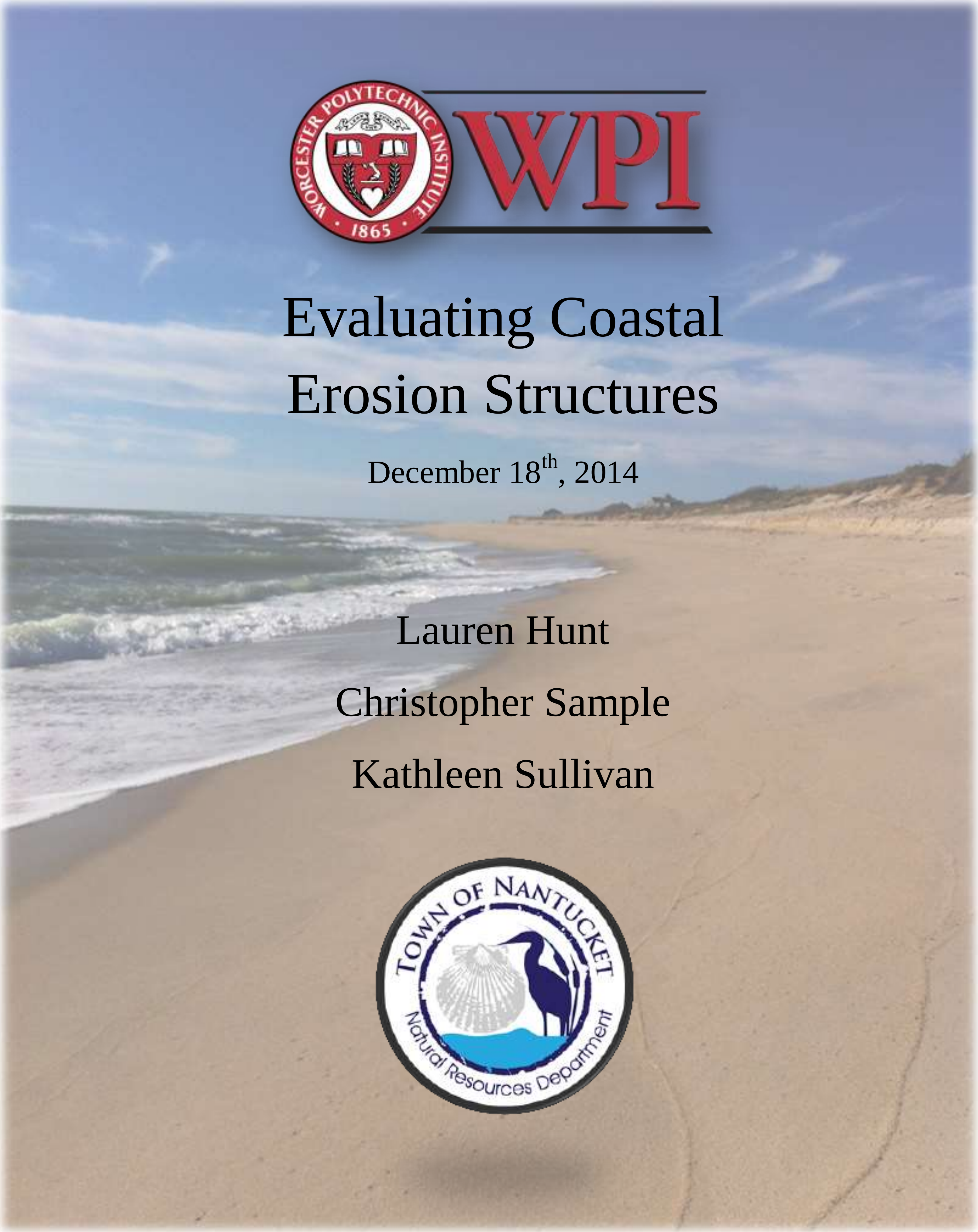

Evaluating Coastal Erosion Structures

December 18th, 2014

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Evaluating Coastal Erosion Structures

An Interactive Qualifying Project
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in partial fulfilment of the requirements for the
degree of Bachelor of Science

by
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December 18, 2014

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Abstract

The island of Nantucket experiences extreme coastal erosion and property owners have built various types of coastal erosion structures to try and limit adverse impacts. The goal of this project was to find, categorize, and conduct a preliminary evaluation of the effectiveness of existing structures. Through reviews of permit information and aerial photographs, site visits, stakeholder interviews, we created a comprehensive database and an interactive map of 72 coastal erosion structures on the island. We conclude that ‘hard’ and ‘soft’ erosion structures may inhibit erosion in the short term over a limited spatial extent, but effectiveness varies dramatically by location and many structures have unintended proximal impacts.

Acknowledgements

The Natural Resources Department IQP Team would like to that everyone that helped make this project possible. We would like to thank our sponsor, Jeff Carlson, and everyone at the Nantucket Natural Resources Department for their help and guidance with our project. We would like to thank our co-sponsors Peter Morrison and Mary Wawro for their insight and dedication to our research and our project.

We also want to thank the following people:

- Shelia Lucey, the Harbormaster, for giving us a place to work
- Our interviewees:
    - The Nantucket Coastal Conservancy
    - Josh Posner of the ‘Sconset Beach Preservation Fund
    - John Merson, a resident of Baxter Road
- Harvey Young for taking us on a field trip to Great Point and showing us a stretch of natural coastline

Young’s Bicycle Shop for providing us with bikes so that we could travel around the island

Andrew Mckenna-Foster and the Maria Mitchell Association for housing us

We appreciate everyone who took the time to talk to us about our project.

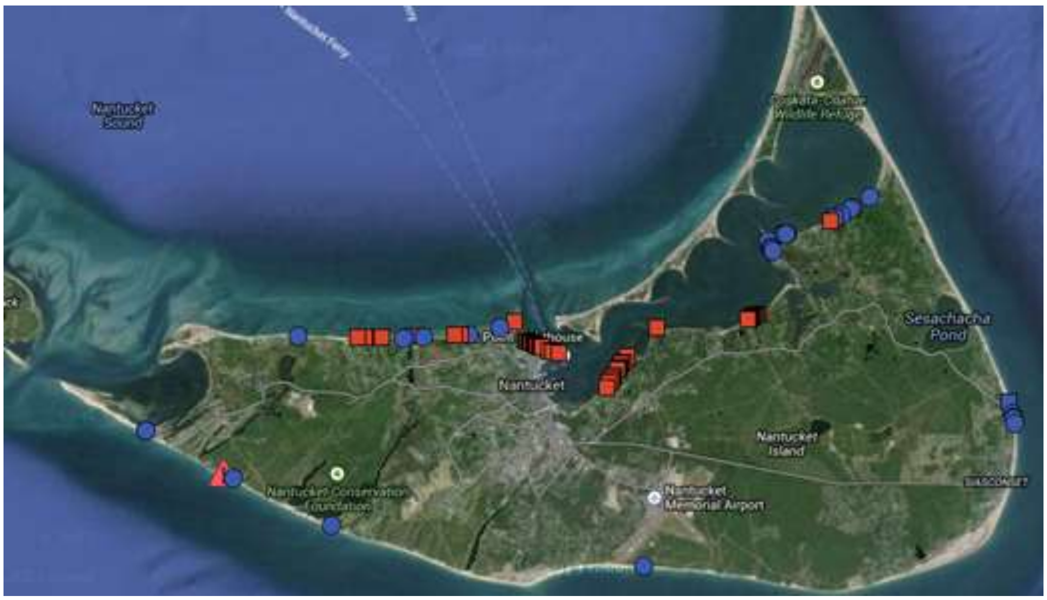
Executive Summary

Erosion is a severe problem on east coast of the US, including Massachusetts, but especially in Nantucket with erosion rates from 2 to 12 feet per year. In Nantucket, some of the methods to mitigate erosion that have been implemented include an array of 'hard' (e.g., bulkheads and groins) and 'soft' structures (e.g., beach nourishment and sand drift fencing). There is no comprehensive database with information regarding all the structures (such as type, condition, location, etc.) currently in use on the island. Therefore the goal of our project was to evaluate the current condition, impacts, and effectiveness of the various coastal erosion structures and techniques used on Nantucket. To achieve this goal, we:

- Identified and catalogued the variety of coastal erosion structures and methods used on the island to date and evaluated the impacts and effectiveness of the different structures and methods;
- Interviewed current stakeholders and officials on the island in regards to coastal erosion practices and policies; and
- Developed a set of recommendations for future policies and erosion strategies

We conducted a physical evaluation and took photographs of each coastal erosion structure we could identify on the island; reviewed past documentation (e.g., permit applications, newspaper reports, etc.) regarding the structures; interviewed key persons involved in the permitting, building, and maintenance of coastal erosion structures; devised a method of evaluating the effectiveness of each coastal erosion structure; and collated all the information in a comprehensive database and interactive map. We began by constructing the basic database structure and content categories in response to the needs of our sponsor and other town officials. Since the evaluation included an assessment of the effectiveness of the coastal erosion structures, we developed protocols guiding how we conducted this assessment. We populated the pilot database with information from the northwest section of the island to see if the database and protocols were adequate. We revised the database and protocols and populated the database with information on all the coastal erosion structures we could identify on the island based on various sources, including field studies and aerial photographs. Once the data collection was complete, we analyzed the data to identify our overall findings with regard to the impacts and effectiveness of coastal erosion structures on Nantucket.

Based on our site visits and analysis of Natural Resource Department files we identified 72 permitted erosion control structures on the island (see figure below), including 42 that we classified as hard structures (red squares) and 30 soft structures (blue circles). The geotubes that have been put in place in Siasconset are indicated with a blue square since they were permitted as emergency structures. Evidently, most of the structures are located in the harbor (50 structures) and northwest sections of the coastline (12 structures), although we also identified 5 structures in Siasconset and 5 on the south shore. We should note that the size, type and complexity of structures vary substantially across the island.



The concentration of structures on the north coast probably reflects the density of population and the large number of houses that were built directly on beachfront property. For example, the majority of structures along Hulbert Avenue belonged to homes that were less than 100 yards from the beach. Records are incomplete, but it appears that many of the soft structures on the island were built more recently, reflecting the shift in emphasis from hard to soft structures that has been a predominant pattern nationally and, in particular, along the east coast. Twenty-three of the hard structures we identified were documented as being built prior to 1978 when more stringent oversight and regulations came into effect.

