APPENDIX D 2009 Revision
NANTASKET BEACH (DCR)
MATERIALS INVESTIGATION
GEO-ENVIRONMENTAL ENGINEERING BRANCH

1. INTRODUCTION

Nantasket Beach is located on the southeast shore of Massachusetts Bay, approximately 10 miles (6 kilometers) east-southeast of Boston in the community of Hull, Massachusetts. Nantasket Beach is a long strip of land stretching between Atlantic Hill on the mainland to Allerton Hill to the northwest, with widths ranging between approximately 425 feet (125 meters) and 2,500 feet (750 meters). The beach side faces Massachusetts Bay to the northeast. The back side consists of tidal flats and Hingham Bay.

The study area consists of the southern portion of Nantasket Beach, approximately 6,800 feet (2,100 meters) in length, from Atlantic Hill to Phipps Street.

An existing seawall, constructed by the Metropolitan District Commission (MDC) now known as the Department of Conservation and Recreation (DCR), extends along the southernmost portion of the study area, and is approximately 5,400 feet long. The study area also includes the 1,400 feet of beach north of the seawall. The seawall is in need of repair due to deterioration over time by coastal storm events. One section of the seawall failed in the December 1992 storm, and the remaining wall continues to be threatened by undermining of its foundation. During storms, damages occur directly related to the seawall, and as a result of overtopping of the seawall and flooding of the backshore. If erosion was allowed to continue unchecked, the road behind the seawall could potentially be lost eventually, cutting off access to the residential area north of the study area.

This Appendix is a revised version of the 2005 Appendix reflecting the results of various new studies performed by the USACE, most notably the 2004 Beach Nourishment/Sand Fill Material Transportation Study Report, the 2005 Nantasket Beach Characterization Study, and the 2008

Nantasket Beach Section 103 Coastal Engineering Appendix. Highlights from these reports will be included where appropriate in this Appendix.

As part of the DCR's efforts to stabilize the Nantasket Beach seawall a temporary seawall fortification (TSF) stone revetment approximately 2,350 feet long was constructed at the south end of the beach in 2006 and a new Northern Revetment approximately 950 feet long was constructed in 2007 to replace the wall segment that failed in 1992. The remainder of the DCR Nantasket Beach Reservation, a 2,200 linear foot central section is located between the Northern Revetment and the southern TSF.

Two potential alternatives were examined; sand to re-nourish and provide protection to the beach, and stone to construct a central stone revetment that would tie in with the existing TSF and Northern Revetment.

This Appendix discusses the geology of the study area, and the materials for the beachfill re-nourishment and seawall reinforcement alternatives. The beachfill alternative consists of building a sand berm in front of the 2,200 foot section of the seawall that is currently unprotected. Periodic re-nourishment of the beachfill would be required to maintain the project dimensions. It is assumed that appropriate maintenance or repairs to the seawall would be performed by the DCR prior to construction of a Corps beachfill project. It is also understood that DCR would place beachfill on the segments adjacent to the Corps project to create a continuous and homogeneous beach that would protect the Corps project from disproportional end losses.

The seawall reinforcement alternative consists of a new 2,200 foot long stone revetment. The new stone revetment would be situated in front of the existing seawall extending 10 feet out. Its armor stone would be underlain by subsequently smaller stone layers ranging in size down to gabion stone and founded upon crushed stone wrapped in filter fabric. The toe of the new revetment would be buried below the existing beach surface so as to minimize erosion effects of future coastal storm events.

2. TOPOGRAPHY

Most of the study area is flat and low-lying, with elevations ranging from sea level to approximately 4.5 meters (15 feet) NGVD. Several nearby drumlin hills (Sagamore, White Head, Hampton Hill, etc.) rise above the surrounding area, reaching elevations of approximately 10 meters to 25.5 meters (30 to 85 feet) NGVD. "NGVD" is the National Geodetic Vertical Datum of 1929, and is roughly equivalent to Mean Sea Level (MSL). Mean Low Water is 4.5 feet below the NGVD of 1929 (or MSL).

Topography in the study area has been influenced primarily by four factors: bedrock geology, the effects of glaciation, coastal processes, and especially construction by man.

