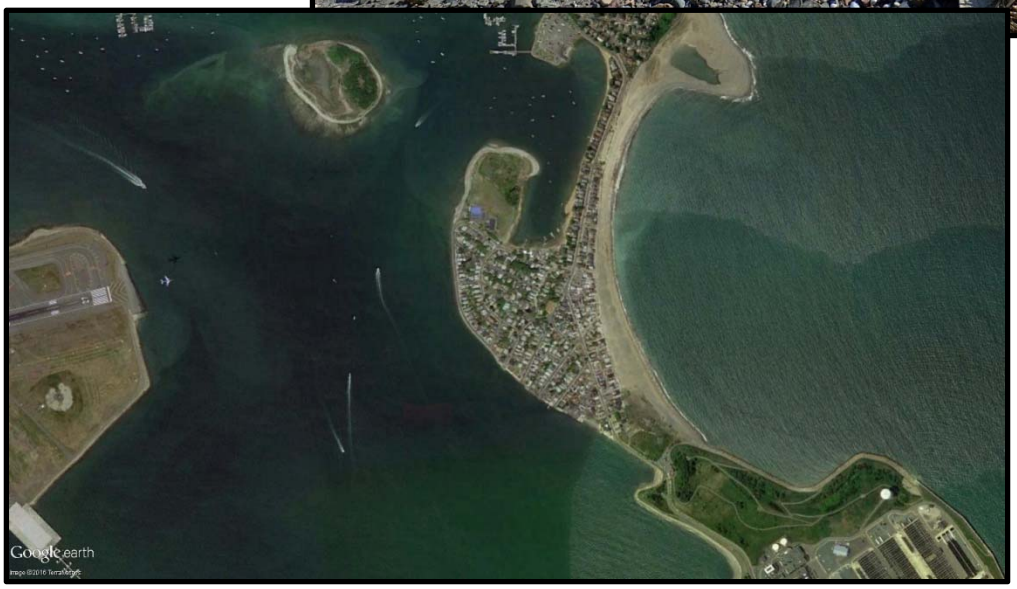
A Plan to Increase Coastal Resiliency At Coughlin Park



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July 2016

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1.0 INTRODUCTION

1.1 BACKGROUND

Each year, Massachusetts coastal communities experience coastal storm damages to property, infrastructure, and natural resources, along with associated economic disruptions. These impacts are projected to worsen and broaden with the effects of climate change. Historically coastal structures including seawalls and revetments have been constructed to control erosion and flooding with the eventual loss of fronting beaches and neighboring properties. Natural approaches can provide coastal storm damage protection and enhance natural resources. To help communities and non-profit organizations address these issues, the Massachusetts Office of Coastal Zone Management (CZM) is administering the Green Infrastructure for Coastal Resilience Grant Program through its StormSmart Coasts program. This grant program provides financial and technical resources to advance the understanding and implementation of natural or non-structural approaches to mitigating coastal erosion and flooding problems. Grants will support the planning, feasibility assessment, design, permitting, construction, and monitoring/evaluation of green infrastructure projects that implement natural or living shoreline approaches instead of hardened or armored shorelines that utilize coastal structures, such as seawalls, revetments, and groins. When properly sited, designed, and installed, coastal green infrastructure, or living shorelines, provides erosion control, buffers storm surge, stores flood waters, creates or restores habitat for aquatic and terrestrial species, and supports recreational and other values of natural systems.

In order to be considered for a grant from CZM potential projects must implement one (or more) of these (or similar) living shoreline techniques that provide coastal storm damage protection and enhance natural resources:

1) Beach, berm, and dune building, enhancement, or restoration with compatible sediment and native vegetation - Beaches, berms, and dunes provide natural buffers to coastal storm waves, tides, and sea level rise, and serve as critical habitat for wildlife. Sediment eroded during large storms typically gets deposited in protective offshore bars that cause waves to break farther away from vulnerable property and infrastructure. Deposited sediment then returns to the beach system over the summer season.
2) Bio-engineering with coir rolls (on coastal banks or for salt marsh restoration/creation), natural fiber blankets, and other organic, biodegradable materials combined with planting/re-vegetation - Bio-engineering approaches with native vegetation trap and stabilize sand on coastal banks providing increased protection against storms and erosion.
3) Natural oyster or mussel reef creation, enhancement, or restoration - Shellfish reefs provide valuable habitat and serve as natural barriers that help reduce the amount of wave energy that reaches the shoreline.
4) Fringing salt marsh creation or restoration - Planted fringing tidal marshes without structures can reduce beach and coastal bank erosion by dissipating wave energy. The width and elevation of the marsh are critical to the success of the project.

5) Natural enhancement of existing coastal structures – Sediment placed over revetments and other coastal structures can serve as more natural erosion buffers and decrease scour that results from structures.

The perspective project had to address one (or more) of the following stages of coastal green infrastructure projects:

- Feasibility assessment and siting - Work to assess and determine whether green infrastructure or living shoreline stabilization is suitable for a particular coastal area or site. Includes evaluation of erosion rates and trends, flooding impacts, sea level rise, and other efforts to analyze and assess site conditions such as elevations, coastal storm exposure, wave regimes, sediment types, existing habitat types, and vulnerable development.

- Design and permitting - Work to engineer and design the project, including plans for site preparation and installation as well as project monitoring for effectiveness. Work to prepare federal, state, and local permits and authorizations for proposed activities.

- Construction, installation, and monitoring - Work to prepare site, construct and install the coastal green infrastructure technique(s) and to monitor and evaluate the projects to assess project efficacy and inform and improve future efforts.

1.2 PROJECT NEED

Coughlin Park is an urban park located on the bayside of Winthrop Barrier spit directly east of Winthrop Beach (Figure 1). The park provides expansive views of Logan Airport and Boston Harbor. The Town of Winthrop has approximately 19,000 residents but is a suburb of the greater Boston metropolitan area.

Figure 1. Project location at Coughlin Park located in the Town of Winthrop

The park is heavily used by Town resident and visitors, who want to exercise by walking around the park, want to watch boats, view Boston Harbor, or simply watch airplanes take off and land at Boston Logan International Airport. The park has tennis courts and in the past has been the home to a baseball field and soccer pitch. In recent years, the park has been experiencing erosion on the bay shoreline that threatens use of the park. The housing development located immediately to the south and adjacent to the park has constructed an extensive revetment that protects Grand View Avenue and the houses located across the street. End effect erosion from the revetments and recent storms has eroded approximately 300 feet of the park shoreline. The Town was faced with a dilemma because there is a need to protect the shoreline but the Massachusetts Wetland Protection Act prohibits coastal engineering structures on properties that do not have houses, structures, or other infrastructure. Therefore, the Town wanted to determine the feasibility of mitigating the shoreline erosion through the use of living shoreline techniques. Implementing a living shoreline project at Coughlin Park would mitigate the erosion of the shoreline, increase the diversity of the nearshore habitat, increase the coastal resiliency, and help protect the salt marsh that is located along the portions of the park shoreline.

The Town proposed to assess which living shoreline techniques are applicable to this location by developing an understanding of the existing environmental conditions and coastal processes at the site. The Town proposed to identify appropriate living shoreline techniques that would mitigate the shoreline erosion and increase the resiliency of the shoreline at Coughlin Park by completing the following tasks:

- Perform a comprehensive coastal process evaluation to assess the existing environmental conditions along the Coughlin Park shoreline and provide information that will be used to evaluate and select potential alternatives for mitigating the erosion and will promote the natural resilience Park shoreline.
- Quantify sea level rise for the project area in order that this information can be used to assess the performance and longevity of the selected living shoreline technique.
- Assess the existing conditions to develop a complete picture of the ongoing coastal processes that shape the entire Winthrop bayside shoreline.
- Perform an alternatives analysis to evaluate living shoreline techniques that are applicable for the energy regime and the coastal resources along this shoreline.
- Select the most appropriate living shoreline alternative to mitigate the shoreline erosion at Coughlin Park.

The following report provides the information that was gathered, the analyses that were performed and the final recommendation for mitigating the erosion at Coughlin Park.

2.0 IDENTIFY EXISTING INFORMATION

In order to streamline the project design and to save costs it was necessary to identify, obtain/download, ad review existing data that was available for the Coughlin Park area. The information that would be helpful in for this project includes data on topography, bathymetry, wetland resources, eelgrass, shellfish beds, historical shoreline change rates, and current FEMA flood zones, which is presented in this document below.

2.1 TOPOGRAPHY AND BATHYMETRY

LiDAR stands for Light Detection and Ranging. This is a remote sensing method that uses light from a laser to map the surface elevation of the Earth. LiDAR data was collected under a United States Geological Survey (USGS) contract in the fall of 2013 and the spring of 2014 for the New England Coastal and Marine Geology Program (CMGP) Sandy Lidar Acquisition project. This is the most recent LiDAR dataset readily available from MassGIS for this area but additional LiDAR data is available from 2002 that was collected as part of a Boston Area LiDAR dataset. As depicted in Figure 1, Coughlin Park itself is relatively flat, and the elevation of the park area ranges from approximately 2 to 3 meters (NAVD88), shown in the yellow colors in Figure 2. The park is surrounded by an intertidal area, which forms a shelf at an elevation between -0.5 and -1.0 meters (shown in the light blue area in Figure 3), before dropping off into deeper water. The residential neighborhood to the south is located at a relatively higher elevation (10 meters NAVD88, and higher).

Comprehensive bathymetry and topography data at and around the Coughlin Park area was also compiled during a previous Woods Hole Group study conducted for Massachusetts Department of Transportation (MassDOT) and the Federal Highway Administration (FHWA) to develop a Boston Harbor flood risk model (BHFRM). Bathymetric and topographic information was assembled as a series of nodes. In the Coughlin Park area, the nodes area spaced 20 to 70 meters apart. These individual nodes,

as well as an interpolated elevation surface based on this BHFRM data are presented in Figure 3 below.

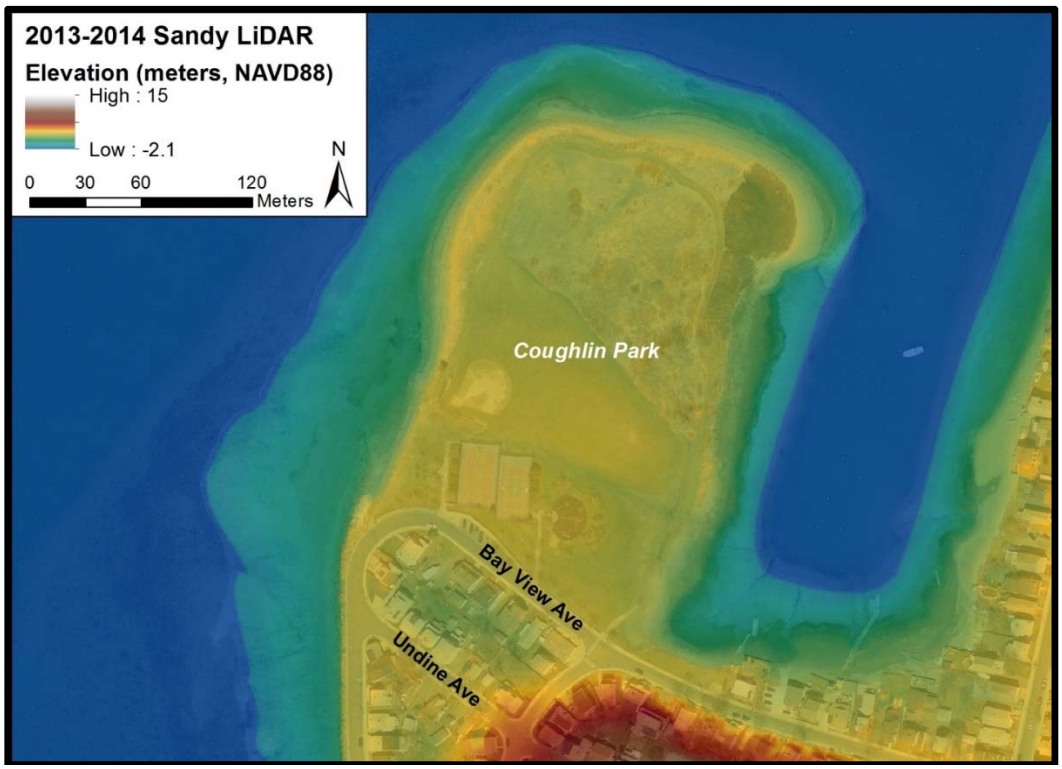

Figure 2. Coughlin Park Topographic Map

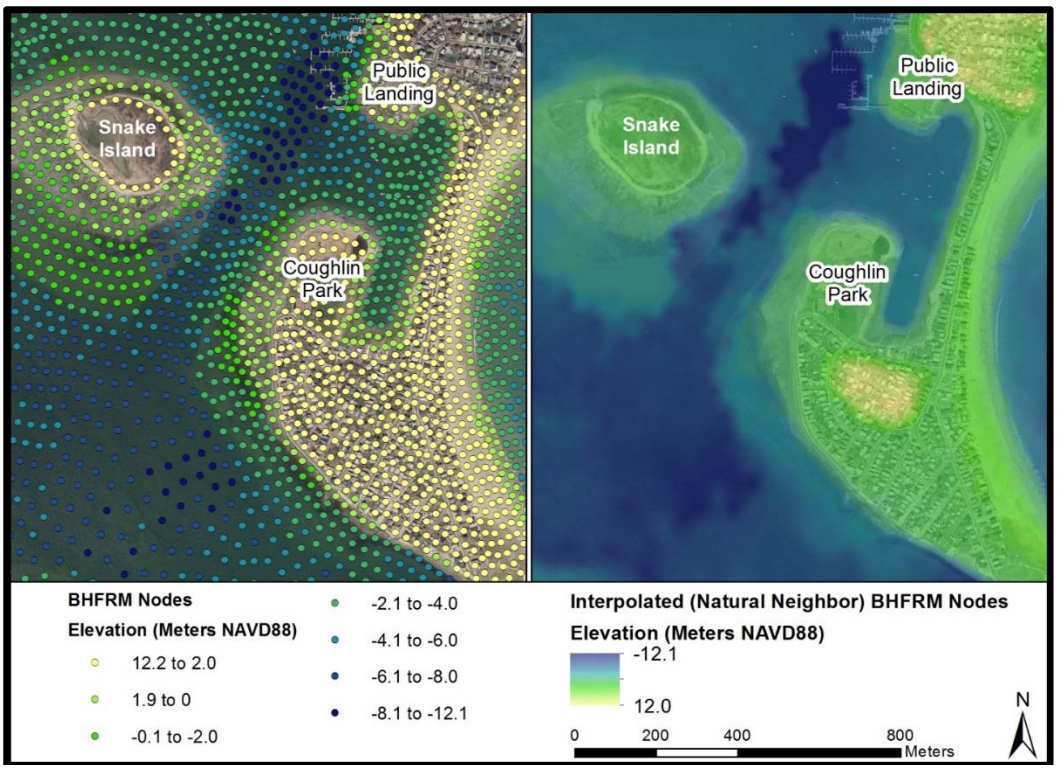

Figure 3. Bathymetry data from the BHFRM grid in the vicinity of Coughlin Park.

Similar to the LiDAR data displayed in Figure 2, this BHFRM data clearly shows the intertidal shelf to the west of Coughlin Park (light green area in Figure 3). However, because this dataset also includes bathymetric information, it is now possible to define the depths of the open water areas. The deepest areas in the vicinity of Coughlin Park are more than 10 meters deep and are found to the north of Coughlin Park near the Public Landing (dark blue nodes and area in Figure 3). The channel between Snake Island and Coughlin Park is also clearly visible in Figure 3.

2.2 WETLAND RESOURCES

The Winthrop Conservation Commission was contacted to determine if there were any locally available maps or data available on wetland resources such as eelgrass, shellfish, marsh and/or coverage. The Town of Winthrop does not have any data or maps that provide additional information on the wetland resources. The Massachusetts Department of Environmental Protection (MassDEP) wetland maps for Winthrop are interpreted from 1:12,000 scale stereo color-infrared (CIR) photography from 1990. This data is presented for the Coughlin Park area in Figure 4, which shows a Coastal Beach (light yellow) on the western and northern side of the park, Salt Marsh (green) on the eastern side of the park, as well as a patch of Salt Marsh on the west, and the entire park surrounded by Tidal Flats (tan) and Open Water (blue). It is important to note that this map of wetland areas is based off large-scale photography, which can not only misinterpret wetland types, but also cannot always accurately measure the boundaries between wetland types. Additionally, the photography the mapping is based on is from 1990. It is entirely

possible that the present day wetlands at the site are different, or have different boundaries. As such, this map should be used as first glance only, and should be augmented with an on-the-ground wetland survey to accurately map the boundaries of present day wetlands.