The database includes a broad array of information on each of these 72 structures, including:

- Map and parcel number;
- The date and time we visited the structure;

- Town address;
- If the structure was permitted;
- If the structure has a Chapter 91 license;
- The date the structure was installed;
- The most recent date that it was updated;
- How it was maintained;
- The name of property owner;
- If the structure is private or public;
- The condition of the structure;
- Permit and site visit notes;
- MORIS transect value; and our
- Effectiveness rating values.

Because some of the structures span more than one property the database includes 85 individual entries covering the 72 structures.

Measuring the effectiveness of coastal erosion structures is extremely complicated. We developed a relatively simple set of measures that we could apply in the field and these were summarized in the database. Based on our observations and measurements, we found that 31 out of the 72 structures scored a 5-6 on our rating scale and were deemed *effective*; we rated 36 structures as *adequate* since they scored between 3-4 and only 4 structures as *ineffective* with a score of less than 2. Surprisingly, we found that 48% of the hard structures were effectives, while only 38% of the soft structures were effective. This is surprising because the Army Corps of Engineers, Nantucket Conservation Commission and others have been moving toward greater use of soft structures in preference to hard structures in the past three decades. This may be because our effectiveness rating scale focuses heavily on the proximal effects of coastal erosion structures coastal erosion structures, the immediate areas in front, behind, and to the sides of the structures and does not try to assess more distant impacts up and down the coast or offshore. It may also reflect the relatively narrow time horizon for our evaluation. Indeed, there are few traces of many structures that have been built in the past because they have been entirely destroyed by storm and wave action; such structures are by definition ineffective, but are not included in our assessment or database.

A preliminary assessment of structures suggests that the advantages and disadvantages of hard and soft structures are not so easily discernible, depending on the type of structure, its method of construction, and location. Soft structures may be successful at decreasing erosion and encouraging accretion while being a more environmentally friendly alternative; however they require more maintenance and upkeep. If a soft structure such as a sand fence is layered in such a way with a jute mesh bag that it forms a solid structure it may act more like a hard structure similar to a seawall. Hard structures may effectively protect the land immediately behind them; however they can cause scouring, the loss of beaches, and other distant impacts by limiting replenishing sand. Hard and soft erosion structures may inhibit erosion in the short term over a limited spatial extent, but effectiveness varies dramatically by location and many structures have unintended proximal impacts. We have observed structures here on island that use a combination of both hard and soft structures to try and make the best out of both techniques and we classified these structures as hard or soft by their primary feature.

From our observations we have made several recommendations to the town to help with the ongoing situation in regards to developing and maintaining coastal erosion structures. The information in our database was limited by time to what we deemed were the most important fields for evaluation.

- We recommend the town maintain and develop the database to include more comprehensive assessments of impacts and effectiveness. (This is recommended as a future IQP.) It is important the database be updated on a regular basis to ensure the information regarding all structures is accurate, while also including information on all new structures.
- We recommend the photographic database on the Google My Maps is maintained. This acts as a user-friendly location for the public to view the structures we found, along with a description of the structure and pictures from site visits. It is critical this be maintained to aid in tracking the upkeep of structures and conditions of the structure, surrounding land, and beaches.
- Due to the preliminary nature of our rating scale, we recommend that our scale be further developed and refined, specified to specific structure types (e.g. sand drift fencing and

groins, which would each have their respective scales), and so future ratings are more accurate and consistent.

- Along with ensuring the information about each structure is centralized, we also recommend that the Conservation Commission continue to work with homeowners in a positive way when permitting new structures. It is important the Commission maintains an open line of communication when permitting structures to ensure homeowners meet the Commission’s requirements and environmental needs, while also getting the most effective structure for their property.

Authorship

The following report was written in a collaborative manner by all three group members: Lauren Hunt, Christopher Sample, and Kathleen Sullivan. The research and writing were divided evenly among all members. Although the sections were written by individual group members, the report was read and edited by all members to assure the objective of the entire group was clear and the writing accurate and concise.

Section	Contributors
1. Introduction	Lauren Hunt, Christopher Sample
2. **Literature Review**	All
2.1 Coastal Erosion in the United States, Massachusetts, and Nantucket	Lauren Hunt
2.2 Methods of Erosion Control	Christopher Sample, Kathleen Sullivan
2.3 Regulation of Coastal Erosion Solutions	Kathleen Sullivan
2.4 Managing Coastal Erosion on Nantucket	All
3. Methodology	All
3.1 Identify and Catalog the Variety of Coastal Erosion Structures	Lauren Hunt
3.2 Determined Stakeholders Opinions Regarding Coastal Erosion Practices	Christopher Sample
3.3 Analyze Results and Make Recommendations	Kathleen Sullivan
4. Findings	All
4.1 The Nature and Impacts of Coastal Erosion Structures on Nantucket	Lauren Hunt
4.2 Structure types and proximal impacts	Christopher Sample
4.3 Stakeholder Perspectives	Kathleen Sullivan
5. Conclusions and Recommendations	All

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1 Introduction

Coastal erosion is a severe problem in the United States. Each year, it threatens over 300,000 homes, destroys more than 1,500 homes and causes $530 million in damages (Heinz 2000, 111). In Massachusetts coastal erosion rates vary along the coast from 0.6 feet per year to 12 feet per year (Leatherman, 1999). Private companies and government agencies, such as the U.S. Army Corps of Engineers, have developed many different techniques to try to mitigate erosion. Early efforts in the 1950s and 60s to limit coastal erosion focused on ‘hard’ structures, such as seawalls and groins, but more recently attention has shifted to the use of ‘soft’ erosion control measures, such as creating dunes and salt marshes, which are considered to be more effective at erosion control and have fewer adverse and unintended impacts (Board, 2014 p. 59)

Nantucket is a small island (approximately 45 square miles) 30 miles off the southern coast of Massachusetts. The island is composed primarily of sandy debris left behind when the glaciers retreated 15,000 years ago. In addition to normal wave action, each year the island is buffeted by severe storms that reshape the coastline, causing erosion in some areas and deposition or accretion elsewhere. Erosion rates vary from 2 feet per year to as much as 12 feet per year in some of the most affected areas, such as Siasconset on the far eastern end of the island (Shoreline Change and the Importance of Coastal Erosion, 2000). Homes along the southern coast of the island are at higher risk of being damaged or destroyed and over the past decade 5 houses have been lost to erosion and 10 have been relocated to avoid the receding coastline (Nicas, 2009). The town and many private landowners have engaged in various efforts over many years to try to limit the damages caused by erosion. These efforts have entailed both ‘soft’ and ‘hard’ measures, and some have been more successful than others. Nantucket has recently developed a coastal management plan that “establishes priorities and procedures for protecting and managing *town owned* infrastructure, public access points and roads around the island adjacent form the coastline,” (Oktay et al, 2014) but they currently do not have comprehensive inventory or database of all the coastal erosion structures on the island. The goal of this project is to evaluate the current condition, impacts, and effectiveness of the various coastal erosion structures and techniques used on Nantucket in recent decades. To achieve this goal, we:

- Identified and catalogued the variety of coastal erosion structures and methods used on the island to date and evaluated the impacts and effectiveness of the different structures and methods;
- Interviewed current stakeholders and officials on the island in regards to coastal erosion practices and policies; and
- Developed a set of recommendations for future policies and erosion strategies.

We conducted a physical evaluation and took photographs of each coastal erosion structure we could identify on the island; reviewed past documentation (e.g., permit applications, newspaper reports, etc.) regarding the structures; interviewed key persons involved in the permitting, building, and maintenance of coastal erosion structures; devised a method of evaluating the effectiveness of each coastal erosion structure; and collated all the information in a comprehensive database.

2 Literature Review

Since mitigating coastal erosion is such a complicated and controversial issue, a significant amount of research has been conducted over the past 150 years. Section 2.1 of the literature review provides an overview of the extent and costs associated with coastal erosion in the US, Massachusetts, and Nantucket in particular. Section 2.2 explains the types and methods of erosion control, the difference between hard and soft erosion structures, and the evolution of erosion control measures. Section 2.3 summarizes the federal, state, and local regulations pertaining to coastal erosion structures. The final section elaborates on the various forms of erosion control currently implemented on the island and the concerns of stakeholders.

2.1 Coastal Erosion in the United States, Massachusetts, and Nantucket

Coastal erosion is a major issue in the United States, Massachusetts, and the island of Nantucket. In 2000, the Heinz Center estimated that approximately $530 million is lost every year in property damages alone due to the effects of coastal erosion while more than 300,000 homes are at risk of eroding coastlines in the United States (Heinz 2000, xxviii, 111). Boston, Massachusetts is one of the top eight cities in the world that has been declared at risk for coastal storms, which is one of the biggest factors in coastal erosion (Board, 2014). It is estimated that an average of 3 feet of land every year is being eroded off the coast of Massachusetts (Heinz 2000, 15). It is expected that erosion on the east coast of the United States will increase in the future as sea levels rise and the frequency of severe storms increases due to climate change. All across the state, approximately 0.56 feet of coast is lost each year due to storms alone (*Shoreline Change and the Importance of Coastal Erosion*, 2000; *Coastal Erosion,* 2009).

Nantucket, an island off the coast of Cape Cod, has some of the highest erosion rates in Massachusetts. It is expected to lose a range anywhere from 2 to 12 feet in a single year (Heinz 2000, 15). Although numerous erosion control structures have been employed by private and public entities, the political, economic, and social issues mean that achieving consensus on appropriate policies and approaches is extremely difficult. Figure 1 below, taken from the Massachusetts Coastal Zone Management mapping system (MORIS), shows the high water marks from the mid 1800's (red dotted lines) to 2009 (black lines) superimposed on an aerial photograph of the coastline of Nantucket in 2012. We highlight two areas (Madaket Harbor and

Sheep Pond Road) that have seen some of the most dramatic changes over the past two hundred years and discuss them in more detail below.

Figure 1: CZM Online Mapping of Nantucket (MORIS, 2014)

Figure 2 is an aerial view with MORIS data showing the detailed changes in Madaket Harbor. There has been a significant amount of both erosion and deposition on the western tip of the island around the northern point of Madaket Harbor. The map data shows that the coast has eroded approximately 1000 feet of sand at the point and deposited approximately 1000 feet of sand at the northern coast. This illustrates dynamism of the coast zone, the enormity of the forces involved, and the risks to properties close to the shoreline.