3. GEOLOGY

The New England region has been glaciated several times and the modern landscape is largely one of moderate to thick surficial deposits of glacial origin overlying bedrock. The retreat of the glaciers brought about a rise in sea level as they melted, and a rebound of the land after it was unloaded. The New England region appears to have stabilized in terms of rebound, and the land is now believed to be either steady or subsiding extremely slowly. Sea level, however, continues to rise.

3.1 Bedrock Geology. The study area is likely underlain by igneous (volcanic lavas and ash) and/or sedimentary rock types (Brenninkmeyer, B. M., 1976; Zen, 1983; and Billings, 1976). Lava and ash deposits (Mattapan Volcanics of Mississippian age) are exposed at Atlantic Hill, while the older shale, sandstone, and conglomerate beds of the Boston Bay Group (Pennsylvanian or Permian age) are exposed at the base of the cliff and in Long Beach Rock (Brenninkmeyer, B. M., 1976). Areas of ledge are also mapped offshore. Within the study area along the beach/seawall alignment, bedrock probably occurs at depths of greater than 10 feet (3 meters).

3.2 Glacial Geology. Most of the sediments overlying the bedrock in this region are composed of glacial deposits of ice contact till and stratified drift (sand and gravel outwash, with minor silt, clay, and till), with localized swamp deposits, and beach sand. Coastal Plain sediments (clay, sand and fine gravel) were deposited offshore over the bedrock prior to glaciation. These deposits were probably much thicker and more extensive originally, but were reduced significantly by the subsequent erosion and reworking of these materials by the glaciers.

The New England area experienced numerous glacial advances and retreats during the Pleistocene time period, and the landscape reflects the variety of glacial drift materials deposited and landforms created in the various glacial environments. The best geologic record exists for the deposits left behind by the most recent glaciation, called the Wisconsinan Stage, which ended roughly 8,000 years ago. Retreat of the glaciers in southeastern New England began around 18,000 to 14,000 years before present.

Glacial till is the poorly-sorted, inhomogeneous material deposited either at the base of the glacier (lodgement till), or as the material within the ice sheet which melted out and was let down on the existing landscape (ablation till). The term "stratified drift" encompasses the generally well-sorted sand and gravel deposited by glacial meltwaters on an outwash plain (or "apron") in front of an ice sheet, or in glaciofluvial ("river") environments under, within, on top of, or adjacent to an ice sheet.

Allerton Hill, Strawberry Hill, White Head, Sagamore Hill, and Hampton Hill are all examples of drumlins. Drumlins are elongate-shaped, "streamlined" hills created by the movement of glaciers over the land. They are composed of variable glacial materials, sometimes mantled over bedrock, or composed wholly of either rock or glacial deposits. The drumlin hills along Nantasket Beach appear to be composed of glacial till. Atlantic Hill appears to be a rock knob, possibly mantled by glacial till.

There are many commercially significant deposits of stratified drift ("outwash") in southeastern Massachusetts. The large, well-established sand and gravel industry in this area utilize these deposits and offer a readily available source of borrow for beachfill.

3.3 Coastal Geology. The specific nature and configuration of the shoreline in a given area are the result of a number of elements at work, on both small and large scales, within the dynamic coastal environment. Such factors include the interaction of the tides and wave action with the situation of the existing shoreline, the resistance of the bordering mainland, the ferocity of individual storms, and sea level changes.

3.3.1 Sea Level Rise. The present rate of sea level rise has been measured in Boston Harbor at a rate of approximately 12 inches (30.5 centimeters) per century, or approximately 0.1 foot (3 cm) per decade (Department of Commerce, National Oceanic and Atmospheric Administration, 1988).

The future rates of sea level rise will depend strongly on the net effect of the changing composition of the atmosphere on temperatures of the Earth. The increasing atmospheric concentrations of certain gases, such as carbon dioxide, released naturally and by human activities, would tend to warm the Earth. If Earth temperatures continue to increase as they appear to be based on current data, more of the water which is presently "stored" as ice in glaciers, polar ice caps, shelves, and the Greenland Ice Sheet could be released into the oceans, resulting in a rise in sea level.

According to a study of the probability of sea level rise conducted for the USEPA, "global warming is most likely to raise sea level 15 cm by the year 2050, and 34 cm by the year 2100" (Titus, J.G., and Narayanan, V.K., 1995). Since most coasts are subject to other factors, such as compaction and subsidence of land, and local climate variations, this study predicts that the total sea level rise will be even greater than that due to climate change alone.