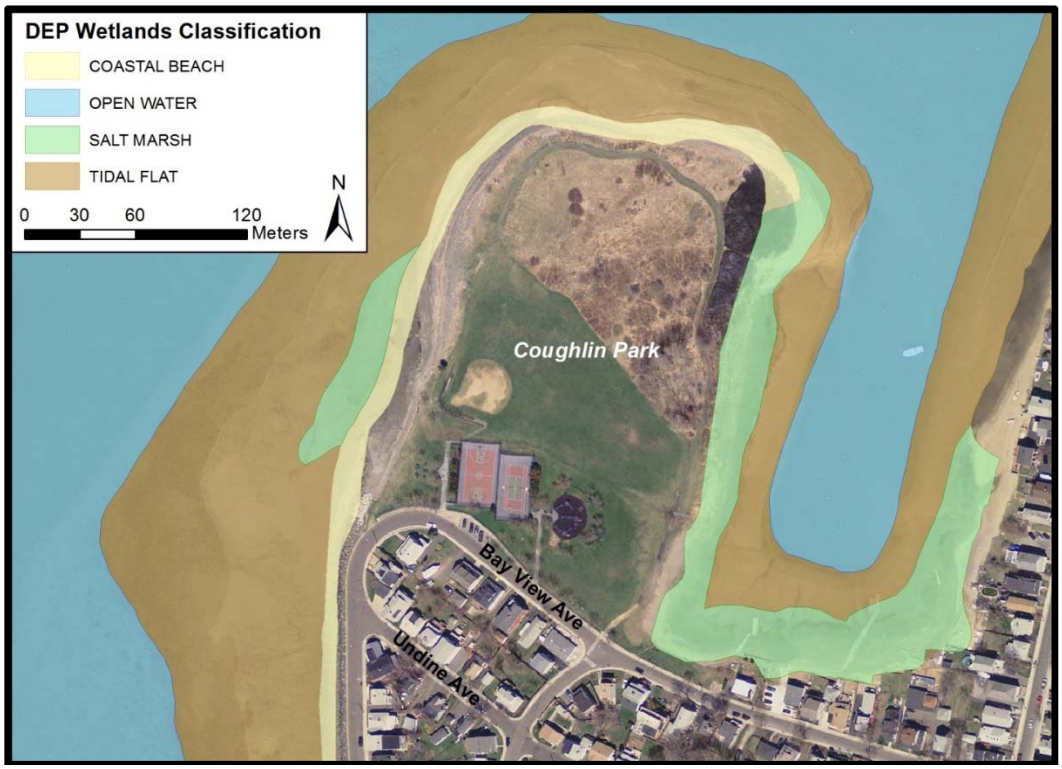

Figure 4. MassDEP mapped wetlands at Coughlin Park

2.3 SHELLFISH

Figure 5 presents the Shellfish Suitability Areas for the Coughlin Park area. Shellfish Suitability Areas are developed with the expertise of the Massachusetts Division of Marine Fisheries, local Shellfish Constables, and input from commercial fisherman. Shellfish Suitability Areas represent places there are believed to be a potential habitat area for shellfish; these areas indicate places where shellfish have been observed since the mid-1970's, but this does not necessarily mean that there are currently any shellfish present. As displayed in Figure 5, potential growth areas for soft-shell clams, symbolized in the light blue shading, extends around the shoreline of this park and out about 100 meters from shore. There are also a number of potential areas for blue mussel growth, symbolized by the blue cross-hatching, overlapping the soft-shell clam areas. These blue mussel suitability areas begin approximately 50 meters from the shoreline.

Figure 5. Coughlin Park Shellfish Suitability Areas

2.4 EELGRASS

The MassDEP Eelgrass Mapping Project has conducted multiple surveys between 1995 and 2013 to map Massachusetts Submerged Aquatic Vegetation (SAV) resources. This project mapped the entire Massachusetts Coast with the exception of the Elizabeth Islands (Gosnold) and Mount Hope Bay. After reviewing the available MassDEP Eelgrass Project Mapping data, there was no evidence that eelgrass has existed in the vicinity of Coughlin Park since 1995.

2.5 HISTORICAL SHORELINE CHANGE RATES

The shoreline change data presented in Figure 6 was developed by the Office of Coastal Zone Management (CZM). CZM's goal for this Shoreline Change Project was to develop and distribute scientific data that would support local land-use decisions. This project illustrates how the shoreline of Massachusetts has shifted between the mid-1800s and 2009. Each colored line represents the location of the high water line from a different year. As depicted in Figure 6, over time Coughlin Park seems to be expanding to the north. In the 1800s, the landmass that is currently Coughlin Park did not exist. However, through placement of dredge material in the middle of the 1900s, Coughlin Park was created. The transects, shown in black in Figure 5, are used to compute the rate of shoreline change over time. The labels at the end of each transect present the long-term shoreline change rate in feet per year, where a negative number indicates erosion and a positive number indicates accretion. The majority of the transects presented in this area

are undergoing accretion, with the exception of the transect near the southwest corner of Coughlin Park (indicated with a star on Figure 6), which is undergoing erosion. Unfortunately, CZM's shoreline change project did not include a transect through the area of bank at Coughlin Park that is currently experiencing erosion, so it is impossible to extract an exact long-term change rate from the data presented in Figure 6. However, Figure 6 clearly shows the 2008 shoreline (in purple) approximately 20 to 25 landward of the 1994 shoreline (red), indicating that between 1994 and 2009, the erosion rate along that shoreline was approximately -1.4 to -1.8 feet per year.

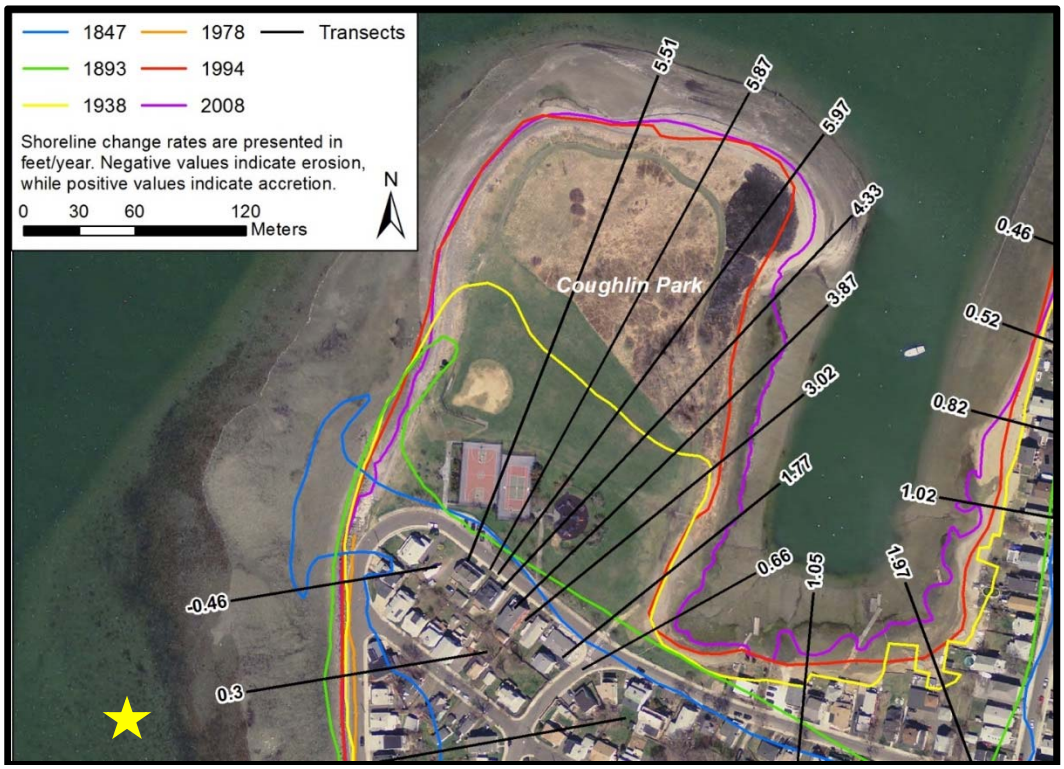

Figure 6. CZM Historical Shoreline Change Rates for Coughlin Park

2.6 FEMA FLOOD ZONES

The Federal Emergency Management Agency (FEMA) is responsible for coordinating responses to disasters that take place within the United States. As part of FEMA's National Flood Insurance Program (NFIP), FEMA develops Special Flood Hazard Area (SFHA) maps. An SFHA is defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the 100-year flood. The data presented in Figure 7 represents the effective flood zones from the recent FEMA Flood Insurance Study (FIS) update, dated March 16, 2016. The shaded red area represents a VE flood zone, meaning this is an area inundated by 1% annual chance flood and it is an area with a velocity hazard due to wave action. The area shaded in yellow represents an AE flood zone, which is an area inundated by 1% annual chance of flooding. Considering that the

eroding bank area at the southwest edge of Coughlin Park is in a VE flood zone, this means there is a higher potential for erosion in this area due to increased wave energy acting against the bank.

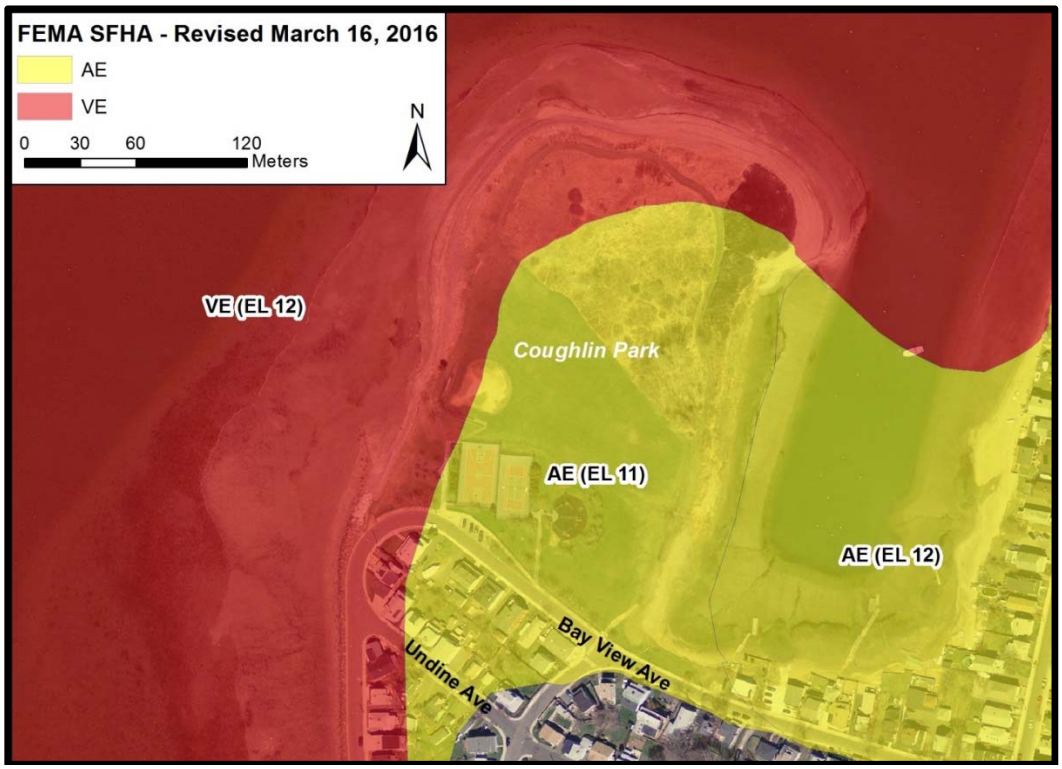

Figure 7. Coughlin Park FEMA Flood Zone Map

2.7 DATA GAPS

The above information summarizes existing data available for the site. While these data are useful background information for the site, some additional and updated information will be crucial to effectively evaluate the existing conditions and prepare suitable alternatives for improving the resiliency of Coughlin Park. A list of potential data gaps are outlined below:

1) Elevation data: Although LiDAR data exists for the site, because ultimately any designed solution for the eroding bank will require detailed current elevation data, an updated, on-the-ground elevation survey should be performed.
2) Wetland mapping: Although MassDEP's wetland maps present a general idea of the wetlands that may be present at and around the site, due to the method of development and timing of that data set, the present day wetlands should be remapped to accurately define the boundaries of these resources.
3) Shellfish survey: The only information about shellfish available for the site is the DMF Shellfish Suitability layer. However, this dataset does not identify where shellfish are found, but rather where they might be found. Therefore, in order to

confirm the types and densities of shellfish around the project area, a shellfish survey would need to be performed.

4) Shoreline and bank change analysis: CZM's shoreline change project provides a general overview of how shorelines have changed over time, however, due to the unique history of the site, the long-term shoreline change dataset presented by CZM shows significant accretion at the site. It is therefore crucial to update this analysis with the most recent aerial photography available to fully understand how the shoreline has been changing in recent years. Additionally, the CZM shoreline change database tracks only the position of the high water line. For this project, it will also be crucial to know the rate of change of the top of the bank. By performing an updated analysis, the location change of this landmark feature can be tracked as well.

3.0 SHORELINE CHANGE ANALYSIS

3.1 INTRODUCTION

A computer-based shoreline mapping methodology, within a Geographic Information System (GIS) framework, was used to compile and analyze changes in historical shoreline position in the vicinity of Coughlin Park in the Town of Winthrop, Massachusetts. The purpose of this task was to quantify changes in shoreline and coastal bank positions using the most accurate data sources and compilation procedures available, and to evaluate long-term rates of shoreline and bank change. Because this information is critical to most coastal zone management decisions, emphasis has been placed on data accuracy and clear presentation of results. The following section provides a detailed description of the methods and data sources used in this study.

3.2 DATA SOURCES

Shoreline change can be determined from accurately overlying historical vertical aerial photography with recent digital orthoimagery. The shoreline, as defined by the high water line, can then be extracted from each of the photos; the high water line is evidenced by a change in gray tone on black and white and color aerial photographs, and the position of this wetted boundary is identifiable on most air photos (Stafford and Langfelder, 1971).

Given the timeframe of interest, this study used only digital orthoimagery (DOQQs) to evaluate historical changes in shoreline (Table 1). There was shoreline data from the Office of Coastal Zone Management (CZM) starting as early as 1839, but only years presented in Table 1 were used in this analysis. We started with 1995 to avoid any misinterpretation of shoreline change rates due to the Boston Harbor dredging activities that artificially extended the land on which Coughlin Park is located. Since the primary focus of this project is to mitigate erosion along the western shoreline of Coughlin Park, the more recent data was more appropriate and would provide a more accurate representation of the conditions that exist at the park.

Shoreline position information was obtained from a series of large-scale digital aerial photographs for the following time periods: 1995, 2001, 2005, 2008, and 2013 (Table 1).

Photographs from these years were selected based on availability of orthoimagery from the MassGIS data base. An additional year of aerial imagery was also obtained from Google Earth for 2015. The time series of photographs selected for this study represents the highest quality and most reasonable spaced photographic data available.

Table 1. Summary of Shoreline Source Data Characteristics for Study Area

Date	Data Source	Comments
1995	MassGIS	1.6 ft/pixel resolution
2001	MassGIS	1.6 ft/pixel resolution
2005	MassGIS	1.6 ft/pixel resolution
2008	MassGIS	1 ft/pixel resolution
2013	MassGIS	1 ft/pixel resolution
2015	Google Earth	1 ft/pixel resolution

3.3 DATA COMPILATION AND ANALYSIS METHODS

The aerial photographs shown in Table 1 provide a synoptic view of the Coughlin Park coastline with a temporal coverage ranging from 2 to 6 years. Orthoimagery from 1995-2013 were retrieved with completed geo-referenced spatial information. The georeferencing tool available within ESRI's ArcMap was used to transform, resample and rectify the 2015 image retrieved from Google Earth against the 2013 MassGIS orthoimagery.

The next analysis step involved identification of a reference shoreline for each of the aerial- and orthophoto years. Air photo interpretation along a shoreline is an art based on science, supported by familiarity with the area and its processes, and includes a certain amount of error and interpretative subjectivity. Delineation of the reference shoreline is the most important and most subjective part of shoreline change analysis, particularly in areas where relief distortion can compound problems. The horizontal position of the high water shoreline as recognized on the beach and on photography was determined using a hierarchy of criteria dependent on morphologic features present on the subaerial beach. The primary criterion was a well-marked limit of uprush by waves associated with the most recent high tide. This generally was recognized as a beach scarp or debris line, marking the upper limit of the foreshore. If a scarp could not be identified, a debris line usually was identified. Reference shorelines for each of the photographs were captured through heads-up digitizing, and stored digitally in GIS.

A second reference line representing the top of bank at the subject property (the west side of Coughlin Park) was also captured through heads-up digitizing. The top of bank is easily visible on most aerial photographs. This additional data was useful in comparing with the high water shoreline to verify temporal changes in bank erosion. For coastal management purposes, the erosion rate of the top of bank also represents the factor most important in determining short-term risk to the park infrastructure.

Once the shoreline and bank data were compiled spatial and temporal changes in the data were quantified. This was accomplished by identifying a series of shore normal transects along the coastline where discrete measurements of shoreline and top of the coastal bank change could be made and could be computed to calculate rates of change. A total of 50 shore normal transects were established at 25 foot evenly-spaced intervals along the shoreline which covered approximately a quarter mile (Figure 8A). The area directly west of the tennis and basketball courts is the immediate area of concern and incorporates the area that was used for the shoreline change analysis (Transects 29-47). This area west of the tennis courts was of high concern because of the client's observations of rapid erosion of this area. For the rate of bank change analysis, a total of 19 shore normal transects were established at 25 foot evenly-spaced intervals at the area of concern (Figure 8B) which runs approximately 455 feet.

Figure 8. Area in of Coughlin Park, Town of Winthrop, MA selected for analysis of historical shoreline change (A). A small area pertinent to the study area was selected for analysis of historical shoreline change. (B). Evenly spaced transects represent points where bank change statistics were computed.

At each transect, distances of shoreline movement were calculated, and annual rates of shoreline change were determined using the various time intervals between shorelines. A matrix of long-term and incremental shoreline change rates was developed using all of the available shoreline data. The rates of shoreline change were calculated using two

different methods. The shoreline change rates were calculated using the end point method, which uses the distance over which the shoreline position changed (measured along the transect), divided by the number of years over which the change occurred. This method was used to compare successive shoreline dates. Shoreline change rates were also calculated using linear regression. The linear regression method was used to determine the rates of change for the entire data set (1995 to 2015) as well as two shorter time periods, 1995 to 2005, and 2005 to 2015. In this method, an average rate of change is based on a best-fit line to a series of points representing shoreline position over a period of time. The linear regression method is most applicable when looking at long-term averages in the rate of shoreline change, and is the method most often used for planning purposes and for management decisions.

