the offshore stockpile sites near Slaughter Beach (MS-19) and Broadkill Beach (L-5), Delaware. The six-year normal condition wave database referenced in the preceding section of this report was used to characterize wave conditions at the stockpile sites. The wave data were ordered in terms of wave height, and statistical measures of wave height adopted in the EBERM methodology were extracted from the database. Additionally, near-bed oscillatory peak speeds were calculated from the wave data base, and compiled into a frequency distribution. Based on consideration of each site's local geometry and configuration of the proposed disposal mounds, wave crest and trough peak speeds were calculated to determine cross-shore transport potential.

The wave, sediment, and geometric data generated for the Slaughter Beach and Broadkill Beach stockpiles were compared to similar data for a number of previously monitored sites in the EBERM database. It was determined that both sites will experience persistent transport of sand in the landward direction. The nature of the EBERM analysis is such that transport rates are not explicitly computed. Rather, comparison of the pertinent EBERM criteria for Broadkill and Slaughter Beaches with criteria from the monitored sites suggests that the onshore transport will occur over a period of decades. The sediment which is transported landward will be gradually dispersed in the alongshore direction at both sites, contributing sand to nearshore environments which presently experience a net sediment deficit. The EBERM analysis thus independently confirmed the findings of the more computationally intensive work performed with the wave and current models discussed in the previous section.

9.4 Impacts of Placing Sand on Broadkill and Slaughter Beaches

The sand stockpiles (MS 19 and L 5) will provide Delaware a source of sand to nourish Broadkill and Slaughter beaches. The

impacts of place sand on Delaware Bay beaches is described in the *Broadkill Beach, DE, Interim Feasibility Study, Final Feasibility Report and Environmental Impact Statement*, dated September, 1996.