The 2008 Section 103 Coastal Engineering Appendix used 3 scenarios to determine the effect of sea level rise on the project; keep sea level at the present day value, a 50 year condition with historic sea level rise at Boston at 0.435 feet/50 years, and doubling of that rate to examine sensitivity to a sea level rise rate of 0.87 feet/50 years. Based on the models used for the Coastal Engineering Appendix for a without project condition it was demonstrated that the impacts of sea level rise were not significant when considering seawall stability but long term erosion would be if the rates in the future are higher that the rates measured over the last 42 years. For with project conditions sea level rise would have am impact on beach fill performance and would require an increased volume of beach fill.

As stated in the Coastal Engineering Appendix “Sea level rise must be kept in context though and especially the predictions of sea level rise rate increase. Considering the project life is 50 years the analysis performed for sea level rise was out at year 50. This basically provided the worst case scenario for the project since in year 20 the impacts of sea level rise will be less. Also consider if the rate of sea level rise is increasing which it has not definitively shown to be yet, early in the project life the sea level rise rate will very likely be the same or similar to the historic rate. This means that even if the rate of sea level rise is increasing it will only impact the project later into the project life.”

3.3.2 Beach Dynamics. In general, the natural Nantasket Beach owes its existence to the erosion and redistribution of sediment from the existing drumlins (Allerton Hill, etc.) as well as the drumlin remnants offshore. There is good evidence that there were originally more drumlins present offshore to the east, based on the orientation of old beaches and wave cut cliffs identified on the remaining drumlins west of the present shoreline, and the existence of rocky ledges offshore from the beach (Johnson and Reed, 1910). The destruction of these eroded drumlins over time provided much of the source material during the evolution of Nantasket Beach, as tombolos formed, tying the drumlins together, and the sediment was reworked and redistributed. The geologic literature notes a remarkable lack of change in the shoreline at Nantasket Beach over the past 300 years, which may be partially attributed to the protection afforded by the presence of these remnant drumlins offshore (Hayes, 1973; and Brenninkmeyer, 1976).

The dominant direction of wave travel during most of the year is practically perpendicular to Nantasket Beach. As a result, there is not a strongly developed direction of longshore drift (Hayes, 1973). Strong winter storms coming out of the northeast, however, would tend to produce a slight southerly longshore flow, given the north-northwest to south-southeast alignment of the beach. It appears that sediment tends to move from north to south along the beach (Brenninkmeyer, 1976). This tendency is supported by the amount and distribution of rounded gravel and cobbles (called "shingle") on the north end of the beach, near

Allerton Hill. The shingle gradually becomes smaller in size and quantity, and more well-rounded, moving south of Allerton Hill. The sand component also becomes finer and more well-rounded moving southward, and increases in quantity to become the dominant beach component within the study area. The relatively recent armorment of the base of Allerton Hill has probably reduced the amount of material being supplied to the beach from this drumlin, contributing to the present sand-starved condition observed near Allerton Hill.

3.3.3 Beach Profiles. Beach profiles for the study area from the years 1963,1995,and 2006 were compared. In almost all of the profiles, the mean high water mark has migrated inland, causing the seawall to be subjected to greater wave attack and associated scour. The slope of the beach is very shallow (1:73 at the north end to 1:45 on the south end; 1:67 typical in the center). At low tide, the beach is approximately 400 feet to 600 feet wide. At high tide, the entire beach in front of the seawall is typically inundated.

In order to address and mitigate/reduce the impacts of increased wave attack and scour on the seawall during high water events, especially at the base of the existing seawall the USACE in 2006 in conjunction with the Massachusetts DCR constructed a temporary seawall fortification (TSF) to protect the deteriorating seawall and prevent further damage to it and the above sidewalk and roadway and to ensure the safety of beachgoers at this heavily used public beach. The TSF was approximately 2,350 feet long was constructed at the south end of the beach.