3.4 SYNTHESIS OF CHANGES IN SHORELINES AND TOP OF BANK

To evaluate the trends in shoreline change at Coughlin Park, a variety of graphical representations have been developed. Three time periods were chosen to address specific questions concerning the shoreline change. The longer term shoreline change period (1995-2015) was chosen to show the rate of change over the entire period of data available. The longer term data provides the most reliable quantification of the shoreline response because it smoothes out the effects of large erosion and accretion events. The shorter time periods analyzed reflect a greater influence of either a large accretion or erosion event may have on the shoreline change rate and are instructive when determining the effect that large storm events have on the shoreline. To analyze whether recent rates of change have been different or similar to longer range trends, two additional periods were also selected (1995 to 2005, and 2005 to 2015). Figures 9, 10 and 11 show the historical shoreline positions from 1995 to 2015, 1995 to 2005, and 2005 to 2015. Graphs showing rates of shoreline change, calculated using both linear regression and end point methods, are displayed along with the shoreline position data in Figures 9, 10, and 11. Thus, trends of shoreline change at any given point along the coast can be visualized and quantified by comparing the three graphs shown in Figures 9, 10, and 11.

For the bank analysis, Figure 12 shows the historical bank positions from 1995 to 2015, and Figures 13 and 14 show the bank positions between two shorter time periods, 1995 to 2005 and 2005 to 2015. The graph showing rates of bank change, calculated using both linear regression and end point methods are displayed next to the bank position data in Figures 12, 13, and 14.

3.4.1 Shoreline Change Results

The data sets in Figures 9 - 11 shows the important longer term trends in shoreline change for this section of coast of Coughlin Park. The rates presented on the map itself are linear regression results in ft/yr, while both linear regression and end point results are shown on the graphs beside each map. Longer term accretion rates between 1995 and 2015 are highest (+0.8 ft/yr) at Transect 5 (approximately 620 feet north of the tennis courts), while erosion rates were highest (-1.7ft/yr) at Transects 32-34 (approximately 220 feet north-west of the tennis courts). Longer term trends at the area of concern

(Transects 29 through 47) show that the shoreline was eroding at an average of -1.2 ft/yr (-0.4 ft/yr using endpoint analysis).

To see whether recent shoreline change rates have followed longer term trends, shoreline change rates were also analyzed for 1995 to 2005 and 2005 to 2015. Between 1995 and 2005, the entire shoreline was accreting at an average of 0.1 ft/yr differing from the longer term average erosion rate of -0.3 ft/yr as noted in Table 2[1]. An interesting observation was seen between transects 13 to 26, where the shorter term trends (1995-2005) showed average accretion rates of 1.2 ft/yr which differs from long term erosion rates of -0.2 ft/yr for the same transects (13-26) (Figure 8A) indicating a transition from accretion to erosion. Erosion rates between 1995 and 2005 were highest (-1.8 ft/yr) at Transects 33 and 41. The observed highest erosion rates at Transect 41 was different from the longer term rates where highest erosion rates were located between Transects 32 and 34. Additionally, for the 1995 to 2005 time frame, the highest accretion rates (+1.5 ft/yr) were seen at Transect 16 (approximately 600 feet north of the tennis courts); again, this was a different area where highest accretion rates were observed in the longer term analysis (1995 to 2015). In fact, the long-term trends at Transect 16 showed erosion of -0.4 ft/yr.

[1] The erosion and accretion rates were averaged across all transects.

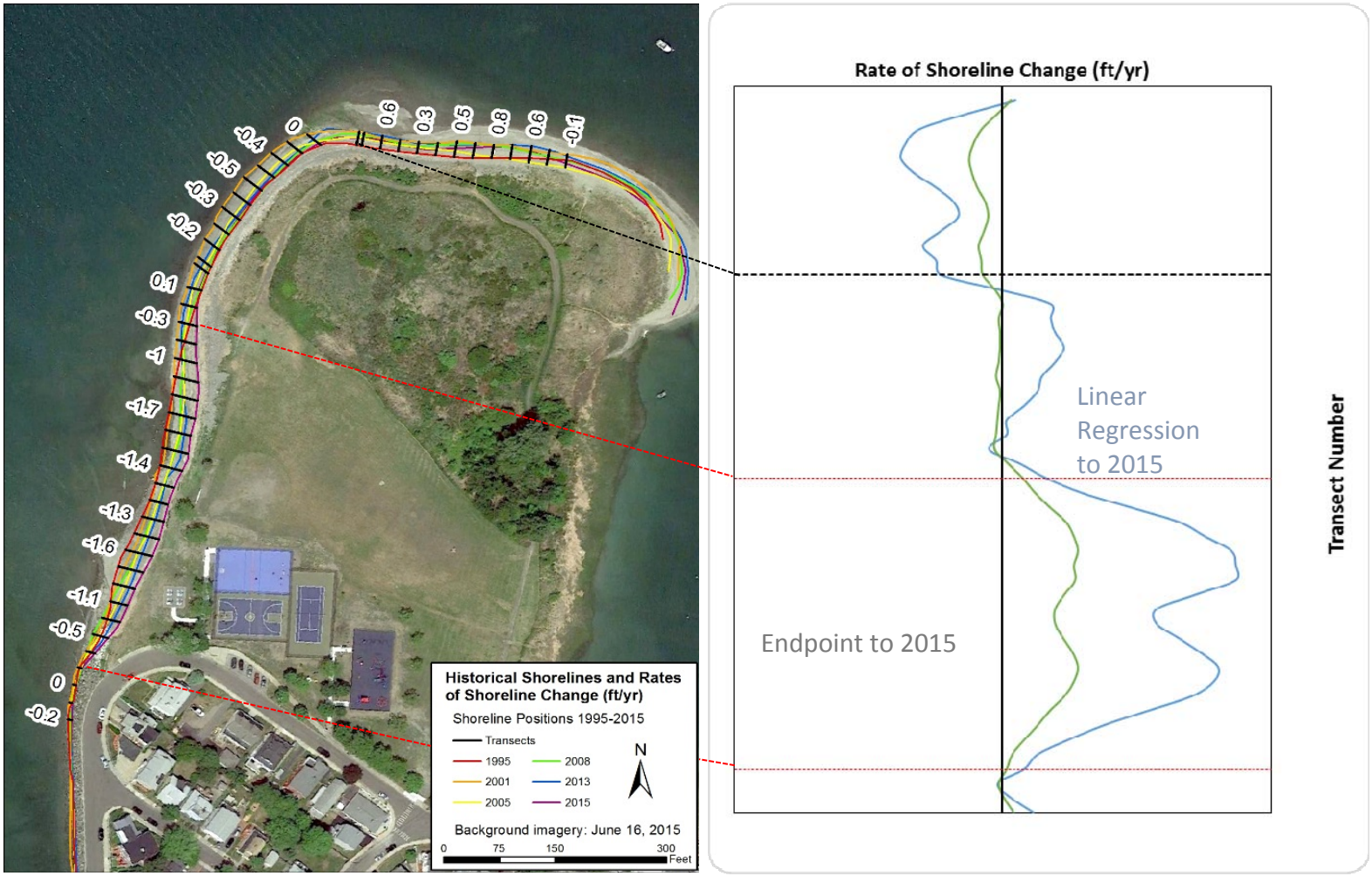

Figure 9. **Historical shoreline (high water line) positions from 1995 to 2015 and long-term rates of shoreline change computed using linear regression and end point methods. Red lines denote area of concern.**

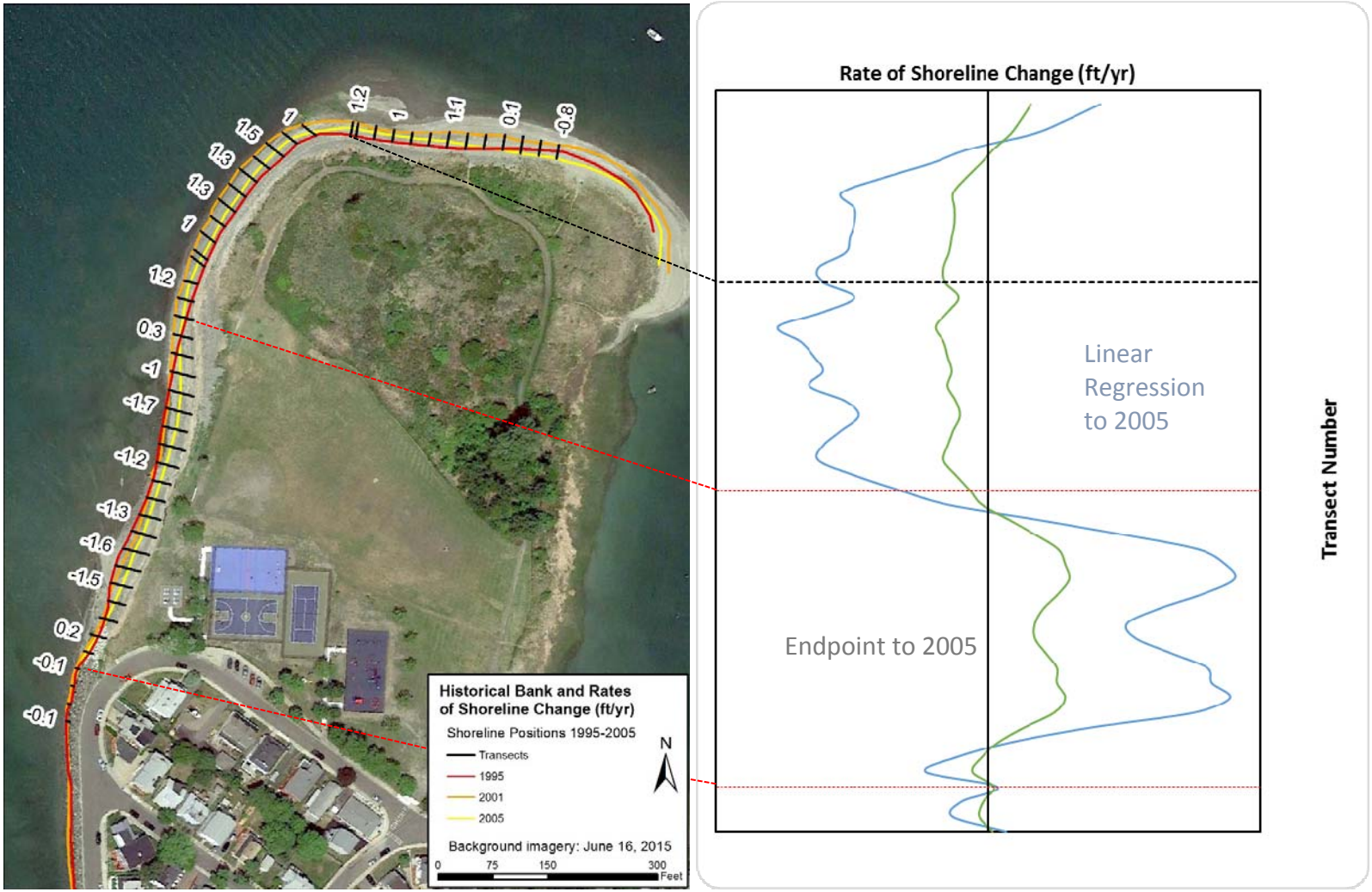

Figure 10. **Historical shoreline (high water line) positions from 1995 to 2005 and shorter term rates of shoreline change computed using linear regression and end point methods. Red lines denote the area of concern.**

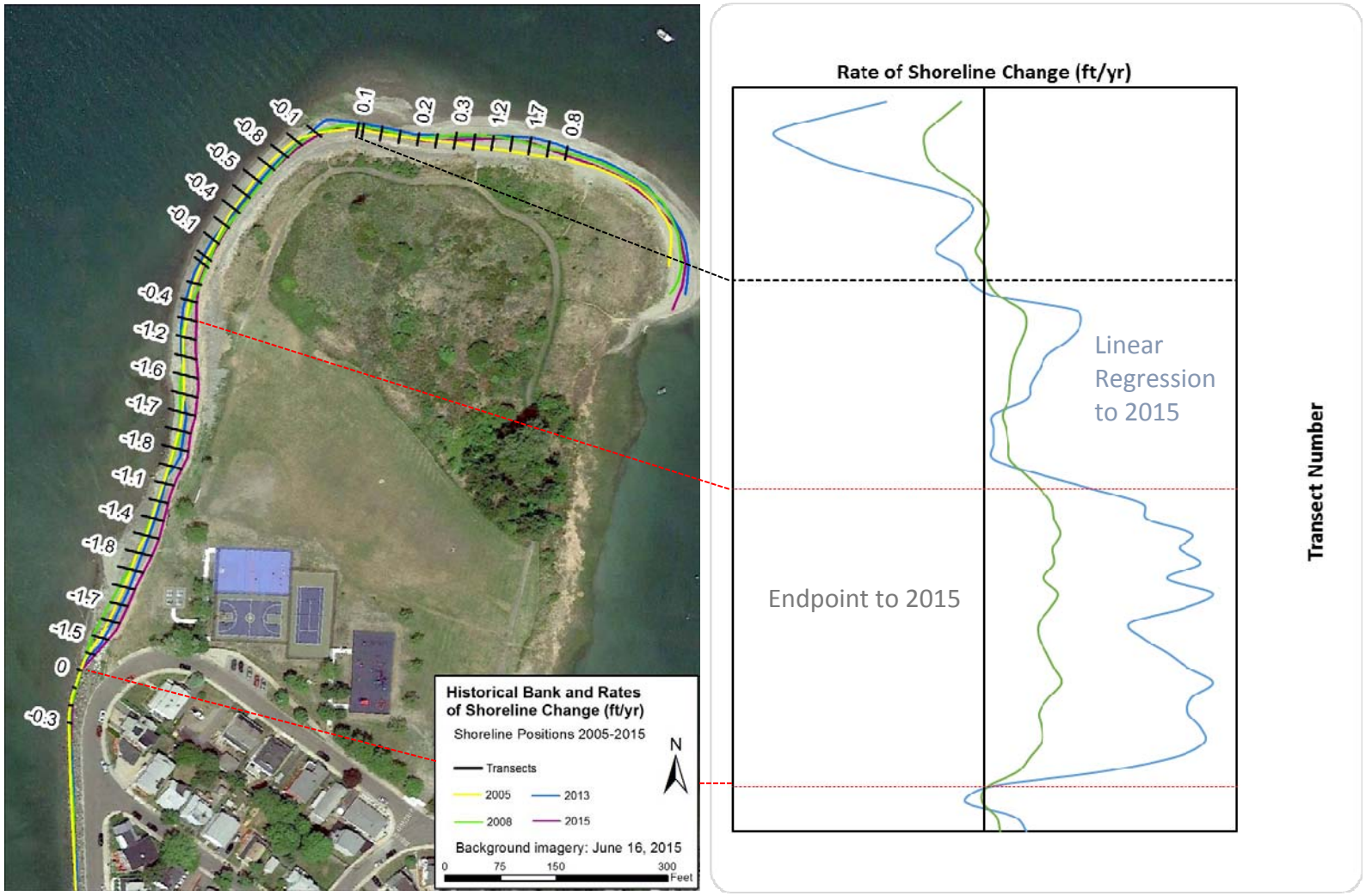

Figure 11. Historical shoreline (high water line) positions from 2005 to 2015 and shorter term rates of shoreline change computed using linear regression and end point methods. Red lines denote area of concern.

Table 2. Average shoreline accretion and erosion rates (ft/yr) (Linear Regression).

Transects	1995-2015	1995-2005	2005-2015
1 to 12	0.5	0.5	0.7
13 to 26	-0.2	1.2	-0.3
27-47	-1.2	-1.0	-1.4
All	-0.3	0.1	-0.5

Shorter and longer term erosion rates for the park shoreline (Transects 27-47) were -1.0 ft/yr and -1.2 ft/yr respectively (Table 2), indicating the erosion rates at the area of concern have been steadily increasing. On the contrary, the area in the northern section of the shoreline (Transects 1-12) showed the same accretion rate of 0.5 ft/yr for both the longer term and shorter term analysis (1995-2005), indicating this area was stable and accreting sand.

Evaluating the recent shoreline change rates from 2005 and 2015, however, showed a transition to a more erosional phase throughout almost the entire study area with the exception of the most northern section of the shoreline (Transects 1 to 12). Between 2005 and 2015, the area between Transects 1 and 12 showed an accretion rate of 0.7 ft/yr (Table 2). Compared to the longer term accretion rate of 0.5 ft/yr for Transects 1 to 12, this area, in recent years, has been accreting sand at a faster rate. In the recent shorter term analysis (2005-2015), the northwest section of the shoreline (Transects 13 to 26) was eroding at a rate of -0.3 ft/yr which differed from the accretion phase this area was enduring during the 1995 to 2005 time period, indicating a change from accretion to erosion from the early to recent time period. This erosion rate of -0.3ft/yr for the 2005-2015 time period was similar to the long-term trend of -0.2 ft/yr for the same area (Transects 13-26). The area of concern (Transects 27-47) had an erosion rate of -1.4 ft/yr for the time period between 2005 and 2015, which was greater than the longer term average of -1.2 ft/yr and the 1995-2005 time period average of -1.0 ft/yr, indicating that in recent years, erosion of the area of concern has increased.