Figure 3 is from the same MORIS data and shows the south coast of the island at Sheep Pond Road. Between 1884 and 2009 the high water mark has receded inland by approximately 1,780 feet, making it one of the most rapidly eroding parts of the coast on the island. Due to its location, the sand that erodes off these beaches is reintroduced back into the ocean with no deposition or accretion to counteract the erosion. The relationship between areas of erosion and deposition is not straightforward. It is not simply a matter of assuming that material eroded from one area is transported to the nearest area of accretion. Depending on the direction of the winds, tides, and currents in relation to the shoreline, especially during a major storm, material may be eroded and deposited in a variety of places over relatively short distances. Much material may even be transported away from the coastline and deposited far off shore.

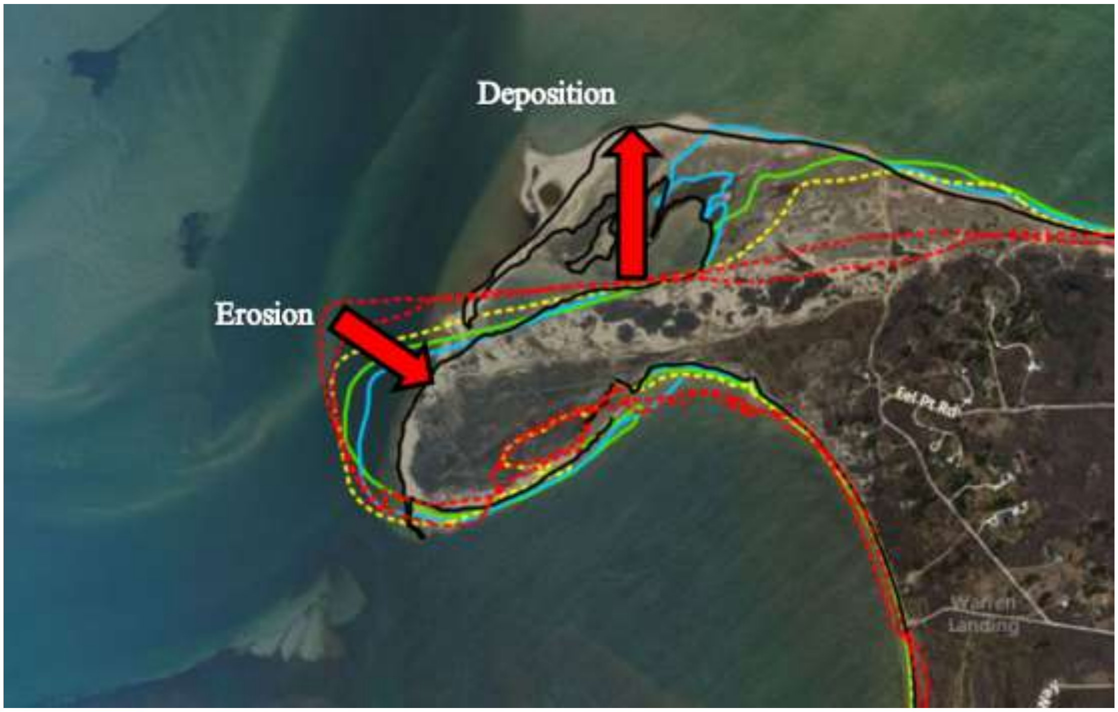

Figure 2: CZM Online Mapping of Madaket Harbor (MORIS, 2014)

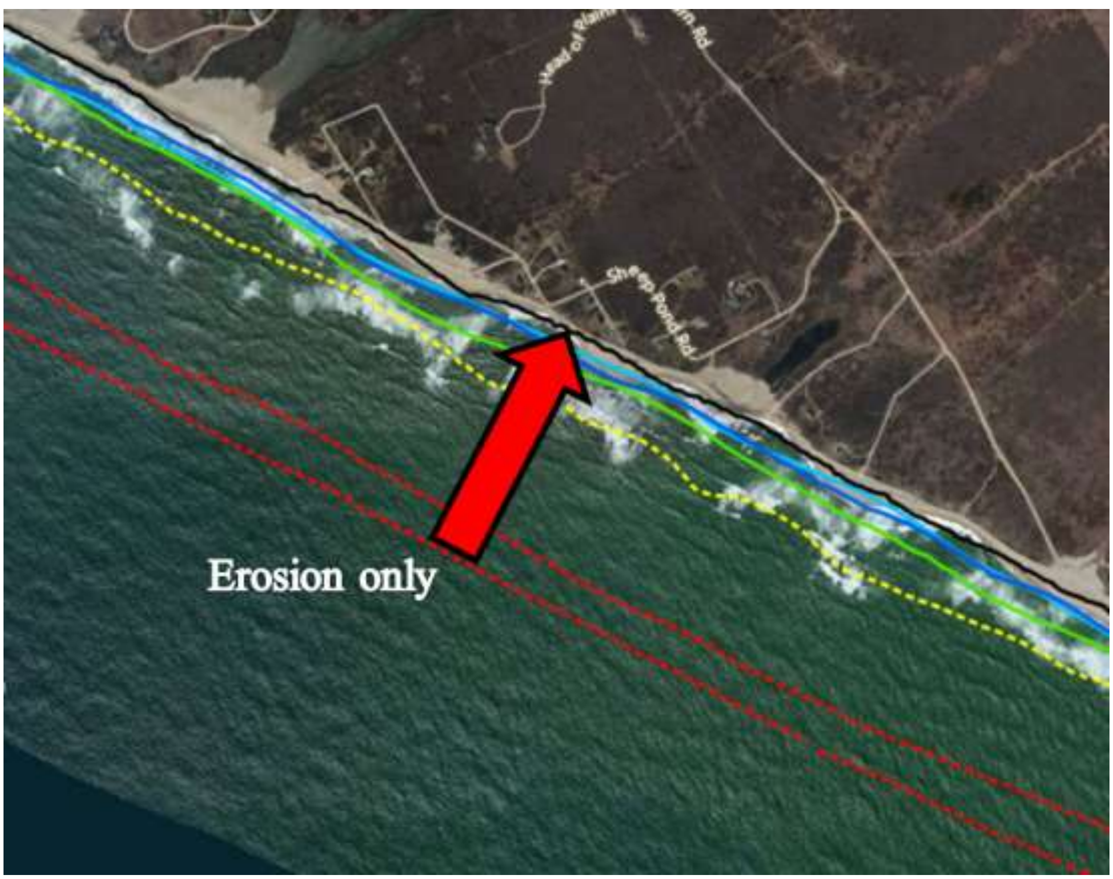

Figure 3: CZM Online Mapping at Sheep Pond Road (MORIS, 2014)

Figure 4 depicts the erosion rates around the island. The line graph in the middle shows the long term rates of erosion in meters per year from the mid 1800's to 2009. The line graph on the right shows the short term rates in meters per year starting between 1970 to 1982 and ending between 2000 to 2009 (Thieler, 2013). Negative numbers to the left of the x-axis on each graph indicate accretion or deposition rates, while positive numbers on the right of the x-axes indicate erosion. The numbers on the y-axis correspond with the 10 kilometer segments marked on the map to the left The figure shows that the segment of beach between Cisco and Madaket (i.e., kilometer markings 30 and 43) has seen some of the greatest erosion in the long term. Indeed, in the past decade 5 houses have been lost due to erosion in this section and 10 houses have been moved away from the shoreline to protect the buildings (Nicas, 2009). In the short term, Tuckernuck Island has seen the most erosion while Esther Island has seen the most accretion (i.e., between the 40 and 50 km marks).

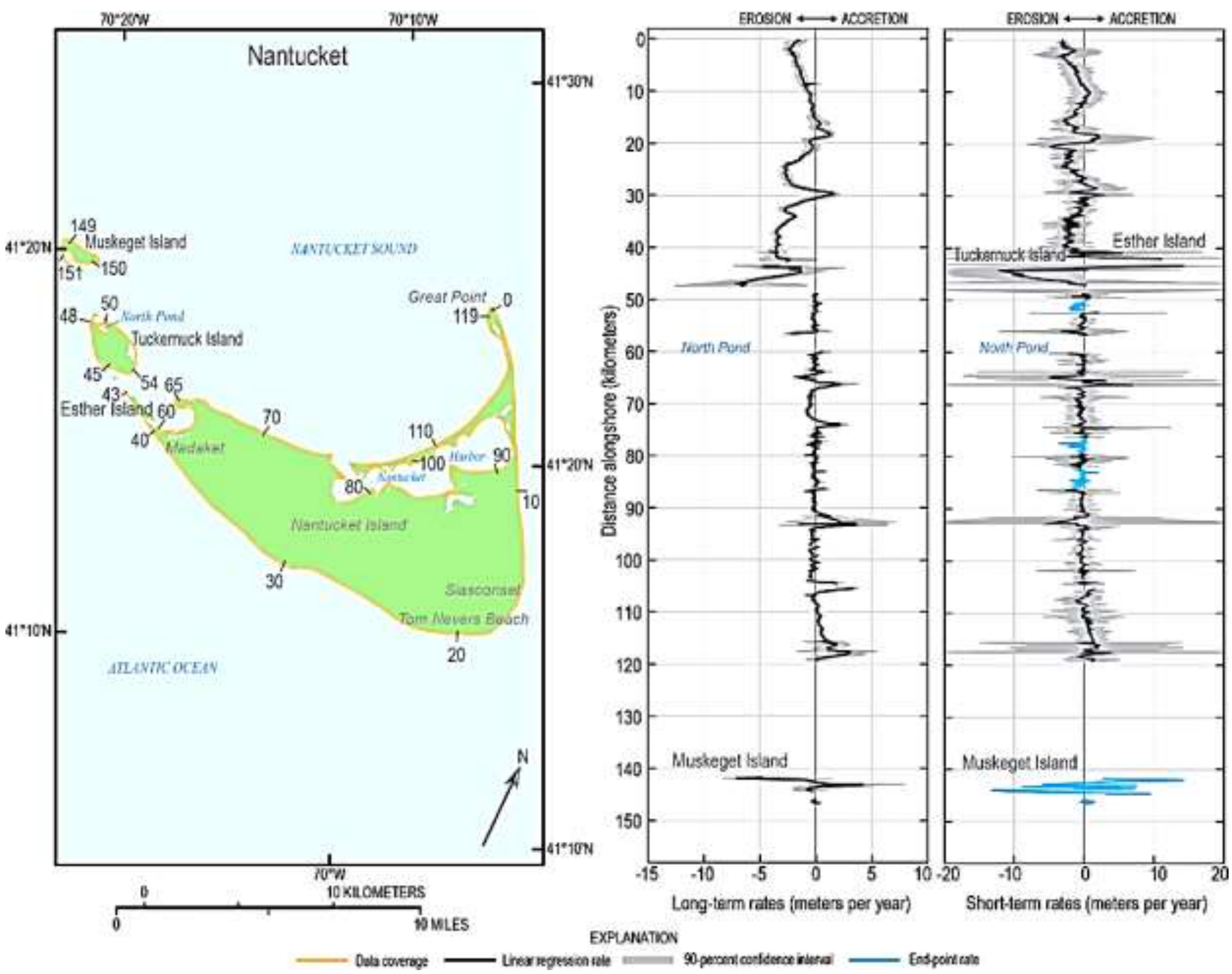

Figure 4: Erosion and Accretion Rates on Nantucket (Thieler, 2013)