3.3.4 Wave Conditions. A study of wave conditions by Hayes (1973) showed that, during periods of higher waves, wave energy is focused at two locations along Nantasket Beach: one in the northern portion of the beach just south of Allerton Hill, and the other just south of Sagamore Hill. The results of a sampling program carried out by Hayes also confirm that the beach sediments generally become finer and better sorted to the south. He also observed a few localized areas of coarser sediment, which correspond to the areas of wave focusing. Hayes attributed these coarser areas to the erosion of remnant drumlins offshore caused by the large scale refraction of waves between the remnant drumlins, and the resultant increased wave energy causing more erosion of the coarse-grained remnant drumlin source material. Coarser sediment may exist in equilibrium with the stronger localized wave action. The finer materials would have been winnowed away. Hayes also noted that there seemed to be a tendency for rip currents to set up during low tide, which would transport sediment seaward.

3.3.5 Effects of Man. Construction in the backshore area, such as the roads and the seawall, has certainly had an impact on the natural cycle of sand transport. Within the study area, the dune system is poorly developed to nonexistent north of the seawall, and nonexistent along the seawall. Strong waves present during storms carry some sediment out into the shallow offshore, where it later accumulates in offshore bars, which may eventually migrate towards shore to be re-introduced to the beach system. During storms, some of the beach and dune sediment is also washed and/or blown inland over the road, into the backshore area and the tidal flats. Much of this sand may be permanently lost from the system.

Past practices reported at the study area have included clamming from boats operating in the nearshore area, and the removal of gravel and cobbles to "groom" the beach surface for recreational purposes. Both practices would tend to make the beach slightly more vulnerable to erosion.

3.3.6 Summary. The long-term prognosis for Nantasket Beach will be determined by many factors, including continued modifications by man, storms, longshore drift, the nature of the drumlin core materials, and the dynamics of a slowly rising sea level. The study area receives some renourishment from the southeasterly longshore drift. Most of the erosion of the shoreline occurs due to wave attack during storms. Some of the sand is lost permanently from the system. Given the predicted trend of rising sea level, without engineering intervention, the shoreline will continue to be eroded back, threatening both the seawall and road.

4. GENERALIZED SUBSURFACE CONDITIONS

Subsurface explorations for engineering purposes were not required for this study. A generalized subsurface profile of the study area consists of granular beach deposits (typically fine to medium sand, with variable gravel content) overlying bedrock. Glacial deposits (till and/or stratified drift) may or may not be present in the subsurface within the limits of the study area. Bedrock is expected to occur at depths greater than 10 feet within the study area. As the beachfill would be added to the existing beach surface, shallow bedrock would not impact the construction of the beachfill alternative.

5. MATERIAL QUANTITIES

Sand

Sand quantities used for the materials survey were obtained from the 2008 Nantasket Beach Section 103 Coastal Engineering Appendix. Depending on project design (berm width), and the level of protection afforded by the project (storm event), the quantity of sand required ranges from approximately 246,400 cubic yards to approximately 378,000 cubic yards.

Stone

If the stone revetment option is selected, then the quantity of stone required would be as follows based on quantities developed by the geotechnical engineer team member:

Size	Quantity (ton)
5,300 lb	3,036
3,500 lb	36,000
3,100 lb	34,000
350 lb	18,000
2-4 in. dia.	3,500
Gabion stone 1.25-2 in. dia.	3,500

6. MATERIAL TRANSPORTATION STUDY.

Battelle and ESS Group, Inc. performed a transportation study in 2004 to determine the most economically and logistically feasible method to transport a large quantity of upland source sand to the Site. Other factors, including social, environmental, and cultural parameters were also considered in determining the best method to use for the transportation of sand to the Site.

Five transportation alternatives were identified for delivering sand from an upland source to the Site.

Alternative 1 – Truck from borrow site direct to beach.

Alternative 2 – Truck from borrow site direct to pier and then load 3,000 cy barges for delivery by sea to beach.

Alternative 3 – Truck from borrow site direct to pier and then load 6,000 cy barge for delivery by sea to beach.

Alternative 4 – Combination of truck from borrow site to beach and truck to pier to barge to beach.

Alternative 5 – Rail from borrow site to pier and load barges for delivery by sea to beach; or rail to truck to beach.

Alternative 5 was removed from the decision process due to lack of rail service to the sand sources investigated.