End point rates, for both the shorter and longer term analyses, were generally lower in magnitude compared to the linear regression rates throughout the site (Figure 9, 10, and 11). This indicated that larger morphological changes were occurring between the endpoint year limits (1995 and 2015).

3.4.2 Long-Term Top of Bank Changes

As discussed earlier in this section, in addition to the shoreline change analysis, we also evaluated the rate of change of the top of the bank in the area of concern (west side of Coughlin Park). The locations of the top of bank as it was delineated from each of the data sources and rate of change data are pictured in Figure 12 -14. Like the shoreline change analysis, the rate of bank change was quantified along shore perpendicular transects. Figure 12 shows the linear regression rates of change of the top of the bank from 1995 to 2015 for the 19 transects at the area of concern. The longer term trend for

the entire length of the bank showed the area eroding at an average rate of -1.5 ft/yr (-0.5 ft/y using end point analysis).

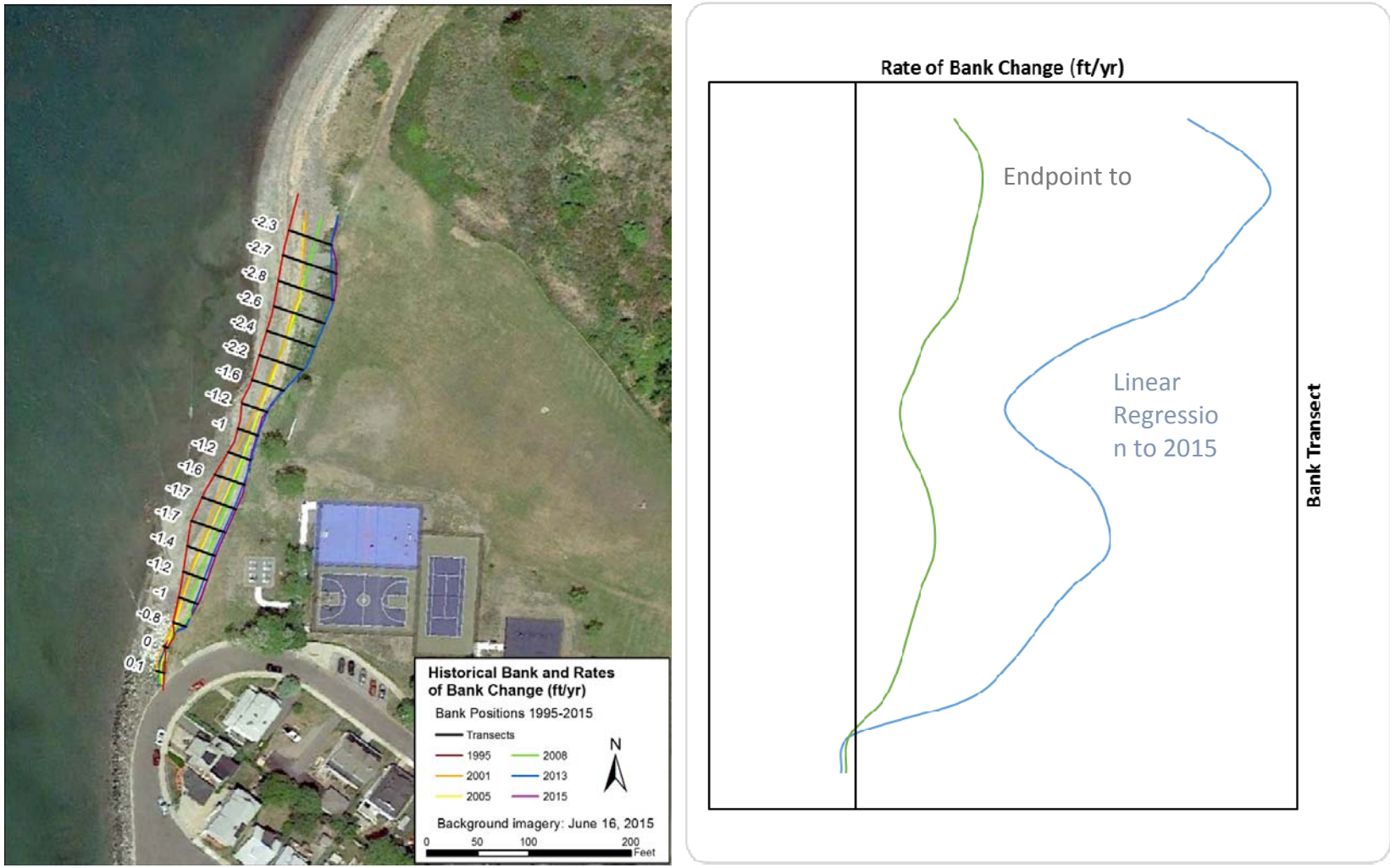

Figure 12. **Historical bank positions from 1995 to 2015 and long-term rates of bank change computed using linear regression and end point methods.**

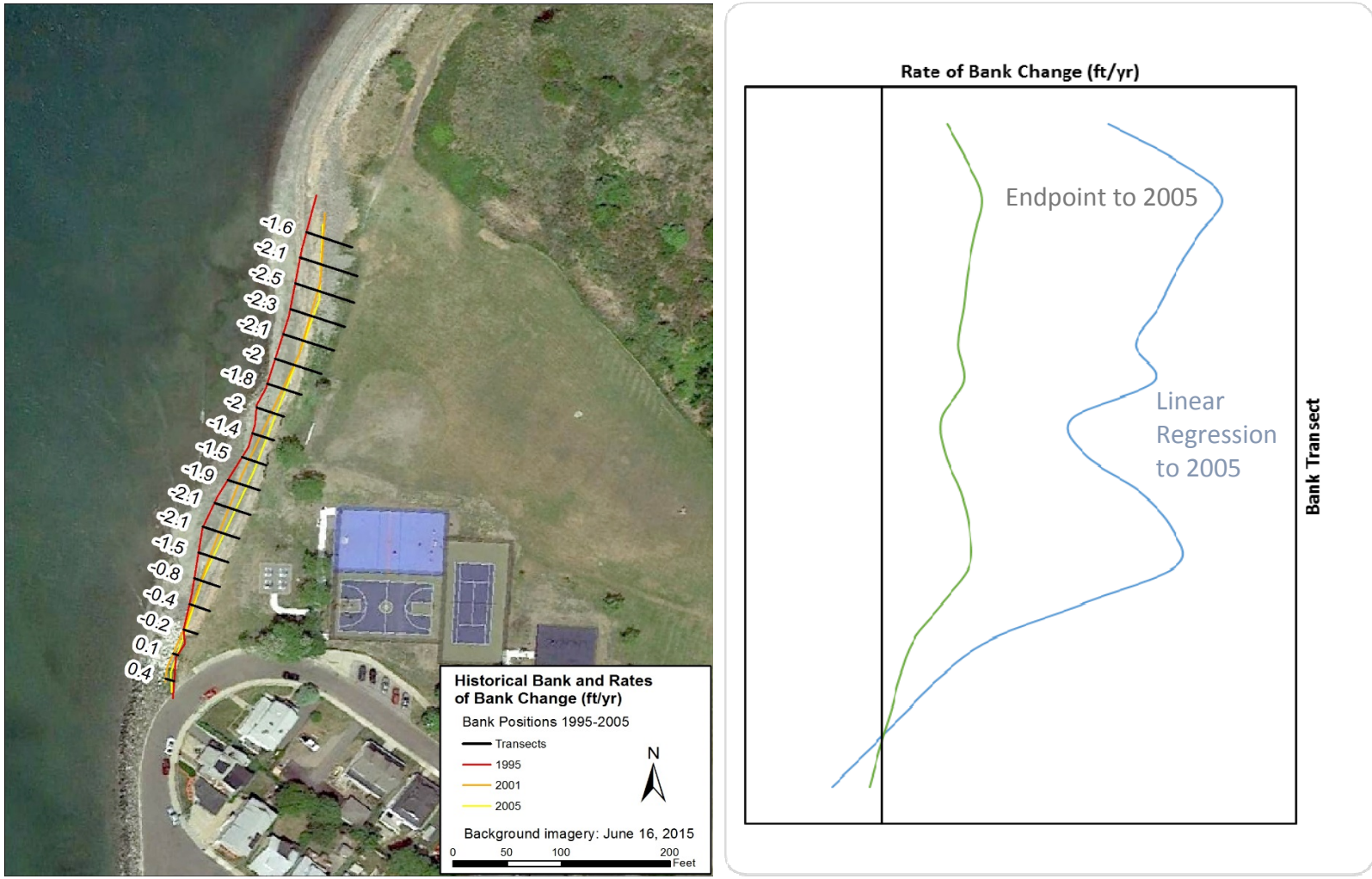

Figure 13. Historical bank positions from 1995 to 2005 and short-term rates of bank change computed using linear regression and end point methods.

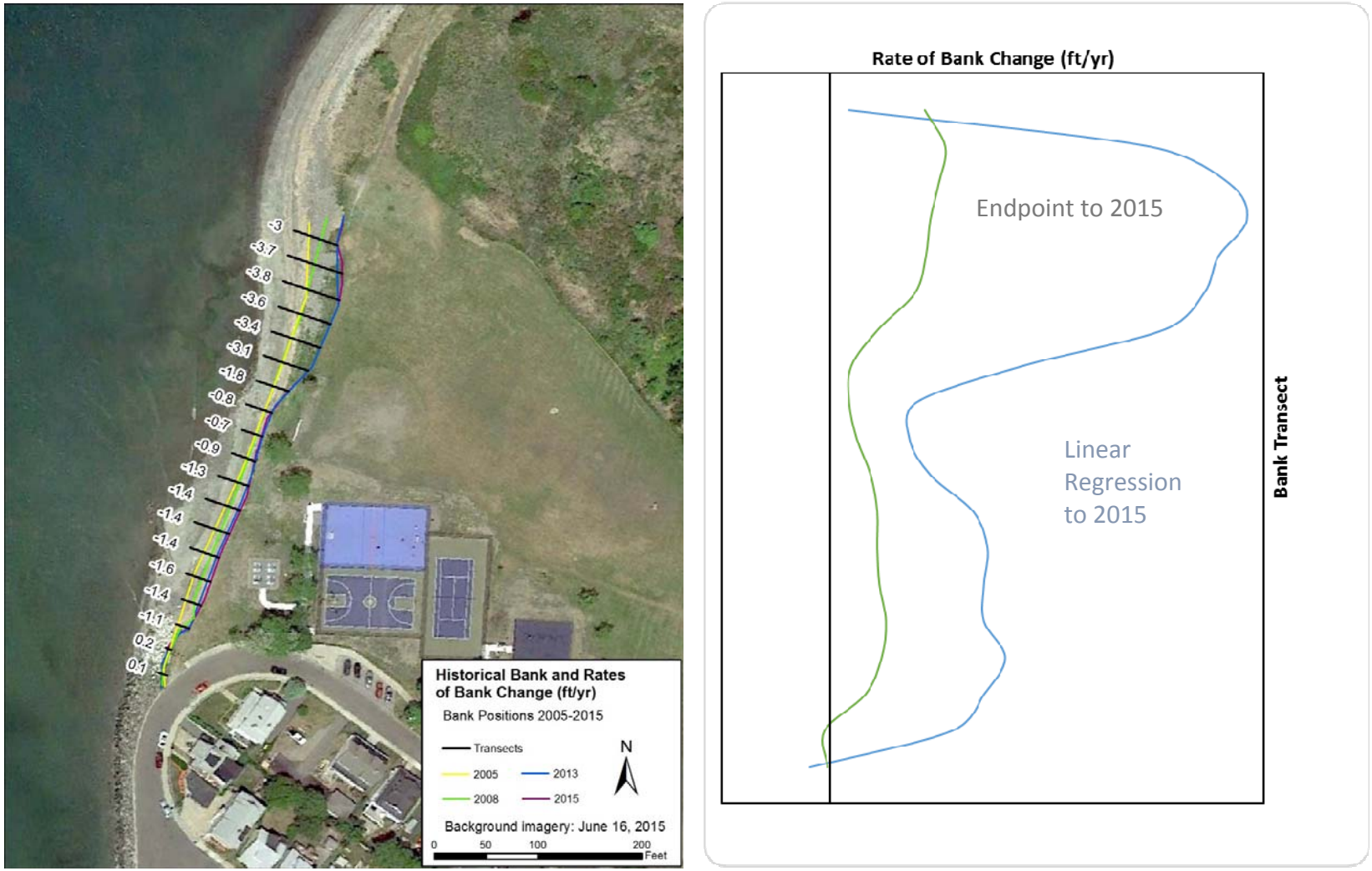

Figure 14. Historical bank positions from 2005 to 2015 and short-term rates of bank change computed using linear regression and end point methods.

Again, it was important to understand whether the shorter term trends followed the longer term trends of bank erosion. The locations of the top of bank as it was delineated from each of the data sources and rate of change data for the two shorter time periods (1995-2005 and 2005-2015) are shown in Figures 12 and 13. The average bank erosion rates for the time periods 1995-2005 and 2005-2015, measured -1.5 ft/yr and -1.8 ft/yr, (-0.4 ft/yr and -0.5 ft/yr using endpoint analysis) respectively. Similar, to the shoreline change analysis, the most recent time period (2005-2015) had a rate of bank change slightly higher than both the earlier time period (1995-2005) and longer term average, indicating an acceleration of bank erosion in recent years.

For both the shorter and longer term analyses, the end point rates were generally lower in magnitude compared to the linear regression. This indicates there were large changes occurring between the first and last years of the analysis time period (1995 and 2015).

3.4.3 Summary of Shoreline the Change Analysis

Given the rates of shoreline and bank change resulting from these analyses, general conclusions about the future state of the area of concern (Transects 27-47; Figure 8A) can be made. The recent 2015 shoreline is approximately 42 feet from the picnic table area, which is directly adjacent to the basketball courts. Assuming the given rates of shoreline erosion continue (-0.4 and -1.2 ft/yr; endpoint-linear regression), the picnic area to the left of the basketball courts could be negatively impacted sometime between 35 to 105 years from present day. Currently (2015), the top of the bank is 32 feet away from the picnic area. If bank erosion rates continue as they are (-0.5 and -1.5 ft/yr; endpoint-linear regression), it would be expected that in 21-64 years the picnic area could be negatively impacted. Based on the analysis, the top of bank is eroding faster than the shoreline and expected negative impacts will occur sooner compared to impacts to the shoreline.

However, it should be pointed out that the area between the top of the coastal bank and the tennis courts is the location of a scenic path that is heavily used by residents to walk their dogs, play with their children, and/or to just enjoy the outdoors. The path and the ability to use the path for recreational purposes is an extremely important use of the Park for the Town. Therefore, the current erosion of the top of the coastal bank will begin to adversely affect the path in the next 2 to 4 years.

4.0 ESTIMATES OF SEA LEVEL RISE AT COUGHLIN PARK

4.1 INTRODUCTION

This following paragraphs summarize the analysis of the waves incident at the shoreline and the expected increase in water levels based on calculated estimates of Sea Level Rise that are expected to occur from present to 2070.

Global mean sea level (MSL) has been rising since the end of the last ice age thousands of years ago. However, when a more recent time period is considered, sea-level rise (SLR) rates have accelerated, with unprecedented rates along the northeastern U.S. since the late 19th century (Kemp et al., 2011). Global sea-level rise is driven by a number of factors, including thermal expansion of ocean water and freshwater inputs from melting

glaciers and ice caps. As discussed in more detail below, global increases by 2100 may range from 0.2 m (0.7 ft) to 2.0 m (6.6 ft). At a local level, relative sea-level rise is a function of both global and regional changes. Local variations in sea-level rise result from factors such as vertical land movement (uplift or subsidence), changing gravitational attraction in some sections of the oceans due to ice masses, and changes in regional ocean circulation (Nicholls et al., 2014).

A consortium of government agencies has completed a National Climate Assessment (Parris et al., 2012, Figure 15) that provides guidance on the appropriate selection of Sea-Level Rise (SLR) scenarios. Under this guidance, four (4) projected rates of sea-level rise (highest, intermediate-high, intermediate-low, and low) are presented. Given the range of uncertainty in future global SLR, using multiple scenarios encourages experts and decision makers to consider a range of future conditions and to develop multiple response options. The highest scenario in Parris et al. (2012) surpasses the maximum of 1.2 m (3.9 ft) recently presented in the IPCC Fifth Assessment Report (AR5) WG1 material (shown in Figure 16). The highest scenario from Parris et al. (2012), combines thermal expansion estimates from IPCC SLR projections with the maximum possible glacier and ice sheet loss by the end of the century, and is therefore useful to consider "in situations where there is little tolerance for risk". A recent article by Bamber and Aspinall (2013) supports using a high sea-level rise projection based on the likely impact of glacier ice sheet melting. CZM also relies on the projections produced by Parris et al. (2012) in their sea-level rise guidance document (CZM 2013), as well as other state agencies, such as MassDOT and Massport. For these reasons, we recommend using the SLR scenarios presented by Parris et al. (2012) for the U.S. National Climate Assessment (Figure 15).