2.2 Methods of Erosion Control

Various methods have been developed to battle shoreline erosion. These methods can be divided into two categories: *hard* and *soft* engineering structures. Each method has advantages and disadvantages (Table 2) depending on the nature of the method used, the location of installation, the materials used, the quality of installation, and the strength and direction of onshore current

Method	Type of structure	Description	Advantages	Disadvantages
Hard	Seawall/ Bulkheads	Reinforced wall that runs parallel to the coastline.	Provides a strong barrier to protect the land behind it from wave energy.	Expensive to install. Improper installation can result in scouring at ends.
	Groins/ Groynes	Perpendicular structure set up in groups along coastline.	Traps sand and sediments from longshore sand drift.	Can have adverse effects on beaches down drift of field. Impacts beach usage.
	Geotextiles	Permeable fabric tubes placed longitudinally to the coastline.	Less visually intrusive. Can be anchored and less costly than other heavy structures.	Can have the same scouring effects as seawalls.
	Offshore breakwaters	Manmade structures located off the shoreline to represent natural reefs.	Slows and decreases wave energy. Is not visible from land.	Costly to install and has limited viable locations to install.
Soft	Beach Nourishment	Replenishing lost sand on dunes and beaches with sand from offsite locations.	More natural look and environmentally friendly.	Requires continuous maintenance and is costly to manage.
	Vegetation	The planting of vegetation on dunes to strengthen loose sand.	More natural look and promotes a natural dune growth.	To dense of placement can lead to disruption of wildlife habitats.

Table 1: Erosion Prevention: Lists advantages and disadvantages of most common erosion preventative measures (Akson, 2012; Erisman, 2014; Kraus, 1998; Linham, 2010; NOAA, 2014; Board, 2014; O'Connell, 2008)

2.2.1 Hard Engineering Solutions

A hard engineering structure is a static and sturdy structure that is intended to withstand the constant onslaught of coastal waves. Hard structures are valuable in densely populated urban areas where space and the use of more ‘natural’ or ‘soft’ techniques are limited (Board, 2014). One of the more common hard structures is a seawall, or a bulkhead, which runs parallel to the coastline as seen in Figure 5. A seawall is not intended to prevent erosion of any beach in front of it, but it is used to prevent the land behind from being washed away (Kraus, 1988). A beach that has been eroding prior to the installation of a seawall will likely continue to erode until the water reaches the armoring (Board, 2014). If a seawall is implemented in such a way that it impedes cross-shore sediment processes then it may stem erosion and cause scouring (i.e., excessive removal of material in a limited area) immediately at the ends of the wall (Kraus, 1988), as shown by the arrow in Figure 4. Seawalls can also have other serious environmental impacts. By changing the water landscape immediately in front of the wall or by erosion of the beach, they can disrupt the habitats of various fish species and shore birds (Board, 2014).

Figure 5: Seawall with Scouring on the Northwest Shore of Nantucket

Similar to seawalls, *groins* are hard structures that are installed perpendicular to the coastline. Different styles of groins have been developed and can be in straight walls (Figure 6) or in an L or T shape (ODNR, 2014). These structures focus on trapping and retaining sand though longshore drift (i.e., the 'natural' direction of transport of material along the beach in response to winds, tides, and currents) and are set up in groups called groin fields. Sediment collects on the up-drift side of the groin and is eroded on the down-drift side. If installed correctly, the longshore drift rate is maintained once the groins fill up with sediment. However before the groins reach this point they can have adverse effects further down the coast known as down drift shorelines (NOAA, 2014). As illustrated in Figure 7 below, if groins are installed incorrectly (middle panel) the down drift sand supply may be interrupted and beach erosion occurs. Additional groins may be needed (lower panel) to support the beach on the down drift side.

Figure 6: Groin Field on the Northwest Shore of Nantucket

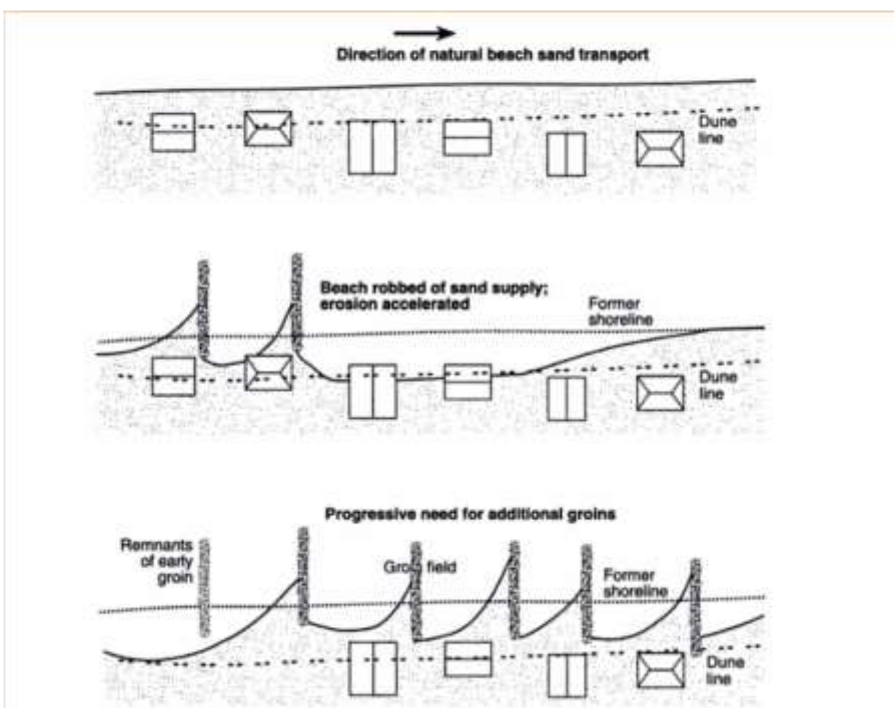

Figure 7: Effects of a Groin System (Pilkey, 1998)

2.2.2 Soft Engineering Solutions

Soft engineering solutions work with the natural environment to prevent erosion. Sandy beaches are in a constant dynamic system that changes with the effects of the waves and the weather and longshore drifts. The beach and beach dunes work together to keep the supply of sediment of the beach maintained at equilibrium (Hanley, 2014). Soft engineering solutions are considered more environmentally friendly but are very costly to maintain and require constant monitoring and management. Soft engineering solutions entail the use of replacement sand to replenish eroded areas and restore protective coastal dunes to limit damages from storm surge (Er*isman*, 2014). When a large quantity of beach material is added to a near shore system it provides replenishment to a sediment deficiency and can allow the shorelines to naturally build (Linham, 2010). Nourishment material can be obtained through offshore dredging on large scale or on a smaller scale be obtained through land base sources away from the shoreline to build up dunes on land (Linham, 2010). Drift fences can then be installed to prevent the newly installed sand from blowing away (O'Connell, 2008). Another method of preventing the newly placed dune from eroding away too quickly is the planting of beach grass. American beach grass, *Ammophila Breviligulata,* is a sand-binding perennial plant that grows along the Atlantic coastline. Beach grass binds the sand because its roots can grow between 10 to 13 meters away from the base of the plant. The grass itself can grow up to a meter tall and is protected by law on some beaches (*Beach Grass*, 2014). Beach grass will also capture drifting sand and continue to grow so that it can also be used to create a new sand dune (Linham, 2010). When planting beach grass for dune restoration it is important to take in consideration the plant spacing because it will affect how quickly it will accumulate sand in that area (O'Connell, 2008). When planting beech grass it is also important to have a form of dune stabilization method so that the seedlings have a chance to establish themselves as seen in the steep dune of Figure 8. The use of a jute mesh has been shown to produce the highest rate of seedling establishment than any other method, and will eventually break down from sunlight and moisture (Maun, 1989). Soft engineering solutions have both aesthetic and environmental benefits because living structures are able to adapt to changing environmental conditions and provide habitats for a variety of flora and fauna (National Research Council, 2014).

Figure8: Beach Grass with Jute Mesh, Siasconset Bluff Nantucket

2.2.3 Alternative Engineering Solutions

In the late 1950s and 60s, hard structures were used as the preferred method of erosion control (Figure9), but in the decades that followed the use of soft structures began to greatly outnumber the hard (Board, 2014).