Five Massachusetts sand sources were identified in the transportation study, three in Plymouth and two in Sandwich. Other Massachusetts sand sources were investigated but did not have the ability to produce the quantity of sand needed for the project. Truck and barge routes from each sand source were investigated. Barge routes from Quincy, South Boston, and Everett were identified. Other factors considered in determining the final alternative included environmental, transportation, and community impacts, timing and duration of sand placement, potential loss of nourishment sand attributable to the duration of placement activities, cost of monitoring and mitigation of any environmental impacts, and most importantly, the cost of sand and transportation to the Site.

According to the Transportation Study, Alternative 4 was the preferred alternative as it would allow two transport options (truck and barge). The total duration of construction would be approximately 8 months and the cost would be, in 2004 dollars, approximately $15.5 million dollars. Since the time of the Transportation Study, diesel fuel prices have increased significantly and therefore the cost of transportation has increased as a response to higher fuel prices. Even though diesel fuel prices may decrease somewhat in the future the price will still be higher than it was during the Transportation Study.

7. BEACH MATERIALS

Based on historical photos, the 2006 beach characterization report, visual observations by USACE staff, and communication with DCR staff it appears that the beach is primarily bimodal in nature, that is, beach materials consisted of 70% to 80% fine sand with 20% to 30% gravel and cobbles up to 6 inches in diameter. This material was observed during field work for the 2006 beach characterization study. Apparently, in the past, the DCR would on a seasonal basis, remove accumulated cobbles from the base of the seawall and dispose of them to an unknown offsite location or they would rake the cobbles down to the low tide mark or have a contractor remove them from the site. The beach profile survey and sampling performed by Ocean Surveys, Inc. on behalf of the USACE confirmed that the beach materials were a mix of cobbles and sand and that reflected the composition of the beach. The 2008 Nantasket Beach Section 103 Coastal Engineering Appendix indicates that the beach had not eroded as significantly as thought by others over the years. This observation may have been due in part to the bimodal nature of the beach.

A potential alternative to mimic a bimodal beach would be to place a wedge of cobble material along the upper edge of the beach (resembling a winter storm berm) and then cover this wedge with finer sand. This cobble placement would replace the cobble deposition that formerly existed and was removed repeatedly over successive years by excavation. This cobble wedge would replicate the natural deposition of cobbles along the upper beach, and would provide additional protection and stabilization. Also, finer sand might be able to be used in conjunction with the cobbles and thus the beach materials would be described as a bimodal distribution with a cobble/gravel portion.

Offshore Sand Sources

Potential offshore sources for beachfill material for Nantasket Beach have been investigated by others, but no definitive conclusion regarding compatibility, supply adequacy, and permittability has yet been reached for any of the sites considered. No further investigations regarding the identification of offshore sources have been performed for this site.

Sand Color.

Overall, the existing beach material is light gray in color and it is understood that local residents would prefer sand similar in color. However, the materials from the land-based sources are generally tan to brown. Over time, it is possible that the sand may bleach out to a lighter color or become intermingled with the existing sand. In some cases however, the sand may not fully blend and patches of brown and gray sand may occur giving a mottled appearance to the beach. The color of beachfill is not a criteria that affects a material's ability to be stable and provide a required level of protection.

8. SAND

The 2006 Beach Characterization study found that the beach is comprised mostly of fine sand with a D_{n50} around 0.22 mm to 0.25 mm with cobble and gravel components mixed in. The cobble and gravel is more evident where it has built up along the seawall and revetments within the DCR reservation. As reported in a March 1968 Corps report, approximately 125,000 cubic yards of cobble were removed between 1945 and 1963. It is uncertain for how long beyond 1963 this practice was continued. It was also found through comparisons to profile data taken in the early 1960's by the USACE that the beach within the DCR reservation has not eroded nearly as much as believed prior to the completion of the study. A Beach Profile Survey was conducted in 2005 by OSI for the USACE.