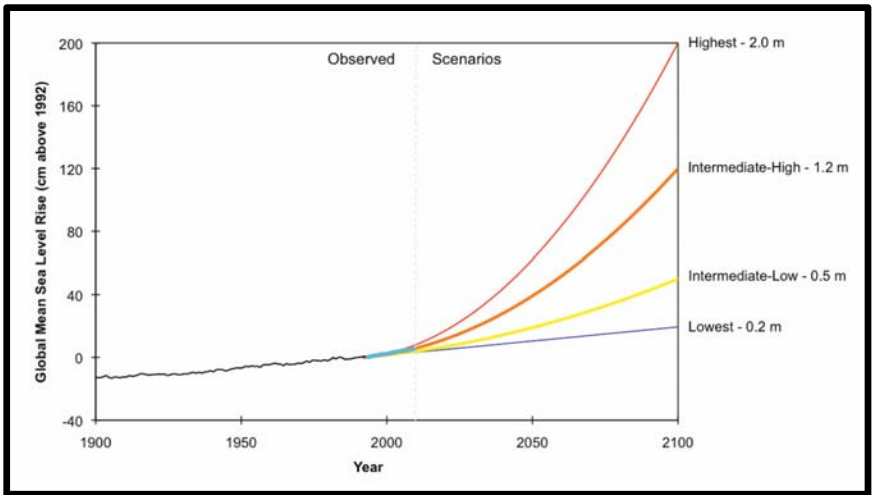

Figure 15. Projections of future sea-level rise recommended in Parris et al. (2012).

The low-SLR scenario presented in Parris et al. (2012) is based on observed historical SLR trends, which can vary from region to region. For example, the mean sea level trend

for Boston is 2.80 millimeters/year with a 95% confidence interval of +/- 0.17 mm/yr based on monthly mean sea level data from 1921 to 2013 (Figure 17). Boston would therefore experience a relative SLR of 10.36 cm by 2050 from 2013 if current rates continued in a linear fashion (equivalent to low-SLR estimates).

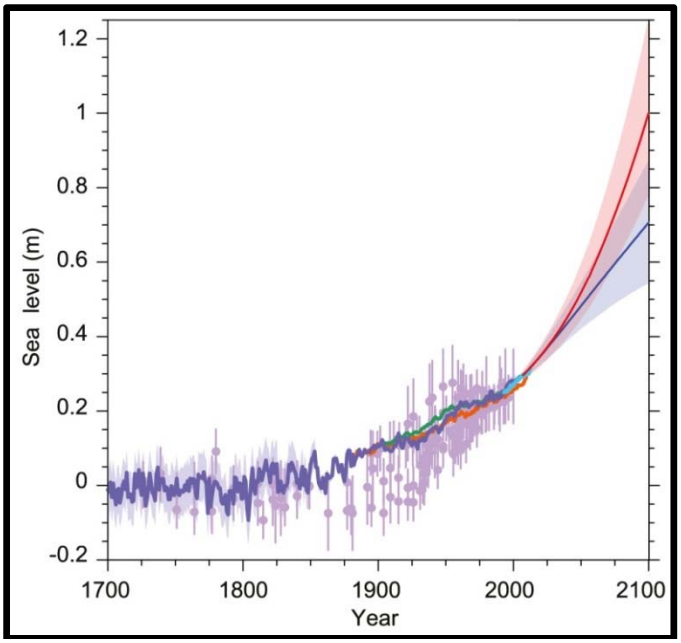

Figure 16. Sea-level rise projections in IPCC AR5 WG1. (Compilation of paleo sea level data, tide gauge data, and central estimates and likely ranges for projections of global-mean sea-level rise for PCP2.6 (blue) and RCP8.5 (red) scenarios, all relative to pre-industrial values.)

4.2 SEA LEVEL RISE AT COUGHLIN PARK

In this study, all four projected rates of sea-level rise are used as presented in the United States National Climate Assessment (Parris et al., 2012) to investigate the impacts of sea-level rise at Coughlin Park in Winthrop MA. This includes the low, intermediate-low, intermediate-high, and high sea-level rise projections. Model results are evaluated for specific out years for each sea-level rise scenario (2030 and 2070).

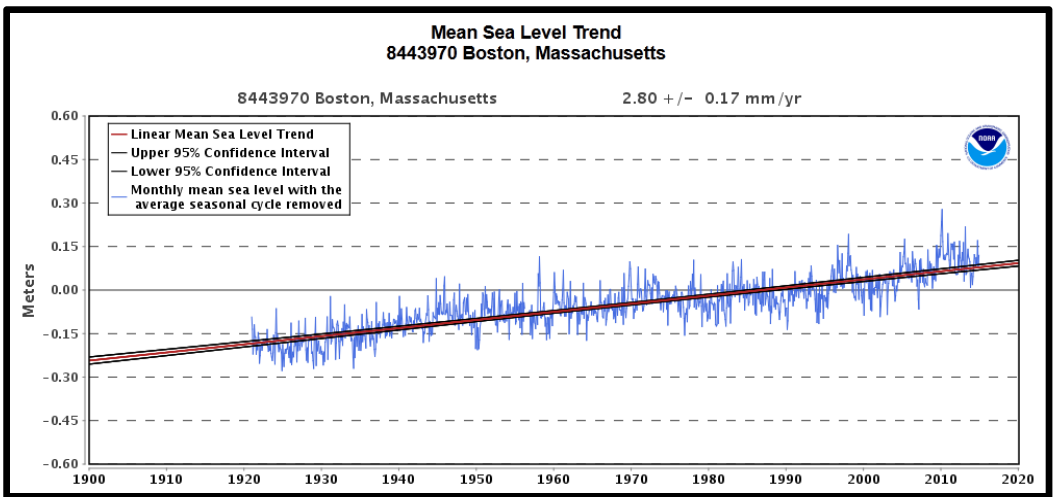

Figure 17. Comparison of mean sea-level rise trend at Boston, Massachusetts (NOAA, 2013).

The sea-level rise projections below (Table 3) indicate the total expected change in sea level between 2015 and the final out year (2030 or 2070). Local subsidence at Boston (0.84 mm/yr) is accounted for in various sea-level rise scenarios. Linearly projecting the historic rates listed above out into the future corresponds to the low sea-level rise scenario presented below. Intermediate-Low, Intermediate-High, and High sea-level rise scenarios correspond to the projected rates of sea-level rise developed by Parris et al. (2012) for the U.S. National Climate Assessment, and discussed earlier in this report.

Table 3. Sea Level Rise projections for Coughlin Park, Winthrop, MA.

Local Sea Level Rise (feet)		
	2030	**2070**
Low	0.14	0.51
Intermediate-Low	0.21	0.95
Intermediate-High	0.39	2.05
High	0.59	3.30

Examining community vulnerability cannot be limited to projecting estimated average sea level rise over a period of time. A complete vulnerability assessment also recognizes the dynamic physical processes and timing associated with storms, along with increasing risks of sea level rise and climate change. For example, typical flooding studies sometimes focus on the "bathtub" approach, which essentially forecasts future sea level rise, adds a static storm surge level, and then compares the forecast elevation to the surrounding land elevations and assumes every property lower than the forecast sea level will be flooded. This type of analysis, while useful at cursory planning levels, is not adequate for a vulnerability assessment. Storms do not produce uniform water levels, and are not the same everywhere due to the dynamic nature of storm events (e.g. winds, waves, etc.). As such, incorporating the dynamic influence of combined storm surge,

waves, winds, and tides into community vulnerability assessments is critical in order for Winthrop to be climate ready. Woods Hole Group has already developed a comprehensive probabilistic flood risk model for Boston (the Boston Harbor Flood Risk Model [BH-FRM]) that can accurately assess flooding risk under present day and future climate change conditions with work completed for MassDOT (Bosma et al., 2015). The results of this investigation are readily available for Winthrop. The results from the BH-FRM model have already been utilized (or are currently being utilized) to complete community-wide and agency vulnerability assessments for MassDOT, Massport, Hingham, Harvard, East Boston, UMass Boston, Cambridge, Quincy, Chelsea, Partners Health Care, Gloucester, and other Massachusetts communities. Table 4 presents the results from the BH-FRM model directly at the Winthrop Coughlin Park site.

Table 4. Results from the BH-FRM Investigation.

Return Period Water Levels (ft, NAVD88)			
	Present	**2030**	**2070**
5-yr	7.7	8.1	11.0
10-yr	8.1	9.0	11.6
20-yr	8.5	9.2	12.1
50-yr	9.0	9.7	12.5
100-yr	9.4	9.9	12.9

4.3 WAVE HEIGHTS AT COUGHLIN PARK SHORELINE

A potential green infrastructure shoreline erosion project on the Coughlin Park shoreline will be subjected to both increase in water levels due to seal level rise and local generated wind waves. It is important to know the height of the water level due to sea level rise that will occur because the increase in water level allows wind waves to reach farther up the shoreline and potentially increase the height of the incoming wave at the shoreline. The wave height at the shoreline may increase because the height of the breaking wave at the shoreline is dependent on the depth of water immediately offshore. If there are relatively large increases in water depth, then the height of the breaking wave at the shoreline may increase. Therefore, we calculated potential increases in wave height using the expected increases in water levels shown in Table 4.

In order to calculate wave heights at the shoreline, it is necessary to obtain wind records and perform an extremal analysis on the wind record to extract wind speeds with the desired return periods. In order to perform wind extremal analysis a data set with a long-record is needed. Ideally, the wind data set would be obtained at or very near the site of interest. For this analysis we selected a wind record from the Weather Underground (www.wunderground.com) at the Boston Logan International Airport station for the years 1945-2015. The annual maximum wind speed value was extracted and then fit into the generalized extreme value (GEV) distribution. Wind speeds for the desired return periods were calculated from the cumulative distribution curve. The results are shown in Table 5.

Utilizing the results shown in Table 5, the wave heights generated at the Coughlin Park shoreline can be calculated. Based on the above return period water levels and wind speed, a combination of 15 scenarios were set up to compute the return period wind-generated waves. They are the years of present, 2030, and 2070 with return period of 5, 10, 20, 50, and 100 years (Table 6).

Table 5. Wind Speeds for 5, 10, 20, 50, and 100-year return periods.

Return Period Wind Speed (mph)	
5-yr	50.9
10-yr	55.9
20-yr	60.9
50-yr	67.7
100-yr	73.1

The Automated Coastal Engineering System (ACES) from US Army Corps of Engineers was applied to calculate wind-generated waves. A set of radials with 10-degree interval were put at the shoreline of the project site to represent the fetch from all possible directions above the water. Different wind directions were compared to get the angle for the maximum wave height. The average depth is about 20 feet along the fetch. Along with other input parameters, such as water levels, wind speed, and fetch length, the wave information (wave height and period) were calculated for each scenario (Table 6).

Table 6. Wave heights and periods generated for the years 2030 and 2070.

Return Period Wind-generated Waves						
	Present		**2030**		**2070**	
	Hmo (ft)	**Tp (sec)**	**Hmo (ft)**	**Tp (sec)**	**Hmo (ft)**	**Tp (sec)**
5-yr	2.38	2.79	2.38	2.79	2.39	2.80
10-yr	2.69	2.94	2.69	2.95	2.70	2.95
20-yr	3.00	3.09	3.01	3.09	3.02	3.10
50-yr	3.45	3.29	3.46	3.29	3.47	3.30
100-yr	3.82	3.44	3.82	3.44	3.85	3.45

Table 6 shows that there is little increase in the expected wave heights in the year 2030. This is because the expected increase in sea level rise is relatively small when compared to the existing tidal range that occurs in Boston Harbor and at Coughlin Park.

5.0 IDENTIFICATION OF WETLAND RESOURCES

5.1 INTRODUCTION

On April 27, 2016, Woods Hole Group conducted a site assessment and wetland delineation of the coastal resource areas along the western side of Coughlin Park in Winthrop, MA for the Town of Winthrop. The work was performed at low tide to ensure all resource areas were visible and the assessment and delineation could be performed accurately. Figure 18 shows the location of Coughlin Park and identifies the area covered by the assessment and delineation.

Woods Hole Group delineated and flagged salt marsh, rocky intertidal, and coastal bank resource areas along the western shoreline of Coughlin Park. There is also a coastal beach seaward of the toe of the coastal bank. Each resource area will be described below in this memorandum. Additionally, a draft map of the locations of these resource areas is provided in Figure 19. This draft map is meant to help facilitate the discussion of the field work and the description of the resource areas and is not to be used for detailed planning or design purposes. The flags set out during the resource area delineation will be picked up and accurately mapped by the surveyor.

5.2 SALT MARSH DELINEATION

The Salt Marsh delineation was performed pursuant to 310 CMR 10.32 (2), to include all plants adapted to saline conditions. The dominant plant observed at the time of the delineation was salt marsh cord grass (*Spartina alterniflora*). Because it is so early in the season, the *S. alterniflora* was just beginning to sprout again for this growing season. However, the extent of the salt marsh could be discerned from the partially remaining *S. alterniflora* stems from last year. Flagging stations were marked as M-1 to M-40 (Figure 19).

The plant density throughout the salt marsh area was variable. At the far southern end (M-1 to M-6 and M-36 to M-40; Figure 19), the *S. alterniflora* stems are sparse, and were growing in a mix of sand and cobble (Figure 20). This sparse area was separated from a denser section of *S. alterniflora* that was growing in peat by a section of cobble devoid of salt marsh (Figure 21). This bare section is located in the drainage path of the large outfall pipe extending from the end of the stone revetment. This area is captured by wetland flags M-27 to M-32 (Figure 22). The denser, more robust area of *S. alterniflora* north of this drainage area also impounds a tidal pool area between the salt marsh and coastal beach (M-9 to M-15; Figure 22); the *S. alterniflora* grass in this area had more new shoot growth than in the sparse, more cobble dominated areas (Figure 22). The tidal pool contained a variety of snails, crabs, and macroalgae, as well as schools of small fish.

Figure 18. Locator Map. The left-hand figure shows Coughlin Park's location in the regional context, while the right-hand figure shows the area of Coughlin Park that was evaluated during the April 27, 2016 site visit and wetland delineation.

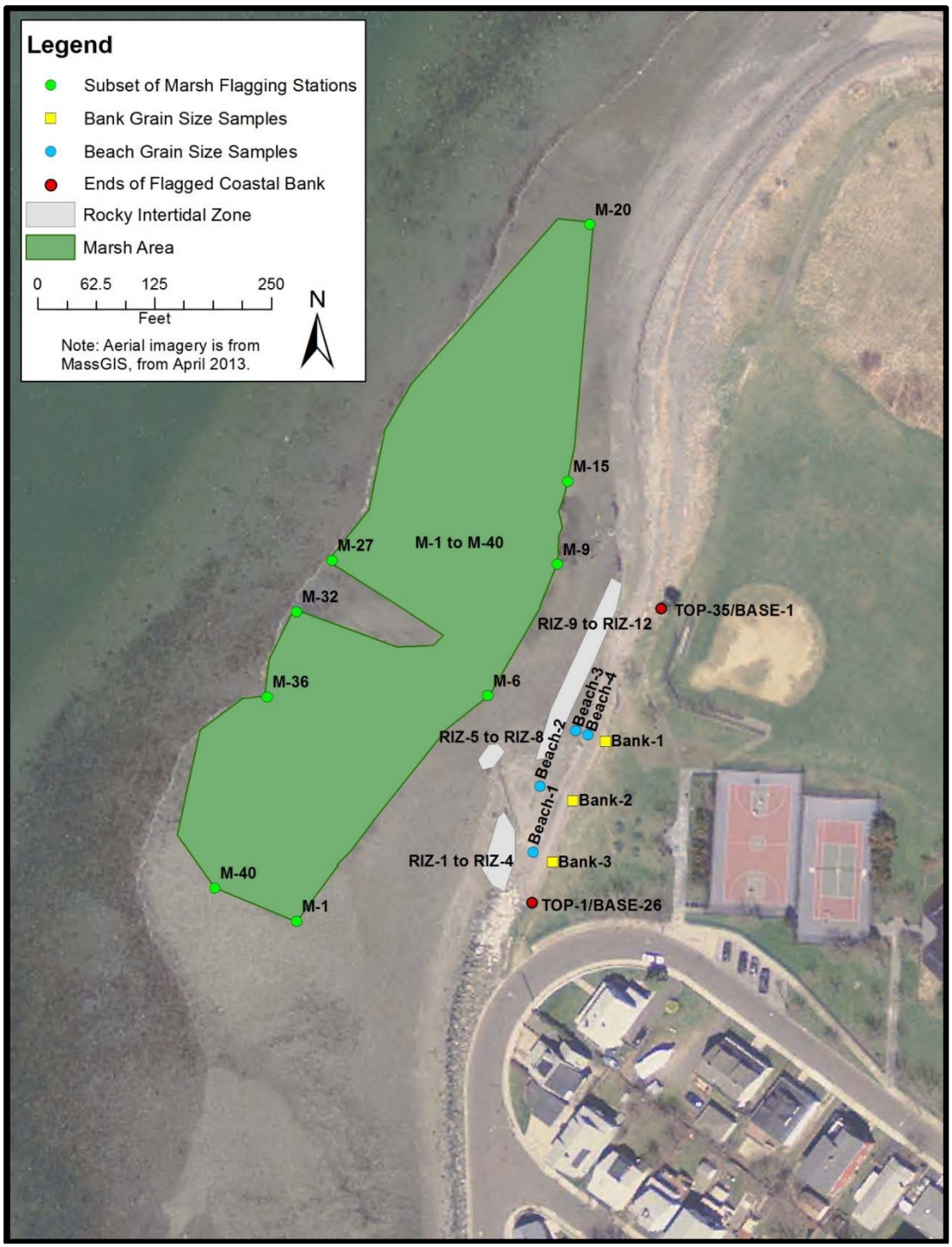

Figure 19. Estimated locations of mapped wetland resources at Coughlin Park.

Figure 20. Sparse *S. alterniflora* growing at the southern end of the salt marsh.

Figure 21. Sparse and dense areas of *S. alterniflora* separated by drainage from outfall pipe.

Figure 22. Dense section of *S. alterniflora* with new shoots in the salt marsh fronting an impounded tide pool.