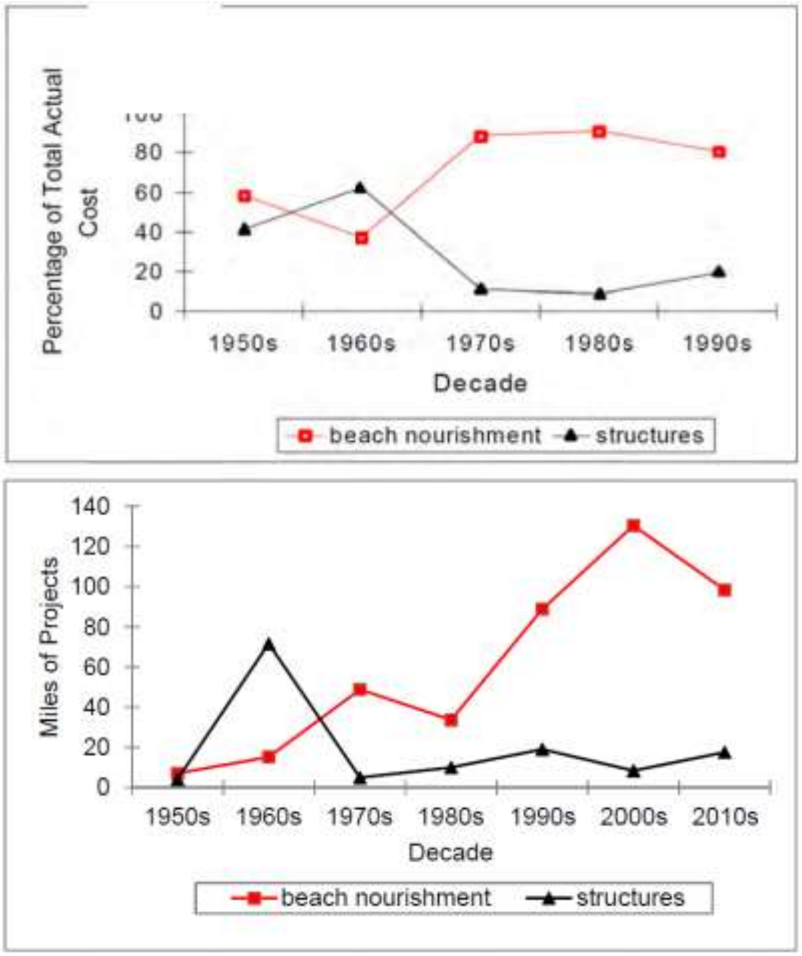

Figure 9: Comparison of Hard and Soft Structures (Board, 2014)

As experts have learned more about the effectiveness and impacts of different erosion control structures, hybrid structures that combine soft and hard structures have become more common (Erisman, 2014). One example of this is the installation of an oyster reef. An Oyster reef is a bed of oysters joined together to form a solid offshore structure. Oyster reefs diminish wave energy and provide a barrier for sediment erosion while providing a habitat for oysters. The oyster reefs acts very similarly to a low-crested submerged breakwater. It has been shown that these submerged breakwaters help prevent erosion in moderate conditions but do not fare so well in high energy events (Board, 2014). Geotextile structures represent a combination of beach nourishment and seawalls. These structures consist of a permeable fabric that is pressure filled with sand. This creates a tube that can be placed longitudinally to the water line and can be covered in sacrificial sand to enhance visual appeal (Figure 10). While they may prevent erosion in the same fashion as seawalls they can have similar adverse effects on sedimentary dynamics. As sacrificial sand is lost from wave energy, the face of the geotextile tube is exposed and can cause scouring and other detrimental effects (Akson, 2012).Every structure has its advantages and disadvantages, but the quality of the design and implementation of the structure determine its effectiveness in reducing erosion.

Figure 10: Geotextile Tubes, Siasconset Bluff Nantucket

2.2.4 Measuring Coastal Erosion

In order to understand how the shoreline is altered due to the presence, or lack, of coastal erosion structures, it is important to understand how to track these changes. Understanding coastal erosion is challenging for multiple reasons. One problem comes from the unpredictable impact of severe storms. Severe storms can cause more erosion in a shorter time than may have occurred in the previous half century. Additionally, shoreline position indicators, such as the high water mark, are inherently imprecise meaning that determining the underlying trend of erosion requires long histories of shoreline marks (Leatherman, 3 June, 2011). In addition to the shoreline indicators being imprecise, there is also uncertainty about what should be considered the universal shoreline indicator. Possible indicators include, but are not limited to, beach scarp, high water lines, vegetation lines, and the bluff edge. The most commonly accepted shoreline indicator, however is the high water line, which is where the dry sand meets the wet or damp sand after the last high tide, as it is the most visible indicator in aerial photos (Leatherman 2003). Mapping the shoreline has its own challenges. Older methods of mapping the coastline were less stringent and less rigorously or systematically applied. Error in mapping frequently came about due to both random and systematic reasons. Systematically, errors commonly occurred due to a difference in the season (mapping in one season the first year would be different than mapping during an alternate season the following). Other sources of error came from early aerial photos in which the calculations did not account for the movement of the planes, and varying surveying methods between surveying groups (Leatherman 2003). To diminish the error in calculating erosion, Leatherman and his associate Clow developed the method of Metric Mapping, which uses computerized data to correct anomalies and distortions in aerial pictures and digitalize NOAA “T” charts. These charts contain key information on the shorelines dating from 1850 to the present, and all are based on the high water marks.

Calculating the actual change in shoreline can be done in various ways. Some of these methods require expensive equipment and access to sophisticated technology. With the ability to reduce noise in a picture of the shoreline, methods of measuring shoreline change have shifted towards aerial efforts. Technology, like the LIDAR system, has become the most accurate photo analysis method. The LIDAR system, attached to an airplane, uses lasers to scan and digitize the ground below while adjusting the measurements for the movement of the aircraft (Zhang et al, 2002). The easiest approach to evaluating erosion and sedimentation patterns involves the assessment of satellite and aerial photographs with historical shoreline data. This approach entails using this imagery to examine erosion and sedimentation over the course of many years, and compare patterns prior to and following the installation of an erosion control structure. According to Leatherman, the way this can be done is by choosing an arbitrary, stationary point, such as the nearest intersection or street corner. Once this point has been chosen, a measurement is made for the distance from that arbitrary point to the high water shoreline mark. (Personal Communication, November 11, 2014). These historic shoreline marks and an appropriate map scale can be found using the Massachusetts MORIS GIS database. By comparing an area where a coastal erosion structure has been implemented as well as its surrounding areas to that of an unaltered part of the same beach, it is possible to estimate effectiveness of these structures.

Other methods, utilize on-ground practices. These include using a device called a sediment erosion table, or SET. To install this device onto a shore, a large, hollow pole is inserted into the beach vertically and then filled with quick-drying cement. This pole then acts as a base for the portable measuring segment of the apparatus (Boumans and Day, 1993). Another on-ground method requires less technology and less time. The tools necessary are much simpler as they are simply a surveyor's tools.

2.3 Regulation of Coastal Erosion Solutions

2.3.1 Federal Regulations and Policies

To aid in protecting the shorelines, the federal government has created multiple regulations. Under current 33 USC § 426, the Army Corps of Engineers (ACOE) is responsible for investigating and creating plans to reduce the effects of erosion on all waterfront areas within the continental US and its properties. In addition to the US Code, federal policies include the Coastal Zone Management Act (CZMA) and the River and Harbor Act (RHA). These acts were put in place to ensure there would be improved monitoring of the nation's coastlines. The CZMA allows the federal government to give grants to states which implement erosion controls that are approved by specific government agencies such as ACOE (NOAA.gov). Under the RHA section 111, ACOE has the ability to investigate "and mitigate shoreline damages" (NOAA.gov). There are additional regulations regarding specific control options. These regulations include the federal Clean Water Act, Section 404 and the National Environmental Policy Act (NEPA), which require that proponents of engineering solutions seek approval. Under the CWA Section 404, any major project that is in, or near, a body of water, requires a permit for disposing of dredging of filling materials. This is especially important for any type of beach nourishment projects as getting permits can be difficult. In order for a beach nourishment project to be permitted, it first must undergo a pre-permit process which includes "public scoping, development of alternatives, impact analysis and mitigation" (NOAA.gov). The table in Appendix C names and explains steps to stay in compliance with the regulations of Section 404.

The CWA permit can also be difficult to obtain as the process is conjoined to NEPA. The purpose of NEPA is to ultimately minimize any adverse environmental effects. NEPA uses the same scoping process that the CWA requires and looks at all possible actions, including not taking any action at all, and determines which route has the least negative impact on the surroundings.

2.3.1.1 Thresholds for CWA Section 404 (in the State of Massachusetts)

The Army Corps of Engineers and the state of Massachusetts (Programmatic General Permit) breaks coastal projects into three categories. However, not all waterfront projects are subject to require a permit. "A Section 404 permit is required for activities that involve the discharge of dredged or fill material into waters of the United States, including not only navigable waters, but also coastal waters, inland rivers, lakes, streams, and wetlands" (Healy 2003 p 38). The permit is required for Category III construction projects. Category I projects, which are described as projects with "minimal environmental impact" (Healy 2003 p 38), do not require the interference of ACOE, but must comply with the state regulations. Category II projects are considered as small projects with unlikely environmental impact, but with the possibility for negative effects. Category II projects also do not require a Section 404 permit, but must receive a "review and authorization from the Corps in writing" (Healy 2003 p 39). Category III undertakings are projects in which there is a high probability of some adverse environmental impacts. Construction in this category requires Individual Permits from ACOE and must be made available to the public. These projects may also require further environmental permitting if ACOE deems it necessary. Below is an example taken from Environmental Permitting in Massachusetts describing different types of projects and what would constitute a Category I, II, or III label:

Activity	Category I	Category II	Category III
Fill in Navigable Waters	No authorization for new fill or previously unauthorized fill.	Up to 1 acre of fill in a waterway; up to 1 acre of temporary fill in a salt marsh.	Greater than 1 acre of fill in a waterway; or greater than 1 acre of temporary fill in a salt marsh
Dredging	Maintenance dredging less than 1,000 cy with upland disposal.	Maintenance dredging greater than 1,000 cy, new dredging up to 25,000 cy.	Any maintenance dredging affecting a special aquatic site, or new dredging greater than 25,000 cy.
Pile-Supported Structures and Floats	Private, bottom-anchored floats up to 400 s.f. in size; private, pile-supported piers for navigational access to the waterway up to 400 s.f. in size with attached floats up to 200 s.f. (total).	Private piers and floats that do not meet the terms of Category I. Expansions to existing boating facilities.	Any structure, pier or float that extends, or with docked or moored vessels that extends within horizontal limits of a Corps Federal Navigational Project. Structures, including piers and floats with a new or previously unauthorized boating facility.

Table 2: Categorized Project Examples (Healy 2003 p 39)

2.3.1.2 Thresholds for NEPA

The NEPA's main priority is to ensure environmental protection in all construction projects. To do so, it requires all federal agencies to be aware of the impacts on the environment that their projects may induce. To mitigate these effects, NEPA requires the agencies to submit project plans along with an Environmental Impact Statement (EIS) (Healy 2003 p 29). This is so NEPA can ensure the chosen project has the least negative impact on its surroundings. The NEPA review process only takes effect when a project is large or environmentally risky enough for it to be categorized under "projects or programs requiring a federal agency action" (Healy 2003 p 29). This means that for CWA Section 404 permitting categories I and II, no NEPA involvement is required.