To summarize the grain size testing results of both the vibracore/ponar effort and the test pit samples, Nantasket beach is technically a bimodal beach that contains a tightly graded sand fraction along with cobble and gravel. A majority of the coarser material is actually classified as gravel, but to most lay people it appears to be cobble. The samples collected along transect number one (1) were the only set that did not encounter penetration issues and were comprised almost entirely of sand (lowest sand fraction was 70%). The other transects (8, 3, 5, 7) all contained some samples low in sand (high in cobble or gravel) or penetration issues. The sand fraction of the samples for the most part has a D_{n50} ranging from (0.15 mm to 0.25 mm). There were some samples close to shore or in deeper water that contained slightly coarse sand fractions in the .30mm to 0.45mm range, but they were the exception. This was the case for both the vibracores and the test pit samples. The cobble and gravel appears to be concentrated more closely to shore or in the deeper water sample areas. There were exceptions to this, but for the most part the intermediate water depth samples contained a high percentage of fine sand. The grain size curves shown in the OSI report indicate that the cobble and gravel screen size ranged from the sub-one inch range to 3 inches for the vibracore samples (not unexpected given the sample tube diameter was 3 inches), so the four to six inch cobbles were not collected due to the restrictive size of the vibracore sample tube, but may have been the “refusal” identified in many of the vibracore sample logs. During excavation of the test pits there were cobbles up to six (6) inches, but this was definitely the exception. The gravel that is 2 to 3 inches in size is fairly significant since cobble and gravel on a beach is often oblong with one axis significantly longer than the other two. This means that the cobble that is classified as being three inches may actually be significantly longer. Based on the 28 vibracore samples and the test pit samples collected, in general, the near shore samples exhibited 20% to 30% gravel and cobble. Some exceptions were noted however.

Six land-based sand sources were contacted to determine if they could produce the quantity of “fine” sand, 0.075 mm (200 mesh sieve) to 0.4 mm (40 mesh sieve). Between 245,000 and 380,000 cubic yards of this material would be required to provide protection to the beach. See the 2008 Nantasket Beach Section 103 Coastal Engineering Appendix for additional details. The fine sand selected was used to determine needed quantities and was based on the beach model developed by the USACE coastal engineer. However, price and availability of this narrow gradation will drive whether or not this material is cost effective or a viable alternative.

Six vendors that would be potential material sources were queried for prices on the fine sand and the bimodal material (bank run). Four of the six sources indicated that they do not sell their bank run material as it is the source of many of their products. One source indicated that they would sell their bank run material and the other indicated that they did not have sufficient quantity to sell. This represents a significant change from previous material availability surveys when bank run material was a commodity readily available and sold. One sand source indicated that to produce a fine sand using our gradation was “very difficult to process.” Other sources indicated that they would not produce a highly customized product such as this. Due to the difficulty in producing such a material there were no costs quoted by the vendors for this type of gradation. It is safe to assume that such a customized material may cost double the current prices obtained of $15 to $30 dollars or more per cubic yard. A joint venture in 2007/2008 between two sand suppliers provided sand for a 400,000 ton beach project in Connecticut. A barge facility in New Bedford, MA was used to transport the sand. This same barge facility could be a possible means of material transportation for the Nantasket project. USACE obtained the sand gradation from the source for that Connecticut project. A sand gradation analysis performed by a Geotechnical testing laboratory indicated that this material met ASTM C-33 test specifications which is a concrete sand but the material used was not crushed as is typically done for concrete sand but was only washed and screened. This material ranged in size from approximately 9 mm to 0.075 mm. The second source in the joint venture used a similar gradation. Costs obtained from both sources for this material was for $15 to $16 per cubic yard. Another source provided a price of $30 per cubic yard for washed materials that had no gradations provided but was described by them as a “washed sand”. This price should be considered a definite outlier and not used to calculate sand costs. The costs that should be used for estimating purposes are $16 - $17/cy which appear to be more in-line with the prices from the three sand sources. Due to the quantity of sand required for this project more than one source may be required to meet the project schedule as the sources need significant lead time (3 to 6 months) to process and stockpile the material.

9. STONE

The stone size specified in the revetment alternative varies from 5,300 pound to 350 pound. Quarries do not typically stock large stone like the required higher weight stone as a regular course of business. Most, if not all quarries produce aggregate as their main product. The larger stone required for this project should be considered a custom-made item especially due to the large quantity required.