5.3 COASTAL BANK DELINEATION

The Coastal Bank delineation was performed pursuant to 310 CMR 10.30 (2). The top of bank was marked with flagging stations labeled TOP-1 to TOP-35, in a south to north direction, while the toe of bank was marked with flagging stations labeled BASE-1 to BASE-26 in a north to south direction (Figure 23). TOP-1 and BASE-26 are located adjacent to the end of the large stone revetment along Grand View Avenue. Most of the top of the Coastal Bank is lawn, and is severely undercut and eroding (Figure 23). Much of this area is fronted by deteriorating hay bales that were placed for runoff control during the construction of the updated recreation facilities at the park last year. The ongoing erosion has exposed sidewalk framing material, filter fabric, and roots, among other objects, as the bank continues to recede. The exception to this, however, is the northern end of the Coastal Bank that was mapped (TOP-33 to TOP-35) less scarped and is an area of transition with a mix of grass and cobble berm (Figure 24).

Three samples were collected from the coastal bank to be analyzed for grain size; these were labeled BANK-1, BANK-2, and BANK-3. BANK-1 was collected from the southern end of the Coastal Bank, BANK-2 was collected from approximately the middle portion of the Coastal Bank, and BANK-3 was collected from the northern end of the Coastal Bank (Figure 19). Figure 25 shows an example of the different soil layers observed in the exposed face of the Coastal Bank.

Figure 23. Eroding coastal bank along southwestern edge of Coughlin Park.

Figure 24. Northern end of Coastal Bank (TOP-35) where it transitions to a cobble berm.

Figure 25. Grain size sample collected from BANK-3. Note the different soil layers, including a significant clay layer at the bottom.

5.4 ROCKY INTERTIDAL SHORE DELINEATION

The Rocky Intertidal Shore delineation was performed pursuant to 310 CMR 10.31 (2), to include all boulder strewn areas between the mean high water line and the mean low water line. Three Rocky Intertidal Shore areas were marked with flagging stations labeled RIZ-1 to RIZ-4, RIZ-5 to RIZ-8, and RIZ-9 to RIZ-12 (Figure 26). The most southern Rocky Intertidal Shore area (RIZ-1 to RIZ-4) was a cluster of large boulders located between the revetment and the outfall pipe. The next Rocky Intertidal Shore area (RIZ-5 to RIZ-8) was a cluster of large boulders around the end of the outfall pipe. The third, and largest of the Rocky Intertidal Shore areas, was comprised of small boulders (10 to 24 inches) located in a 15- to 20-foot wide band landward of the salt marsh (Figure 26).

Figure 26. Larger area of Rocky Intertidal Shore (RIZ-9 to RIZ-12) landward of the salt marsh.

5.5 COASTAL BEACH

The Coastal Beach at the site was not delineated explicitly, however, all areas seaward of the toe of the bank that are not delineated as Salt Marsh or Rock Intertidal Shore are in fact Coastal Beach pursuant to 310 CMR 10.27 (2). In addition to the grain size samples collected from the Coastal Bank as described above, four additional sediment samples were collected from the Coastal Beach for grain size analysis (BEACH-1 to BEACH-4; Figure 19). BEACH-1 was collected seaward of BANK-1, and was predominantly sand. BEACH-2 was collected seaward of BANK-2, and was predominantly gravel and cobble with some sand. Finally, BEACH-3 and BEACH-4 were collected seaward of BANK-3, which had a mix of finer sand and gravel; the sampling team opted to collect two sediment samples located at different elevations of the Coastal Beach to more appropriately capture the range in grain size observed at the site.

5.5.1 Grain Size Analysis

The results of the grain size analyses are attached in Appendix A. The results of the analyses show that the sediment have a cobble and gravel fraction that is intermixed with sand.

6.0 LIVING SHORELINE/GREEN INFRASTRUCTURE ALTERNATIVES ANALYSIS

The following provides an alternatives analysis that examines potential shoreline erosion mitigation alternatives that could be considered to mitigate the shoreline erosion at Coughlin Park in Winthrop, MA. At the completion of the alternatives analysis a regulatory interagency meeting was held to discuss the and solicit comments from agency partners concerning the preferred alternative.

6.1 INTRODUCTION & BACKGROUND

There are many options to choose from when considering mitigating shoreline erosion. However, not all options will be considered coastal resilient or green infrastructure. There are two broad categories of coastal resilient projects. They are soft engineering alternatives and hybrid alternatives. In general, soft engineering alternatives do not incorporate hard infrastructure into the design. The soft engineering alternatives would include alternatives such as bank grading, planting, and coir fiber rolls. A hybrid alternative incorporates a hard coastal engineering component into the engineering design. Examples of a hybrid alternatives would include an offshore sill with marsh planting and low profile revetment at the toe of the coastal bank. The hybrid alternatives are usually used where the incident coastal processes are too high to support a totally soft engineering alternative. The Massachusetts Office of Coastal Zone Management's Green Infrastructure for Coastal Resilience Grant Program specifically requires that green infrastructure designs be considered for implementation on this project. The grant solicitation specified the following broad categories that a potential shoreline mitigation design must fall into:

- Beach, berm, dune building, enhancement or restoration with compatible native sediment
- Bio-engineering with coir rolls, natural fiber blankets, and/or other biodegradable materials with planting/re-vegetation
- Natural oyster or mussel creation or restoration
- Fringe marsh creation or restoration

Therefore, after careful consideration and consultation with CZM the following potential design options have been selected for consideration. This memorandum will outline the advantages and disadvantages of each potential mitigation alternative and then each alternative will be evaluated with its viability in light of the storm surge and wave energy that will occur along the shoreline. The following green infrastructure design alternatives will be evaluated for the Coughlin park shoreline:

6.1.1 Beach, Berm, Dune Building, Enhancement or Restoration with Compatible Native Sediment

- Beach Nourishment
- Bank nourishment with cobble/gravel mix
- Cobble berm
- Re-grading and planting of the coastal bank
- Expand/enhance existing rocky intertidal area on the intertidal beach

6.1.2 Bio-Engineering with Coir Rolls, Natural Fiber Blankets, and/or Other Biodegradable Materials with Planting/Re-vegetation

- Fiber rolls at the toe of bank
- Fiber matting with planting on face of bank

6.1.3 Natural Oyster or Mussel Habitat Creation or Restoration

- Sill/offshore low crested reef composed of:
  - Oyster or mussel shell bags
  - Cobble or rock (rocky intertidal enhancement) to enhance substrate for mussels

6.1.4 Fringe Marsh Creation or Restoration

- Fringe marsh creation with fiber rolls

The following is a discussion of the advantages and disadvantages of each of the green infrastructure design alternatives listed above.

6.2 BEACH, BERM, DUNE BUILDING, ENHANCEMENT OR RESTORATION WITH COMPATIBLE NATIVE SEDIMENT

6.2.1 Beach Nourishment

Beach nourishment is a green infrastructure alternative that is widely accepted as a shoreline erosion mitigation alternative. Beach nourishment is a process in which sediment that is of similar grain size that has been lost by erosion and longshore drift are replaced on the beach. The sediment size is selected to be similar in size to the sediment that is naturally found on the beach. While many beach nourishment projects use sand as the primary sediment, the beach sediment along the Winthrop Beach are a mix of sand and cobble with cobble making up the majority of the sediment. Sediment from an outside source of the similar grain size as the natural beach is placed on the eroded beach to replace the lost sediment. Often a dune building component is incorporated into the beach nourishment project to increase the volume of sand placed on the beach, to raise the elevation of the back beach. One of the advantages of a beach nourishment project is

that the project adds sediment to the littoral system replacing sediment that has been lost due to coastal erosion and longshore transport.

Additionally, the restored beach and/or dune acts as a wave buffer between the nearshore and the coastal bank dissipating wave energy before it reaches the coastal bank or the upland. When coupled with a dune building project it increases the elevation of the back beach and helps improve the beaches ability to provide storm damage protection to the adjoining upland. A beach nourishment is flexible and the design can easily be readjusted or modified during the re-nourishment phase to compensate for sea level rise. Additionally, a beach nourishment project expands the usable beach area and in general has a lower impact on the environment than hard coastal engineering structures. The newly nourished beach and dune creates or re-establishes habitat for birds and other animals that inhabit the beach and/or dune ecosystem.

The disadvantages of a beach and dune project is that it requires periodic re-nourishment. This can often be expensive and can potentially disrupt the offshore if an offshore borrow site is used as a source of sand. The height of protection from storm surge is limited to the height of the beach or the dune system. Additionally, the addition of large quantities of sediment may adversely impact intertidal and/or nearshore resources such as saltmarsh and subaquatic vegetation such as eelgrass.

6.2.2 Bank Bourishment with Cobble/Gravel

This design alternative is similar to beach nourishment in that it adds sediment to the system and is often combined with other design alternatives to provide protection to the coastal bank (Figure 27). The eroding face of the coastal bank is covered with suitable sediment and the face of the bank is built seaward. The new face of the coastal bank can be vegetated depending on the sediment size that is selected for the bank grading materials. This reduces the vertical slope of the erosion scarp and allows waves to break on a gentler slope. The sediment selected should closely resemble the native sediments of the beach and nearshore regions. The sediment eroded from the nourished bank will provide sediment to the beach and intertidal area. Selecting sediment grain size should be guided by the sediments that are in the nearshore area and on the beach.

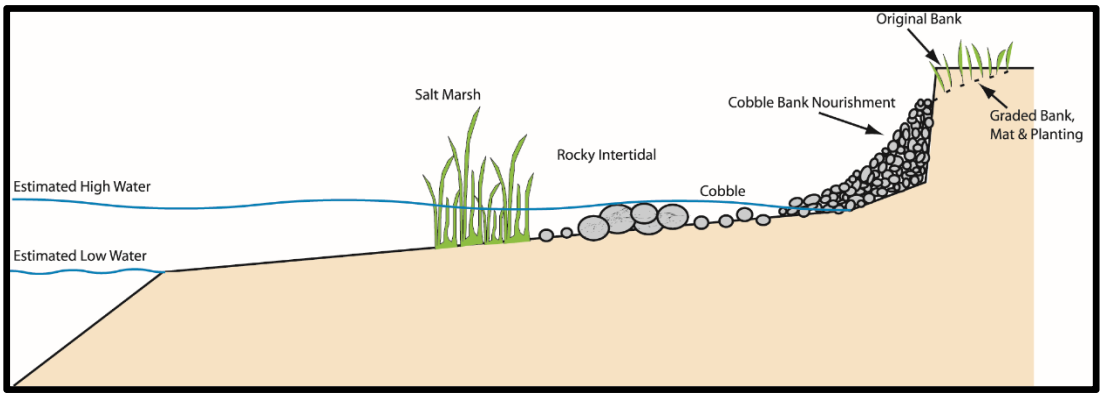

Figure 27. Bank nourishment with cobble and gravel

The advantage of this design alternative is that the top of the bank does not need to be cut back landward to reduce the vertical or near vertical slope of the eroding coastal bank. Additionally, the cobbles on the newly shaped slope will attenuate wave and help prevent the waves from breaking directly on the bank and reflecting energy back onto the beach. This alternative will also provide a source of sediment to the adjacent beach.

The disadvantage of this alternative is that it will require maintenance and periodic replacement of sediment of the appropriate size. Additionally, as with any soft engineering solution it will be subject to damage from a severe storm and will most likely need to be repaired after a severe event. The height of protection from storm surge is limited to the height of the coastal bank which may result in overtopping depending on the severity of the storm and the height of the storm surge.

6.2.3 Cobble Berm

A cobble berm is similar to a cobble dune. The primary difference is where they are located. They both are a mound of sediment (cobble in this alternative). A dune in usually constructed on the beach face and not necessarily at the toe of the coastal bank. A berm is normally constructed at the toe of the coastal bank and is specifically designed to reinforce and protect the toe of the coastal bank. The size of the cobble varies depending on the size of the cobbles and gravel on the beach. This alternative is often used in conjunction with another alternative designed to stabilize the coastal bank face.

The advantage of this alternative is that it utilizes cobbles that are near or slightly larger than occur on the beach. The cobble berm is slightly mobile and will move around on the upper beach area during large storms. Normal beach geomorphic formations such as beach ridges often form in the cobble as the result of waves breaking on the cobble berm. However, the loose nature of cobble berm will absorb wave energy and reduce wave runup.

The disadvantage of this alterative is that it will require periodic maintenance and re-nourishment. Additionally, as with any soft engineering solution it will be subject to damage from a severe storm and will most likely need to be repaired after a severe event. The repair may be as simple as using a front end-loader to reposition the berm or it may require the placing of additional cobble on the berm to rebuild its height and width. Additionally, the height of protection from storm surge is limited to the height of the coastal bank which may result in overtopping depending on the severity of the storm and the height of the storm surge.

6.2.4 Re-grading and Planting of the Coastal Bank

This design alternative reshapes a vertical or near vertical coastal bank and plants native vegetation on the face of the coastal bank. The bank top of the bank is cut back (landward) to reduce the angle of the bank to more closely approach an angle of repose. Once the gentler slope is achieved, the face of the coastal bank is planted using native vegetation. Ideally the plants selected will have a deep root system with a relative small over-story. This design alternative is generally most suitable for low wave energy environments because there is no protection provided to the toe of the coastal bank.

The advantage of this design alternative is that it is generally less intrusive and will have less impact on natural community and ecosystem services. The affects from project construction and project implementation will normally be less than other potential design alternatives. If the project includes planting of the back beach area then, the project will help maintain the connectivity between the aquatic and terrestrial habitats.

The disadvantages of planting alone is that it does not provide protection from storm surge or increase the beaches and nearshore height and/or width to reduce the impacts of storm surge. This design alternative will have applications in relatively few locations because of its potential vulnerability to storms. Additionally, growing plants on the beach and on the face of the coastal bank is difficult because of poor soil conditions, limited nutrients, and limited availability of water when the juvenile plants are most vulnerable.

6.2.5 Expand/Enhance Existing Rocky Intertidal Area on the Intertidal Beach

This alternative will place additional boulders on the intertidal beach to enhance and expand the existing rocky intertidal area. The boulders will range in size from 10 – 15 inches in diameter to 1-2 feet in diameter.

The advantage of this alternative is that it will enhance the rocky intertidal habitat presently on the inter-tidal beach. If placed carefully the rocks can also break waves during small storm events and reduce runup. Additionally, it is unlikely that the newly placed rocks will be moved by normal storms if the rocks placed on the intertidal beach match the larger sizes of rocks that make up the rocky intertidal resource area.

The disadvantage of this design alternative is that during large storms with high storm surge the enhanced rocky intertidal area will not provide protection to the coastal bank toe. The waves and storm surge will simply overtop and inundate the rocky intertidal area.

6.3 BIO-ENGINEERING WITH COIR ROLLS, NATURAL FIBER BLANKETS, AND/OR OTHER BIODEGRADABLE MATERIALS WITH PLANTING/RE-VEGETATION ALTERNATIVES

6.3.1 Fiber Rolls at the Toe of Bank

This alternative anchors fiber rolls at the toe of the coastal bank. A fiber roll is a densely packed tube of coconut fiber (coir) that can be wrapped in either biodegradable and /or non-biodegradable cordage that holds the coir filling in the tube (Figure 28). The fiber rolls are usually covered with bank compatible sediment to reduce degradation from ultraviolet light.

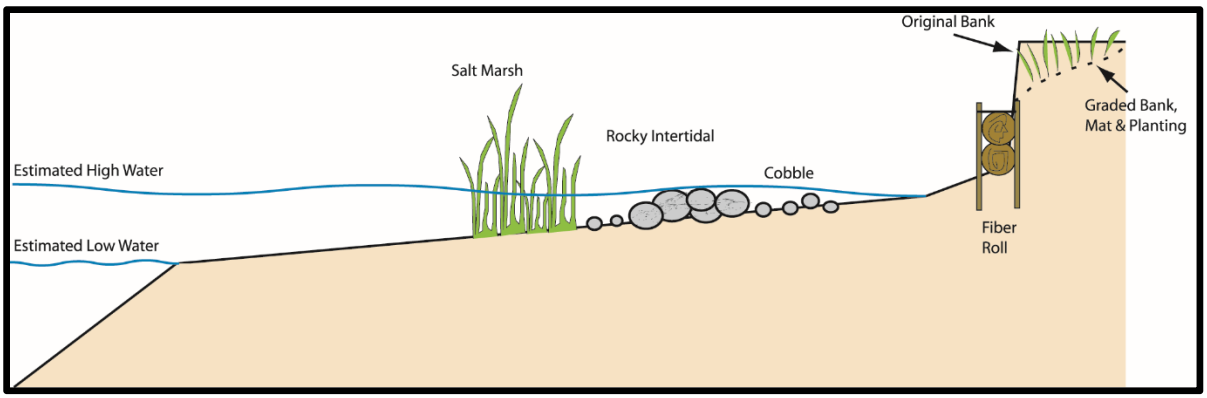

Figure 28. Fiber rolls installed at the base of the coastal bank.

This design alternative is often used in conjunction with other alternatives such as bank grading and/or planting to increase the stability of the coastal bank.

The advantage of this alternative is that the fiber roll acts as a buffer between the toe of the coastal bank and the incident wave and/or storm surge. Protecting the toe of the coastal bank allows the face of the bank to stabilize and results in an environment that is conducive to grow vegetation which helps stabilize the coastal bank.