2.3.2 State Regulations and Policies

In addition to federal laws and regulations, the states have also passed laws regarding the management of coastal areas and the installation of erosion controls. In December 2009, the state of Massachusetts launched its "Ocean Management Plan" which lays out a statewide goal of managing and defending the shorelines. Specifically, it details the potential benefits of sand extraction for beach nourishment (Bowles, 2009, p. 30-32). In addition to the current Massachusetts Ocean Management Plan, the state has numerous laws pertaining to the protection of the coastal zone and waters. These other regulations include "the Water Quality Certification, the Wetlands Protection Act, the Massachusetts Environmental Policy Act, and the Ocean Sanctuaries Act" (Bowles, 2009, p. 37). All of these Acts have been implemented to protect the wetlands, and waterfront locations (private or public), especially if the state deems they are endangered due to storms, erosion, or human impact. In 1957, Massachusetts enacted the Conservation Commission Act, which allowed for the creation of conservation groups to oversee municipal natural resources (Erisman, 2014, p. 30).

2.3.3 Local Regulations and Policies

While the state legislature passed the Conservation Commission Act in 1957, a Conservation Commission (ConCom) was not created on Nantucket until 1963 (Erisman, 2014, p. 31). To this day, the Conservation Commission remains the primary local group responsible for overseeing and approving the design and implementation of any coastal erosion control measures on the island anywhere within 100 feet of wetlands. (Prior to the existence of the Conservation Commission and the creation of zoning regulations, however, many erosion control structures were built without any type of approval or regulatory oversight. Many of these older erosion control structures are in precarious locations and various stages of decay and are not regulated by the town.) Presently, any planned erosion control project (whether soft or hard) requires Conservation Commission approval prior to the initiation of construction. The Conservation Commission is responsible for ensuring that any project complies with the state laws noted above, especially the Wetlands Protection Act and Wetlands Protection Regulations passed by the town. Several other local bylaws may also apply:

> "The Town of Nantucket has several other bylaws pertaining to activities within the coastal zone and protection of the beaches: Chapter 56: Beaches, Regulation of Motor Vehicles On; Chapter 66: Coastal Areas and Open Spaces, Protection Of; Chapter 67: Coastal Properties Owned by Town, Management Of; Chapter 99: Nantucket and Madaket Harbor Watersheds; and Chapter 137: Wharves and Waterways, Town."
>
> (Erisman, 2014, p. 33)

The Commission is made up of seven members appointed by the Board of Selectmen and the application process for obtaining an erosion structure permit is described in detail below. The homeowners must file a notice of intent with the Conservation Commission, outlining their project and identifying possible affected areas and the possible impacts of the project. After the

Conservation Commission reviews the application, the project undergoes a series of public hearings. If the project design is not acceptable, the homeowners can redesign their project, offer additional details supporting it, or withdraw their application, or the commission can deny their application. Once the reviewing process is completed, the Conservation Commission board can either approve or deny the permit with an order of conditions. The order of conditions lays out the guidelines of what structure is allowed to be built, the additional conditions under which the structure must be built, environmental impact mitigation conditions, and the installation and maintenance of the permitted structure. The basic process is shown in the following flowchart in Figure 11.

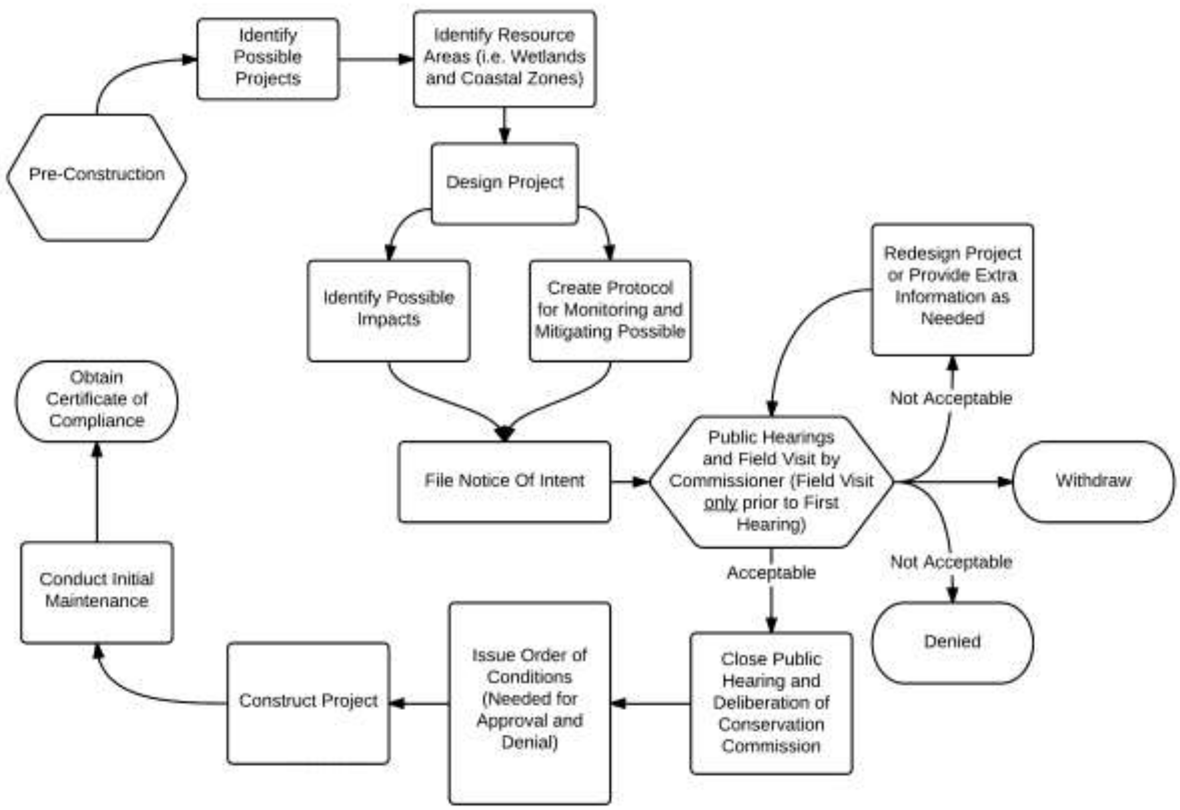

Figure 11: Conservation Commission Process for Permitting

The National Research Council (2014) notes that, despite the maze of federal, state and local regulations and policies, there is no central governing law that guides coastal erosion control efforts. This leads to an ad hoc and sporadic vision for coastal management. In an effort to provide more coherence to coastal erosion management on Nantucket, a working group just completed the Nantucket Coastal Management Plan.

2.4 Managing Coastal Erosion on Nantucket

Erosion mitigation practices have been a controversial topic for many years on Nantucket. The town and private landowners have used a variety of hard and soft methods to attempt to reduce erosion. Some of these efforts have not worked as effectively as anticipated and many have caused adverse impacts on neighboring properties, farther along the shore, and even offshore (e.g., when materials interfere with boating and fishing operations). As a result of concerns about potential adverse impacts, the town of Nantucket put a moratorium on the installation of all seawalls and other hard structures until the town could approve a coastal management plan. Any seawall or hard structure built before 1978 was grandfathered in so the structure is allowed to be rebuilt or repaired in the same manner it was permitted, however modifications or additions are not allowed unless they go through the permitting process as a separate structure. It is estimated that nearly a hundred structures are permitted on island, but no comprehensive database or evaluation of current state of these structures exists.

In March 2012, a committee was formed with the aim of creating a plan on how the island should handle its coastal erosion structures, called the Coastal Management Plan Workgroup. This committee created a coastal management plan which was adopted in 2014. The Management Plan workgroup conducted an inventory of existing municipal properties to determine how the town should manage and protect these facilities. This included an assessment of erosion impacts and potential control measures. The plan also divides the island's coasts into ten sectors, as shown in Figure 12 below. Table 3 lays out the structures identified and any issues noted with the area.

Figure 12: Map of Coastal Management Zones as Laid Out in the Nantucket Coastal Management Plan (Oktay et al)

Sector	CES	Issues
Sector 1	Bulkheads, jetties, beach nourishment	Must integrate the Municipal Harbor Plan
Sector 2	Jetties, storm drains, dune stabilization	ACOE to maintain jetties
Sector 3	unknown	Extensive eelgrass beds and significant salt marshes
Sector 4	No structures recommended	Ecologically significant; habitat for piping plovers and roseate terns
Sector 5	No structures recommended	Ecologically significant; habitat for gray seals, beach voles, piping plovers and roseate terns
Sector 6	Beach nourishment, dune stabilization, Jersey barriers	Ames bridge needs to be monitored as well as the sewer beds
Sector 7	Beach nourishment, dune stabilization	Must maintain communication with the Airport
Sector 8	Beach nourishment, dune stabilization, Jersey barriers	Tidal and wave energy should be encouraged
Sector 9	Beach nourishment, dune stabilization, geotubes	Projects should not impede ability to open Sesachacha pond
Sector 10	Beach nourishment, dune stabilization, jetties	To be maintained for recreation

Table 3: Summary of Coastal Erosion Structures (Oktay et. al., 2014)

The CMP provides guidance on how the town should proceed in managing coastal erosion in the future. All projects must be evaluated for potential effects on water quality, local endangered species, debris from any structure, adverse effects caused by those structures, the impact on any offshore resources (such as fisheries), accessibility of the beaches to the public, and the legality of the structure. The Coastal Management Plan deals primarily with structures that have been built on municipal land or with municipal funding and does not address structures built on private property.

As discussed, there has been a significant amount of controversy on the island because of coastal erosion structures. Along with a variety of opinions, there are several groups on Nantucket that have been outspoken with their concerns. Two of the main parties involved are the Nantucket Coastal Conservancy (NCC) and the Siasconset Beach Preservation Fund (SBPF). The Nantucket Coastal Conservancy is a group that wishes to "protect and preserve Nantucket's coastal resources through education, research, and advocacy…" The Siasconset Beach Preservation Fund is an "organization that was formed by a group of Siasconset homeowners concerned about erosion of the Sankaty Bluff and the threat it poses to the village of Siasconset…" Both of these committees represent views and ideas that are often in opposition to each other regarding protecting Nantucket's coastlines.

2.5 Conclusion

Erosion is a major issue on the east coast of the United States that is predicted to get worse with increased storms and sea level rise due to climate change. It is a particular problem on Nantucket where numerous erosion control structures have been built by different parties over the years. This project will assess these structures on Island and build a database from the collected data.

3 Methodology

The goal of this project was to evaluate the current condition, impacts, and effectiveness of the various coastal erosion structures and techniques used on Nantucket in recent decades. This project consisted of three major objectives. The team:

1. Identified and cataloged the variety of coastal erosion structures and methods used on the island to date and evaluated their condition and effectiveness;
2. Determined the opinions of some island stakeholders on coastal erosion practices and policies; and
3. Created a set of recommendations for future policies and erosion control strategies for the island.