During the last TSF construction phase in 2006, stone quantity became a major issue (stone quality was a minor issue due to various rock types encountered and their degree of weathering) as the quantity required for that phase could not be obtained from any one single source with such a short lead time. Six different sources were investigated by representatives of the USACE, the contractor, and the Massachusetts DCR. One source was an active quarry and others were ephemeral in nature as one location was a former quarry site being developed for commercial and retail purposes. The other four stone source locations were construction sites where bedrock and glacial boulders were encountered during site development activities.

Sources for this significant quantity of stone do exist but may potentially have to be obtained from more than one source due to the large volume required and the timeframe in which it would be required for the project. Conversations with numerous quarry supervisors and sales personnel indicated that a lead time of 3 to 6 months would be ideal to stockpile the larger 1.5 to 2.5 ton stone as stone of this size are not produced on a regular basis. It is important to understand as well that the quality and stone shape may not fit the project specifications and would require a larger stockpile for the Contractor to select from and an investment in time to select the proper stone. Another factor to keep in mind is that quarry operations typically close for the winter months and this could impact the project schedule depending upon when the notice to proceed is given to the Contractor.

To be cost effective due to significantly higher transportation costs and labor since the last TSF phase, the stone would have to be obtained from quarries in Massachusetts, Connecticut, and Rhode Island. Another potential stone source is located in the Province of New Brunswick, Canada. The quarry in this Canadian Province is substantial in size and may be able to produce all the stone sizes and quantities required. The stone products would more than likely have to be barged to a port terminal possibly in the Boston area (Everett, Chelsea, or Boston) then trucked south to the site. As far as can be determined there is no direct rail line to this area from Boston. CSX railroad does have a small siding located in Braintree but there is no space for stockpiling of stone. This would add an unavoidable additional handling sequence and therefore the opportunity for additional damage to the stone could occur. Most stone damage occurs in the handling phase (source to truck/barge to site to placement). However, the Canadian stone source did not provide prices. Another stone source is in south central Connecticut in very close proximity to New Haven and stone could be barged to one of the Boston port terminals and transferred to trucks for transportation to the site or trucked directly from the source to the site. This stone source has the quality and reportedly has the quantity that would meet or exceed the specifications for this project.

A quarry in Westfield, MA is the largest operation out of the 3 quarries who responded. This quarry is a major supplier of aggregate ballast for various railroads. CSX railroad has a rail siding at the quarry. Conversation with the CSX representative in Baltimore, Maryland indicated that stone could be transported via rail to a dock facility in Boston. However, there was no short or long-term storage available at the dock facility. From there the stone would be loaded onto trucks for transport to the site. The CSX representative also stated that a short line railroad existed in the Braintree area that may have short-term storage capability.

10. CONCLUSIONS

Sufficient quantities of suitable sand can be supplied by the land-based sand sources located within roughly 30 to 40 miles of the site. At least two sources also have the capability to barge sand from their land-based source to the site. Sufficient lead time is required to produce and stockpile sand (3 to 6 months). The sand that would be used would not be a fine sand but one that contained a small fine gravel with coarse to fine sand which should provide the needed beach protection. Only one of the sand sources indicated that they would sell their bank run material which is very similar in nature to the bimodal materials observed on the beach. Bank run typically consists of fine to coarse sand, fine to coarse gravel and cobbles. This material used to be readily available from sources in the past but now is more difficult to acquire. One of the benefits of using a bimodal material would be the use of less sand and thereby reducing the total volume required which translates to lower overall material costs. This material would be placed at the base of the existing seawall. However, there is the possibility that the overall visual appearance of this bimodal material to the general public may not be acceptable even though the main focus of this project is shore protection.

One sand source does sell their bank run (bimodal) material at a cost of almost less than half the price of sand but the required quantity may not be available and it may prove very difficult to locate sources that would be willing to sell their bank run material or have the required quantity on hand. Multiple sources may have to be utilized to obtain the required quantity. Substantial transportation costs could also be incurred as well if sources are located at a greater distance from the project. Further detailed investigation into other potential sources would be required if this alternative was pursued as well as a cost/benefit analysis to determine if using this type of material was appropriate and cost effective.

Most of the stone quarries contacted have the capability to produce the quantity needed but like the sand sources, require sufficient lead time to produce and stockpile the stone, especially the larger sized stone which are typically not produced on a regular basis. Ephemeral stone sources may be available as well but the time spent identifying them can be costly time-wise and the quantity and quality of the stone material questionable.

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