The disadvantage of this alternative is that the fiber rolls are biodegradable and have a design life that is dependent on the incident wave energy, the length of exposure to ultraviolet rays. The average design life is between 5 – 8 years. The fiber rolls are difficult to stake in place if the wave environment is too great. Usually the fiber rolls can be used to protect the toe of the coastal bank if the wave height impacting the bank is less than 3 ft. Ideally, the fiber rolls are placed high on the beach where they are exposed to runup only. The average design life for the fiber rolls is between 5 to 8 years. During this period, it will be necessary to keep the fiber rolls covered with sediment. Therefore, if a storm uncovers the fiber rolls it will be necessary to replace the sediment covering the fiber rolls. Additionally, if the fiber rolls become displaced during a storm it will be necessary to reset and/or re-stake them at the base of the coastal bank.

6.3.2 Fiber Matting with Planting on Face of Bank

This design alternative places biodegradable mat on the face of the coastal bank. Once the mat is staked and/or secured to the bank face, the bank face is planted with vegetation. The mat provides a stable surface so that vegetation can root into the bank face. Ideally the plants selected with have a large root area and a relatively small overstory because the plant roots stabilize the coastal bank face. The alternative is often used in conjunction with other alternatives.

The advantages of this alternative is that it composed entirely of biodegradable materials and uses indigenous plants to stabilize the bank.

The disadvantage of this alternative is that it depends on plantings to stabilize the coastal bank. Additionally, if the toe of the coastal bank is not stabilized then the erosion scarp will undermine the root system and destabilize the bank face.

6.4 NATURAL OYSTER OR MUSSEL HABITAT CREATION OR RESTORATION

6.4.1 Sill/Offshore Low Crested Reef Composed of Oyster or Mussel Shell Bags

This alternative constructs a sill on the intertidal beach by placing bagged oyster or mussel shells in the intertidal area. The exposed shell in the bags create a favorable location for new shellfish spat to set. Normally the shellfish are packaged into a jute or coir bags and anchored on the intertidal beach. The bags containing the shell act as a substrate for the shell spat to set and if located in a low energy environment can break small waves or boat wakes before they reach the toe of the coastal bank.

The advantage of this alternative is that it enhances the nearshore area by increasing biodiversity. Additionally, the mussels or oysters filter water that will remove particulates, pollutants, and nitrogen from the water. Additionally, the mussels or oysters can be harvested as a cash crop. If the waters are clean then the shellfish can be harvested and directly marketed. If the shellfish are in close waters, they can be relayed to a clean location and allowed to clean themselves. Once they have been cleaned, they can be harvested.

The disadvantage of this alternative is that the oyster/mussel shells need to be anchored to the bottom so that there is a stable substrate for the shellfish. If the bags are not anchored securely to the bottom small waves and boat wakes will move the bags and the coir or jute netting will tear releasing the shellfish from the bag. When this happens the shellfish will be distributed across the nearshore area resulting in a degradation of the shellfish habitat and the loss of the potential for the sill to reduce wave energy.

6.4.2 Sill/Offshore Low Crested Reef with Cobble or Rock (Rocky Intertidal Enhancement) to Enhance Substrate for Mussels

The alternative would increase the rocky intertidal area by adding additional boulders in an unorganized /randomly placed manner. The intent would be not to create a structure but to increase the rocky intertidal area. This would create additional intertidal area for the shellfish spat to set.

The advantage of this alternative is that it improves the nearshore bio-diversity of the habitat by providing additional area for shellfish and other marine flora and fauna to live. Additionally, the increased rocky intertidal area will increase the roughness of the nearshore area and will help break small waves, boat wakes, and reduce runup during small storms or during lower water levels.

The disadvantage of this alternative is that it will only reduce wave energy for relatively minor storms. While this alternative will increase the biodiversity of the nearshore area, it will not significantly reduce wave energy at the toe of the coastal bank.

6.5 FRINGE MARSH CREATION OR RESTORATION

6.5.1 Fringe Marsh Creation with Fiber Rolls

This design alternative will lay a series of fiber rolls across the intertidal beach to create a sill. The sill can be allowed to fill naturally with sediment or can be filled with sediments suitable for growing marsh species such as *Spartina alterniflora* of *Spartina patens*. This alternative would most likely require filling the sill because sedimentation rates in New England are on the orders of millimeters per year and would require a long time the accrete sediment to reach an elevation that would be suitable for growing marsh species.

The advantage of this alternative is that it increases the diversity of the nearshore habitat. Raising the elevation of the marsh will act as a natural buffer between the high tide beach and the nearshore area. Marshes act as nursery areas, help filter pollutants and sediments from runoff, and if the sill is high enough it can help break boat wakes and/or waves during small storms.

The disadvantage of this alternative is it will only provide limited wave dissipation during a large storm. Additionally, the fiber rolls used to contain the sediment can only be used in relatively low energy environments. Medium size waves will dislodge the fiber rolls resulting in a loss of sediment behind the fiber rolls. When this occurs elevation behind the fiber rolls will be reduced and the marsh plants will be dispersed into the nearshore area. Additionally, the fiber rolls may be removed from the restoration site and become flotsam.

6.6 PREFERRED ALTERNATIVE

The preferred alternative of a combination of fiber rolls, bank grading and planting, cobble bank nourishment, and cobble berm was selected based on the following criteria:

- Consultation with representatives of the DPW and Conservation Commission from the Town of Winthrop.
- Evaluation of the incident energy at the site
- Examination of the Massachusetts Wetlands Regulations
- Consultation with CZM
- Feed-back from the regulatory interagency meeting

The preferred alternative will begin by installing a row of three fiber rolls at the base of the bank (Figure 29).

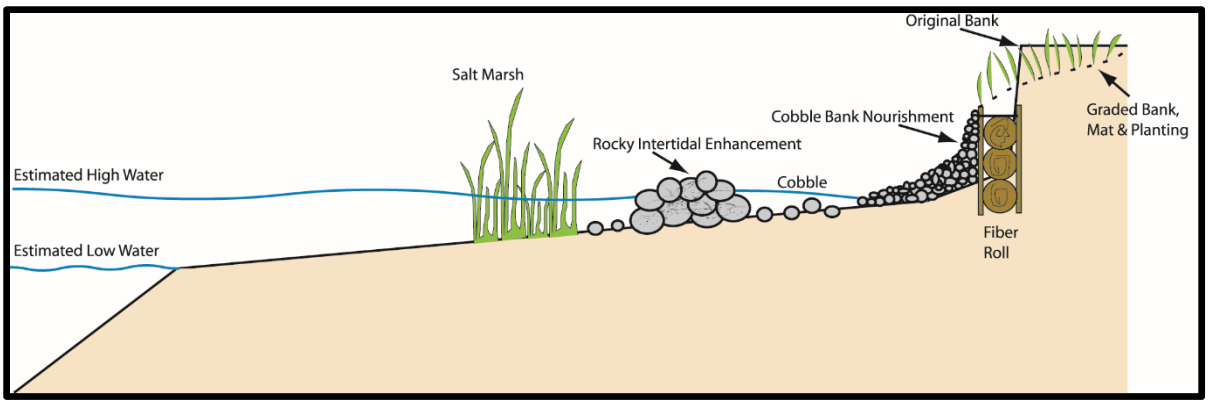

Figure 29. Preferred alternative of fiber rolls, bank grading, planting, cobble bank nourishment, cobble berm.

The lowest fiber roll will be excavated into the beach and then an additional two rows of fiber roll will be stacked vertically on top of the lowest fiber roll. The fiber rolls will be anchored into the coastal bank using a duckbill anchor system. The top of the coastal bank will be cut back to a stable slope and then planted with native grass species. The fiber roles will be covered with cobble that mimics (3 to 6 inches in diameter) the size of the cobble on the beach. The cobbles will help protect the fiber rolls from UV degradation. The last step in the mitigation will be the installation of a cobble berm at the toe of the coastal bank. The elevation of the berm will be approximately 3- 4 feet and will have a relatively shallow 1 on 10 to 1 on 15 slope. The cobble berm will help absorb wave energy and protect the fiber rolls during severe storms.

6.7 INTERAGENCY COORDINATION MEETING

An interagency meeting was help at Coughlin Park on June 7, 2016 to discuss the project with the following agencies:

- Coastal Zone Management
- Massachusetts Department of Marine Fisheries
- Winthrop Conservation Commission
- US Army Corps of Engineers
- Massachusetts Department of Environmental Protection
- Winthrop Department of Public Works
- Woodard & Curran
- Woods Hole Group, Inc.

The meeting was held at low tide and the preferred alternative was presented. After the project components were discussed the wetland resource areas at the site were examined and potential impacts of the project were discussed. While there were no major objections to the project, the agency representatives were careful to say they would reserve formal comment when a filing was filed. The sign in sheet from the meeting is attached below (Figure 30).

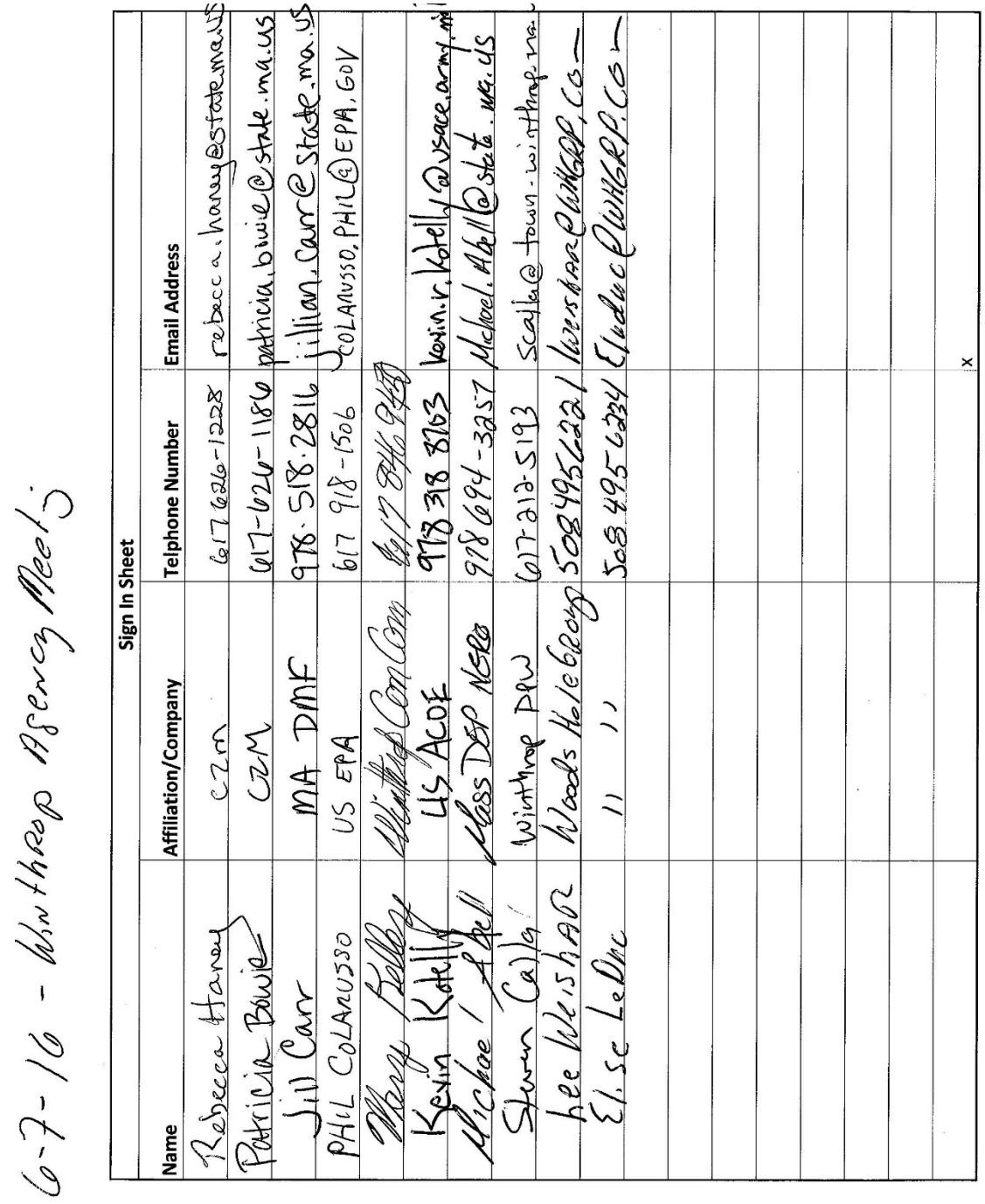

Figure 30. Sign in sheet from the interagency meeting held at Winthrop on June 7, 2016.

7.0 REFERENCES

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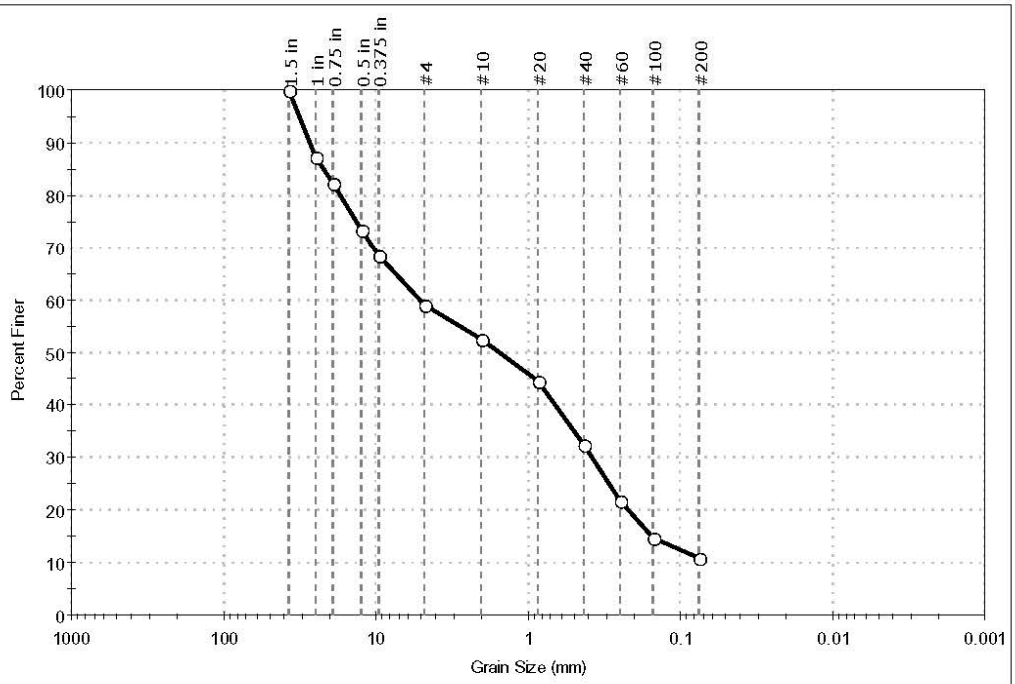
APPENDIX A. GRAIN SIZE ANALYSES

GeoTesting EXPRESS

Client:	Woods Hole Group				
Project:	Sand Samples				
Location:	---			Project No:	GTX-304691
Boring ID:	---	Sample Type:	bag	Tested By:	jbr
Sample ID:	Bank #1	Test Date:	05/10/16	Checked By:	emm
Depth :	---	Test Id:	376419		
Test Comment:	---				
Visual Description:	Moist, brown sand with silt and gravel				
Sample Comment:	----				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
--	40.9	48.3	10.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	87		
0.75 in	19.00	82		
0.5 in	12.50	74		
0.375 in	9.50	69		
#4	4.75	59		
#10	2.00	52		
#20	0.85	44		
#40	0.42	33		
#60	0.25	22		
#100	0.15	15		
#200	0.075	11		

Coefficients

D_{85} = 22.0655 mm D_{30} = 0.3755 mm
D_{60} = 5.0846 mm D_{15} = 0.1542 mm
D_{50} = 1.5348 mm D_{10} = N/A
C_u = N/A C_c = N/A

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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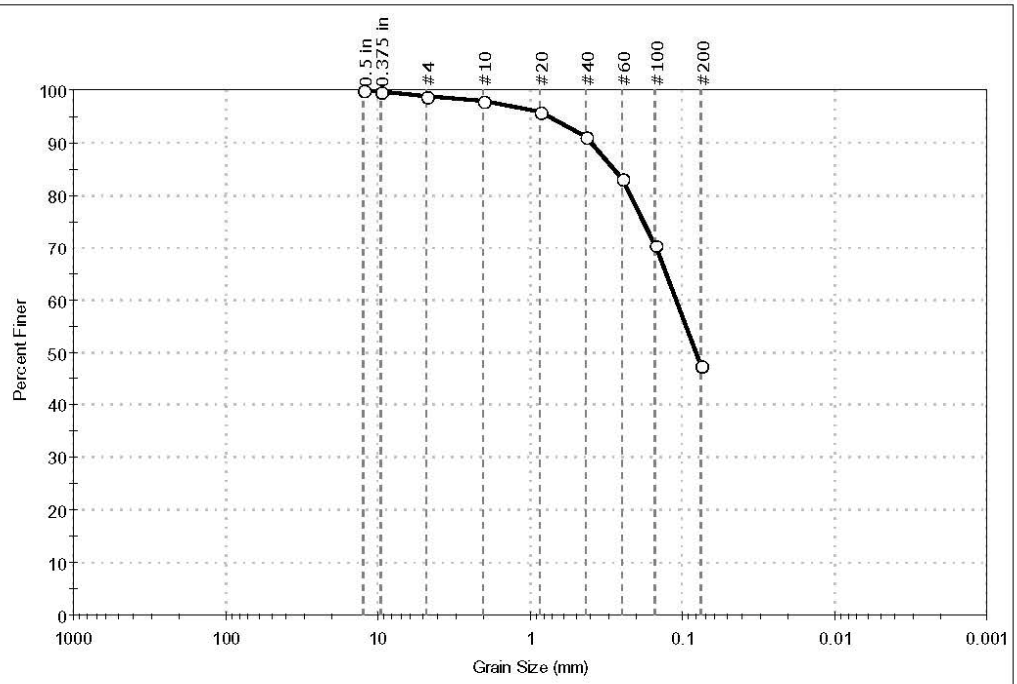
GeoTesting EXPRESS