The team created a timetable of tasks (Appendix D). This helped the team stay on track and make sure all objectives are completed in a timely fashion.

3.1 Identify and Catalog the Variety of Coastal Erosion Structures

In order to identify and cataloged the coastal erosion structures on Nantucket we constructed a database and then populated it with data from existing records and field investigation. We began by constructing the basic database structure and content categories (Section 3.1.1) in response to the needs of our sponsor and other town officials. Since the evaluation included an assessment of the effectiveness of the coastal erosion structures, we developed protocols guiding how we conducted this assessment (Section 3.1.2). With the protocols and draft database in hand, we populated the database with information from the northwest section on the island to see if the database and protocols were adequate or needed further modification (Section 3.1.3). After we revised the pilot database and protocols, we populated the database with information on all the coastal erosion structures we could identify on the island based on various sources, including field studies (Section 3.1.4). Once the data collection was complete, we analyzed the data to identify our overall findings with regard to the impacts and effectiveness of coastal erosion structures on Nantucket.

3.1.1 Determined Preferred Database Type, Structure, and Content

In order to evaluate a coastal erosion structure and catalogue its information, each individual structure was evaluated based on a series of questions presented in a checklist (Appendix A). The results of our on-site findings were then organized into an Excel ™ spreadsheet based on each structure's address, location on the island, and parcel number. This spreadsheet made up the database, organized by the location and type of coastal erosion structure. In the spreadsheet we include the map and parcel number, the street address, the date and time of site visit, the type of structure, date of installation and most recent repair, the structures condition, the property owner, changes in the shoreline before and after the structure was implemented, and the structure's effectiveness rating based on three specific guidelines. In a separate document we included site photographs of the structure.

Noteworthy characteristics pertaining to each individual coastal erosion structure, which did not fall under a previously specified field or category, were included in the database classified as "notes" and included information such as pre- and post-evaluation notes. This allowed for easy, side-by-side comparisons of the data. A key part of the spreadsheet database was the inclusion of information that provided specific characteristics about each individual coastal erosion structure from the pre- and post-evaluation notes and if the standards of the structure met the expectations of the multiple stakeholders' expectations.

3.1.2 Develop Schema and Protocols for Evaluating Condition and Effectiveness

In order to be considered an effective coastal erosion structure, the rate of erosion should be reduced or reversed, after the structure had been put in place and the threat to the property minimized. We recognize that measuring the impact or effectiveness of any erosion structure is extremely complicated, since it is difficult to know if erosion or depositional changes might have occurred due to natural processes independent of any human intervention. It is also extremely difficult to assess impacts that may result offshore or at some distance along the shore following the installation of a given erosion control structure. Accordingly, we developed a rudimentary schema for evaluating effectiveness with the understanding that a more refined assessment would require much more extensive field measurement and more detailed analysis of other data, such as aerial and satellite imagery. Such detailed analytical assessments were beyond the scope and resources of our project. As a result, our findings and conclusions regarding the effectiveness of individual structures are indicative rather than definitive. In our schema, three evaluation tests were constructed to determine the structure's condition and effectiveness: evaluating the structure itself, evaluating the surrounding land, and evaluating the beach in front of the structure. Each test was based on a "Good, Fair, or Poor," rating scale with specific instructions included so that the tests could be conducted by multiple people and all arrive at the same or similar answer. The protocols (included in Appendix E) are rating scales that allowed us to assess and assign a numeric value to the condition of each coastal erosion structure as well as its apparent impacts on the surrounding land and beach. The rating scale gives a score based on physical characteristics of the property and awards each a value accordingly. There are three effectiveness tests that award a point value between 0 and 2. The highest rating a total property can achieve is 6 points with the lowest being 0 points. In order to have a property in "good standing" or to be considered an effective coastal erosion structure, said structure must score either a 5 or better. An adequate structure will score between a 3 and 4 and an inadequate structure will score a 2 or below. We created a pilot version of the condition and effectiveness tests and tested them ourselves by using three different site locations. From there we each individually rated each structure based on the guidelines and then compared scores. We continued to adjust the wording of the guidelines in order to arrive at the same score of each location.

In addition to the qualitative assessment of condition and effectiveness in the field, we also analyzed historical data on high water marks from 1884. We attempted to measure effectiveness in two ways: by qualitative assessments conducted in the field and by analysis of high water marks in the MORIS data maintained by the Massachusetts CZM office. By using GIS and Google Earth software to extract time-lapse photos of coastal erosion, it provided a map view of erosion over a period of time from 1998 to 2014. In order to add to the effect and visual representation of the Nantucket GIS map, we also looked at the high water mark map from the Massachusetts state website of CZM data (MORIS) so that we can compare property lines and property information with structure locations and high water marks. Figures 13 and 14 below are images from MORIS and Nantucket GIS respectfully; they included a series of changing high water marks between the years 1884 and 2009 from the MORIS map and individual property lines of Nantucket from the Nantucket GIS map. Using Morris maps allowed the team to assess changes in shoreline around the island due to variations in erosion and deposition.

Figure 13: Nantucket High Water Marks 1844-2009 (MORIS, 2014)

Figure 14: Nantucket Map and Parcel (Nantucket GIS) (MORIS, 2014)

3.1.3 Build, Test, and Refine Pilot Version of Database

As stated above, the database of coastal erosion structures was an accumulation of figures (such as age and ownership) and photos from onsite visits. The spreadsheet ensured that the data collected was pertinent data for the database and evaluations. When the beginning version of the database was created, the results of the database were presented to our sponsors for evaluation and critique. This database was the trial run and only consisted of data from the northwest section on the island to critique how well it worked. Once the database passed the evaluation, we refined its structure by adding in sections such as "Difference in High Water Mark", while also deleting categories such as "Overall Cost" since this information was not available in the permits. Other minor changes were made to the content, categories, and evaluation protocols based on lessons learned from the field assessment and the pilot test.

Analyzing these data required comparing how the changing characteristics of each structure evolved over time as well as the change in high water marks since the structure had been implemented. It allowed us to determine the effectiveness of the structure. Due to the changing wave currents and weather patterns that are site specific to different areas on the island, it also showed a pattern of what kind of structure succeeded or failed in any given location. Our inferences of the patterns are described in more detail in our Findings chapter.

3.1.4 Conducted Coastal Erosion Structure Inventory Following Protocols and Populate Database

We reviewed over eighty structure permits on file at the Natural Resources Department as well as any other data we could find in town records in order to assemble an initial list of structures on the island as well as basic information about each structure. When the initial analysis was complete we made on site visits to observe the coastal structures ourselves. While in the field, we gathered the information pertinent to the database and extracted as much data as possible regarding each individual structure. Once the data had been collected, the database consisted of 85 lines of data that listed characteristics of the 72 different structures we located on the island. Each line of data was then broken down into 20 different categories that highlighted the major characteristics of a structure. Table 4 is a small section of our database but shows different categories that were included in our spreadsheet.

Date and time surveyed in person	Structure Address	Type	Permit (Y/N)
11/3/2014-1:00pm low tide	15 Hallowell Ln	Bulkhead/Groin	Yes
11/3/2014-1:00pm low tide	11 E Hallowell Ln	Groin	Yes
11/3/2014-1:00pm low tide	28, 31 Hinckley Ln	Jagged Fence/Rock Filled Gabions/Mattress/Drift Fence/ Sand Replenishment	Yes
11/3/2014-1:00pm low tide	46 Jefferson Ave, 54 Jefferson Ave, 41 Jefferson Ave	Fence, Retaining Wall/ Beach Grass	Yes
11/3/2014-1:00pm low tide	7 Hallowell Ln	Beach Nourishment (with bulkhead)	Yes
11/3/2014-1:00pm low tide	13 Hallowell Ln (and abutters)	Bulkhead/Groin	Yes

Table 4: Database snapshot

We used this database to centralize all of our data and to make it easier to compare structures side by side when we began looking for patterns which we elaborate more on in the findings chapter. In addition to the database, a Google My Maps (a GIS based system) was created that displays an aerial view of the island with a point given to each coastal erosion structure location while also providing our onsite photographs and quick description of the structure. This aided in providing a more complete understanding of the location of coastal erosion structures on the island.

The accumulation of data we found and categorized during our project was one of the main focal points of our research project. This database was the central location of all our research presented in the form of an Excel ™ spreadsheet and places all site photos online into a Google My Maps which was available online. The data collected from site visits is included in the final database along with site photographs that were taken ourselves. From this, we have presented as much information as possible; however, in some areas a conflict arose (such as missing data). Specific measures were taken to correct this such as stating in the database itself that there is data missing. The database and its deliverables were given to the Natural Resources Department located on Nantucket for it to be continued and updated as needed. A "How To" manual (Appendix F) was created so that future attempts to maintain the database followed the same protocol.

3.2 Determined Stakeholders Opinions Regarding Coastal Erosion Practices

To determine the opinion of various stakeholders on the island regarding the current, past, and future erosion control practices, the team conducted a small number of interviews with selected town officials as well as affected property owners. In particular, the team reached out to members of the Conservation Commission, Coastal Management Plan Committee, the Siasconset Beach Preservation Fund, and other groups and individuals who have been opinion leaders in the various debates. A list of interviews can be found below in Table 5. The team however first reviewed minutes, reports, and other relevant documents to better understand the nature of the debate about coastal erosion practices on the island and the views of the principal actors.

List of Interviews Name	Affiliation	Date of Interview
Natural Resources Department	Natural Resources Department	October-December 2014
Nantucket Coastal Conservancy	Nantucket Coastal Conservancy	11/10/2014
John Merson	Baxter Road Resident	11/11/2014
Josh Posner	President, SBPF	12/7/2014
Harvey Young	Young's Bicycle Shop	12/11/2014

Table 5: Table of Interviews

The team reviewed the minutes and reports from town and Conservation Commission meetings related to coastal erosion issues. These minutes provided information on the legal process of applying for and obtaining permits for installing coastal erosion structures, the technical information typically required, the key factors involved, and the nature of the debates. The team also attended three Conservation Committee meetings (10/29/14, 11/12/14, 12/3/14) pertaining to coastal erosion that occurred while we are on island to ensure we are cognizant of current concerns regarding erosion.