Client:	Woods Hole Group				
Project:	Sand Samples				
Location:	---			Project No:	GTX-304691
Boring ID:	---	Sample Type:	bag	Tested By:	jbr
Sample ID:	Bank #2	Test Date:	05/10/16	Checked By:	emm
Depth :	---	Test Id:	376420		
Test Comment:	---				
Visual Description:	Moist, very dark brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
–	1.1	51.4	47.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	98		
#20	0.85	96		
#40	0.42	91		
#60	0.25	83		
#100	0.15	71		
#200	0.075	47		

Coefficients

D_{85} = 0.2826 mm D_{30} = N/A
D_{60} = 0.1092 mm D_{15} = N/A
D_{50} = 0.0809 mm D_{10} = N/A
C_u = N/A C_c = N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---
Sand/Gravel Hardness : ---

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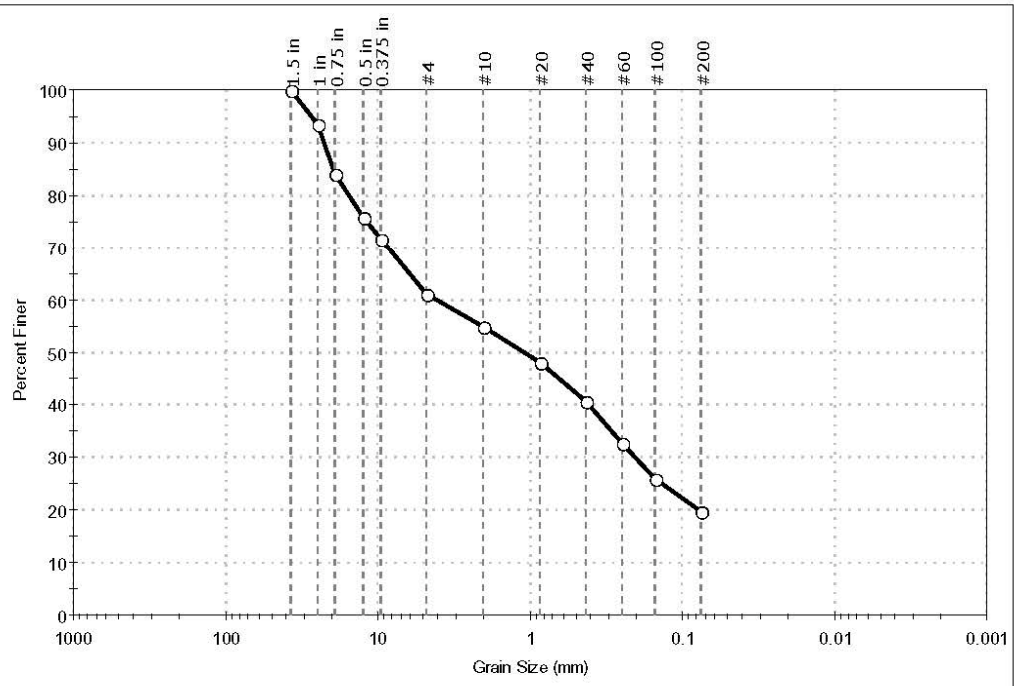
GeoTesting EXPRESS

Client:	Woods Hole Group				
Project:	Sand Samples				
Location:	---			Project No:	GTX-304691
Boring ID:	---	Sample Type:	bag	Tested By:	jbr
Sample ID:	Bank #3	Test Date:	05/10/16	Checked By:	emm
Depth :	---	Test Id:	376421		
Test Comment:	---				
Visual Description:	Moist, dark brown silty sand with gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
--	38.9	41.4	19.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	94		
0.75 in	19.00	84		
0.5 in	12.50	76		
0.375 in	9.50	72		
#4	4.75	61		
#10	2.00	55		
#20	0.85	48		
#40	0.42	41		
#60	0.25	33		
#100	0.15	26		
#200	0.075	20		

Coefficients

D_{85} = 19.4975 mm D_{30} = 0.2021 mm
D_{60} = 4.1026 mm D_{15} = N/A
D_{50} = 1.0893 mm D_{10} = N/A
C_u = N/A C_c = N/A

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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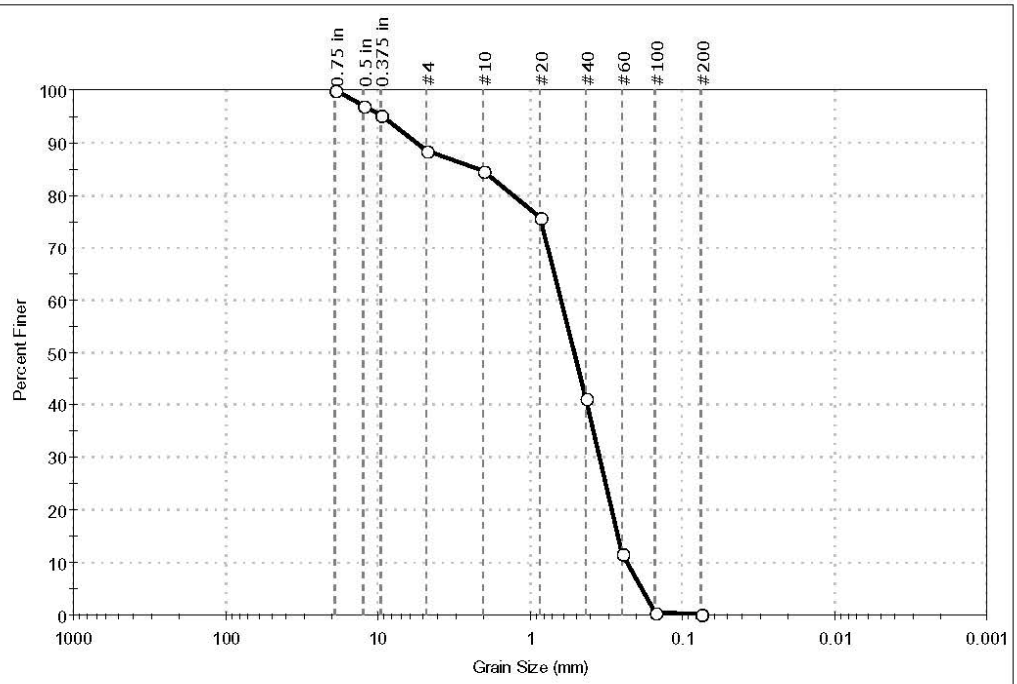
GeoTesting EXPRESS

Client:	Woods Hole Group				
Project:	Sand Samples				
Location:	---			Project No:	GTX-304691
Boring ID:	---	Sample Type:	bag	Tested By:	jbr
Sample ID:	Beach #1	Test Date:	05/10/16	Checked By:	emm
Depth :	---	Test Id:	376415		
Test Comment:	---				
Visual Description:	Moist, olive sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
–	11.6	88.1	0.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	97		
0.375 in	9.50	95		
#4	4.75	88		
#10	2.00	85		
#20	0.85	76		
#40	0.42	41		
#60	0.25	12		
#100	0.15	1		
#200	0.075	0.3		

Coefficients

D_{85} =2.2304 mm D_{30} =0.3471 mm
D_{60} =0.6188 mm D_{15} =0.2651 mm
D_{50} =0.5063 mm D_{10} =0.2308 mm
C_u =2.681 C_c =0.844

Classification

ASTM Poorly graded sand (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (1))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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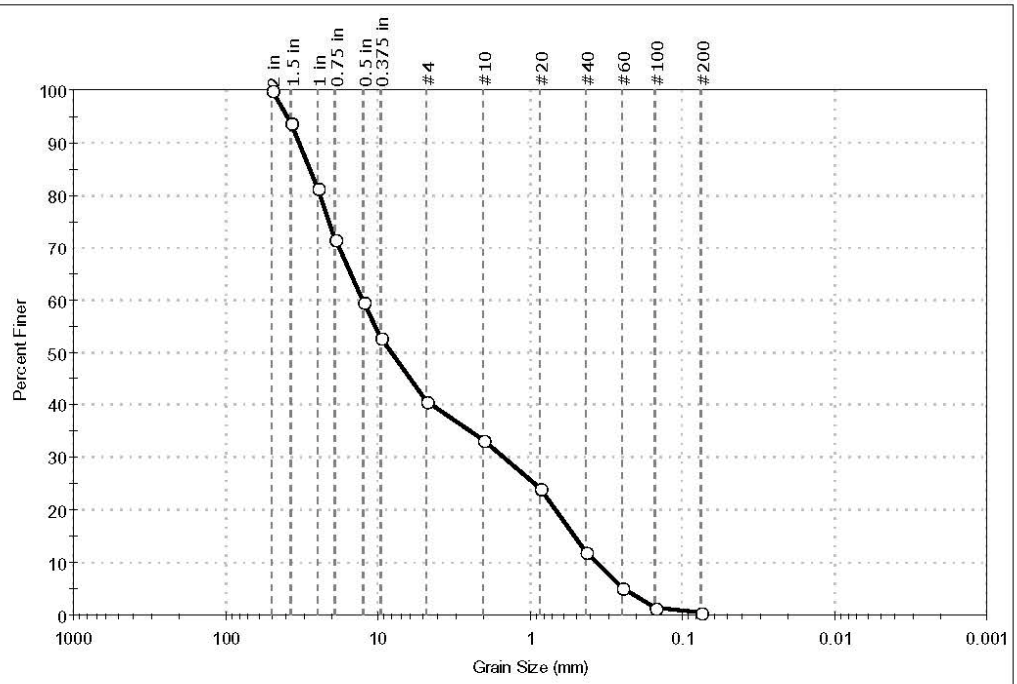
GeoTesting EXPRESS

Client:	Woods Hole Group				
Project:	Sand Samples				
Location:	---			Project No:	GTX-304691
Boring ID:	---	Sample Type:	bag	Tested By:	jbr
Sample ID:	Beach #2	Test Date:	05/10/16	Checked By:	emm
Depth :	---	Test Id:	376416		
Test Comment:	---				
Visual Description:	Moist, dark brown gravel with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
–	59.2	40.3	0.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
2 in	50.00	100		
1.5 in	37.50	94		
1 in	25.00	81		
0.75 in	19.00	72		
0.5 in	12.50	59		
0.375 in	9.50	53		
#4	4.75	41		
#10	2.00	33		
#20	0.85	24		
#40	0.42	12		
#60	0.25	5		
#100	0.15	1		
#200	0.075	0.5		

Coefficients

D_{85} =28.0541 mm	D_{30} =1.4489 mm
D_{60} =12.7171 mm	D_{15} =0.5020 mm
D_{50} =8.1061 mm	D_{10} =0.3618 mm
C_u =35.150	C_c =0.456

Classification

ASTM — Poorly graded gravel with sand (GP)

AASHTO — Stone Fragments, Gravel and Sand (A-1-a (1))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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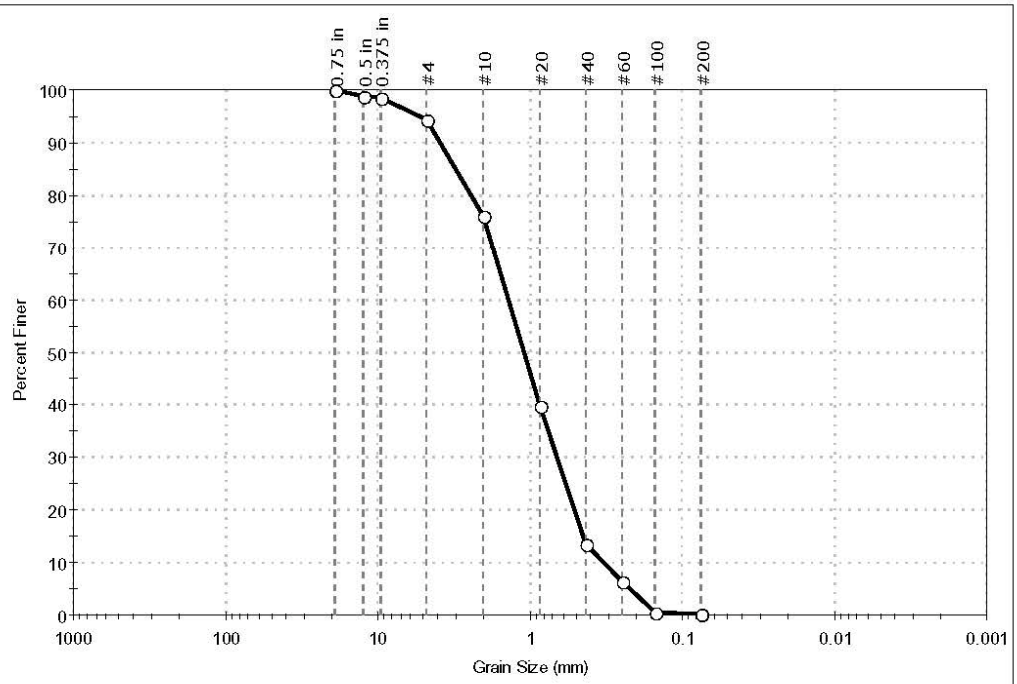
GeoTesting EXPRESS

Client:	Woods Hole Group				
Project:	Sand Samples				
Location:	---			Project No:	GTX-304691
Boring ID:	---	Sample Type:	bag	Tested By:	jbr
Sample ID:	Beach #3	Test Date:	05/10/16	Checked By:	emm
Depth :	---	Test Id:	376417		
Test Comment:	---				
Visual Description:	Moist, very dark olive gray sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
–	5.6	94.1	0.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	99		
0.375 in	9.50	98		
#4	4.75	94		
#10	2.00	76		
#20	0.85	40		
#40	0.42	13		
#60	0.25	7		
#100	0.15	1		
#200	0.075	0.3		

Coefficients

D_{85} =3.0387 mm D_{30} =0.6578 mm
D_{60} =1.3694 mm D_{15} =0.4423 mm
D_{50} =1.0829 mm D_{10} =0.3245 mm
C_u =4.220 C_c =0.974

Classification

ASTM Poorly graded sand (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (1))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED
Sand/Gravel Hardness : HARD

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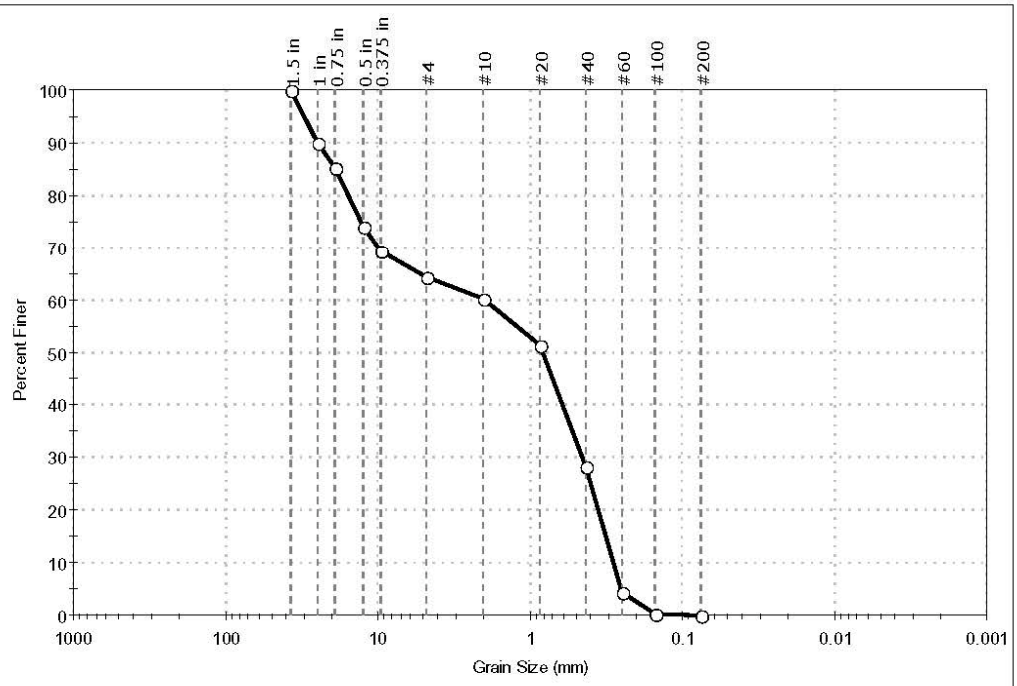
GeoTesting EXPRESS

Client:	Woods Hole Group				
Project:	Sand Samples				
Location:	---			Project No:	GTX-304691
Boring ID:	---	Sample Type:	bag	Tested By:	jbr
Sample ID:	Beach #4	Test Date:	05/10/16	Checked By:	emm
Depth :	---	Test Id:	376418		
Test Comment:	---				
Visual Description:	Moist, gray sand with gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
–	35.8	64.1	0.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	90		
0.75 in	19.00	85		
0.5 in	12.50	74		
0.375 in	9.50	69		
#4	4.75	64		
#10	2.00	60		
#20	0.85	51		
#40	0.42	28		
#60	0.25	5		
#100	0.15	0		
#200	0.075	0.1		

Coefficients

D_{85} =18.8262 mm D_{30} =0.4476 mm
D_{60} =1.9725 mm D_{15} =0.3158 mm
D_{50} =0.8147 mm D_{10} =0.2823 mm
C_u =6.987 C_c =0.360

Classification

ASTM Poorly graded sand with gravel (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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