All interviews were conducted in an in-depth qualitative style. The team had a set of starter questions and then developed questions as the interview proceeded to clarify responses depending upon whom the team was interviewing. The set of starter questions and topics the team used can be found in Appendix B. These questions were pretested with our advisors and sponsor liaisons to ensure they elicit the desired information. The interviews were conducted with the presence of at least two team members, one to be the interviewer and the other to take notes. To set up the interviews with potential contacts the team used email or made a phone call discussing the intent of the interview and how they could participate if willing. The interview was then conducted in person or by phone depending upon the preference of the interviewee. The people the team chose to interview were determined by the methods in the past section. The team began by interviewing key stakeholders and opinion leaders recommended by our sponsor and then proceeded with others individuals identified in our review of newspaper reports and meeting minutes. From there we asked each interviewee to identify others we should interview as a snowball sample. After identifying erosion structures in our first objective we attempted to contact the homeowners with these structures on their property. We intended to interview a sample of homeowners because they could provide information on the structure that is located on their property that may not be recorded elsewhere, such as how and why it was installed, how it has been maintained, and how effective they believe the structure has performed. After arriving on island we realized this was difficult to accomplish since many of the homeowners leave island after the summer months and they are difficult to get in contact with. After the interviews were completed the notes were compiled and key statements were taken from them and used in our analysis and conclusion. Before publishing any information from interviews the team sent a copy of the report to all individuals interviewed to confirm that the information they stated was correctly portrayed. This was also to allow the interviewee to request for any information to be dissociated with his or her name and or have any parts from their interview removed.

3.3 Analyze Results and Make Recommendations

Once all the field research was completed, we first analyzed the data we collected on the structures themselves. This consisted of looking at the effectiveness of each individual category, or type, of structure based on our rating scale (Section 3.1.2), and taking into consideration the duration each structure had been in place, where it was located (its corresponding street address), the positive and/or adverse effects it had on the immediate and surrounding beaches and properties, and whether or not the structure was maintained. If the structure was maintained, we made a note in the database concerning the frequency of maintenance and, when the information was available, who was in charge of the upkeep, be it the town or private property owners. Additionally we were able to keep track of the different coastal environments of the island by recognizing where a structure was and placing it in the corresponding regional category (i.e. harbor region) and thus we were able to offer multiple recommendations based on the varying environments. From this gathered information, we were able to identify which structure type(s) appeared effective based on our ratings, what benefits or disadvantages, the structures gave both the town and private property owners, and in some cases, if the structures were permitted or not.

Based on the information from the interviews and reviewing of archived information, such as newspaper articles and town meeting minutes, we were able to gauge the opinions of the individual people and groups involved in regards to coastal erosion and the preventative methods currently in place. We aimed to obtain as varied opinions on the topic as we could while maintaining as neutral a stance as was possible.

4 Findings

In our Findings chapter, we focused on presenting the facts and key patterns that were discovered through all of our observations. Because coastal erosion is such a major part of the island's history and politics, we chose to focus solely on the scientific facts found based on our research and observation. We first analyzed patterns between structures (Section 4.1) and apply our effectiveness rating scales to each structure. Our ratings on effectiveness are preliminary as there is currently no concrete way to determine a structure's effectiveness. With our preliminary ratings, site visits, and permit data, our database is the most comprehensive collection of data concerning coastal erosion structures on Nantucket. We then address the proximal impacts of specific structures (Section 4.2) and observations of specific structures and locations. Finally, we address stakeholder perspectives (Section 4.3) through interviews and town meetings.

4.1 The Nature and Impacts of Coastal Erosion Structures on Nantucket

To address our database analysis findings we first looked at each individual structure and analyzed the patterns of their characteristics (Section 4.1.1) based on their location to allow side by side comparisons of structures in the same locations. We divided the island into four different sections: the northwest (Section 4.1.1.1), Siasconset Beach (Section 4.1.1.2), the south coast (Section 4.1.1.3), and the harbor area (Section 4.1.1.4).   From there we addressed the quality and style of each structure (Section 4.1.2) to show what type of structure was more common on the island or in a specific area and how they each compared. The final section was used to incorporate our effectiveness rating scales (Section 4.1.3). By using this we could make comparisons of what kinds of structures were most effective and to what area.

4.1.1 Structural Patterns by Location

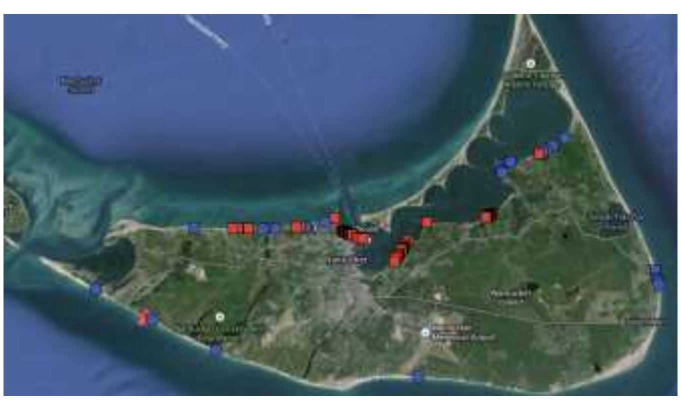

Figure 15: Nantucket Coastal Erosion Structures (Google My Maps, 2014)

The structures are organized in the database by five coastline sections (Northwest Coast, Siasconset Beach, the South Shore, and the Harbor Section) and then ordered numerically by map and parcel number. Figure 15 shows our Google My Maps application. The map shows every structure documented in a specific section and represents that structure based on its type as either a hard structure (red square), soft structure (blue circle), or a structure that has qualities of both a hard and soft structure (blue square).

4.1.1.1 The Northwest Section

The northwest section spans from North Point to Bathing Beach Road. Figure 16 was taken from our Google My Maps application. We identified 12 private structures across 23 separate properties in the northwest section. Many of the structures are periodically repaired to maintain their structural integrity since all have been built in the last 40 years. Of these structures half were hard structures and the other half were soft structures. We found the following types of structures: fences, bulkheads, beach grass, groins, plantings, zigzag fences, rock walls, gabion baskets, and sand replenishment efforts (Table 6). We discovered (Table 6) that the majority of structures were structurally stable and 7/12 (58%) were showing signs of visible accretion of sand however 9/12 (75%) structures were showing signs of erosion. Five (42%) structures showed signs of both. Three (25%) structures showed signs of scouring on either edge of the structures.

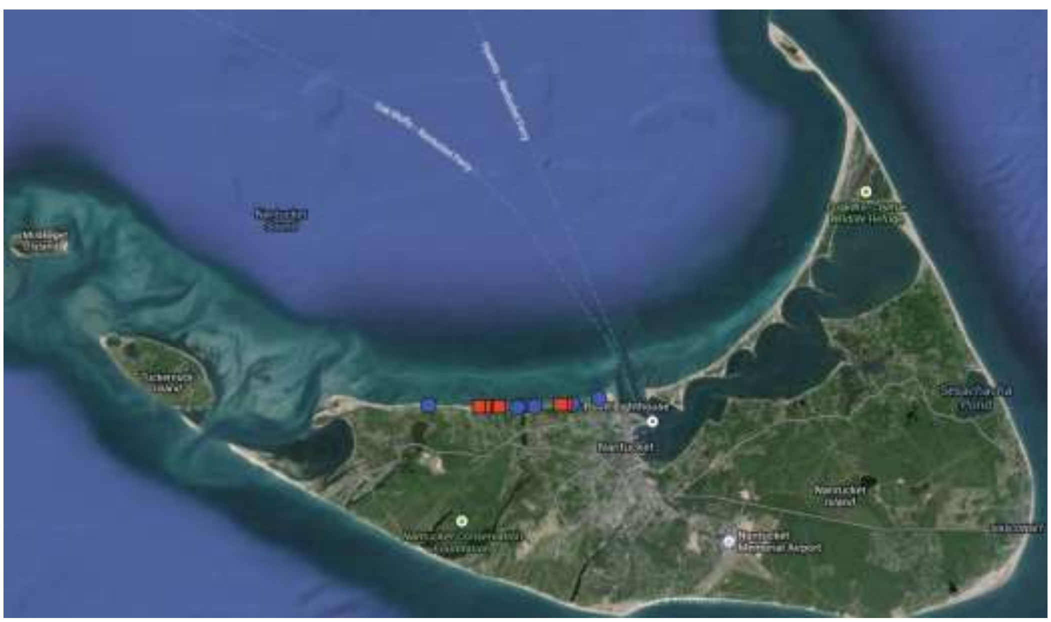

Figure 16: Northwest Section (Google My Maps, 2014)

Structure and Parcel Number(s)	Erosion	Accretion	Scouring	None/New Structure
Dune Fencing and Beach Grass (Soft) 30 44, 30 44.1, 30 45	X	X		
Zigzag Fence and Beach Grass (Soft) 30 22.2	X	X		
Wooden Groins (Hard) 30 93	X	X		
Wooden Groins (Hard) 30 257, 30 257.1, 30 11, 30 10, 30 17	X			
Metal Bulkhead with Wooden Groins (Hard) 31 18.1	X		X	
Wooden Bulkhead (Hard) 31 1	X		X	
Rock Wall with Wooden/Stone Groins (Hard) 31 4	X			
Rock Wall and Sand Fence (Hard) 31 5, 31 7, 31 8, 31 9	X		X	
Sand Fence (Soft) 31 13.3				X
Zigzag Fence (Soft) 31 15.5		X		
Dune Fencing and Beach Grass (Soft) 31 19		X		
Zigzag Fencing, Jute Bags, and Beach Grass (Soft) 32 9, 32 10, 32 11	X	X		

Table 6: Effects of Northwest Structures

4.1.1.2 The Siasconset Beach Section

The Siasconset beach section spans from the eastern end of Milestone Road up to Sesachacha Pond. We identified 5 private structures across 6 separate properties along the coast below Baxter Road (Figure 17). The controversial geotubes that have been put in place by the SPBF are shown as the blue square (i.e., hybrid soft and hard structure) on Figure 17. These geotubes act as soft structures when covered with sand and hard structures when uncovered. The remaining 4 structures are soft structures located on multiple properties where the homes have been moved further away from the bluff in the past 10 years. The types of structures at Siasconset include: jute bags, jute mesh, beach grass, and sand replenishment. These structures were all installed in the past 5 years and some even during our site visits. Since these structures have been installed very recently they have not been updated or modified, except for sand replenishment. Of these 5 structures, we were able to locate 4 of the erosion structure permits. As shown in Table 7, we discovered that one structure was showing signs of visible accretion of sand but three structures were showing signs of erosion already. The remaining structure was being installed the day of our site visit and therefore could not provide any data.

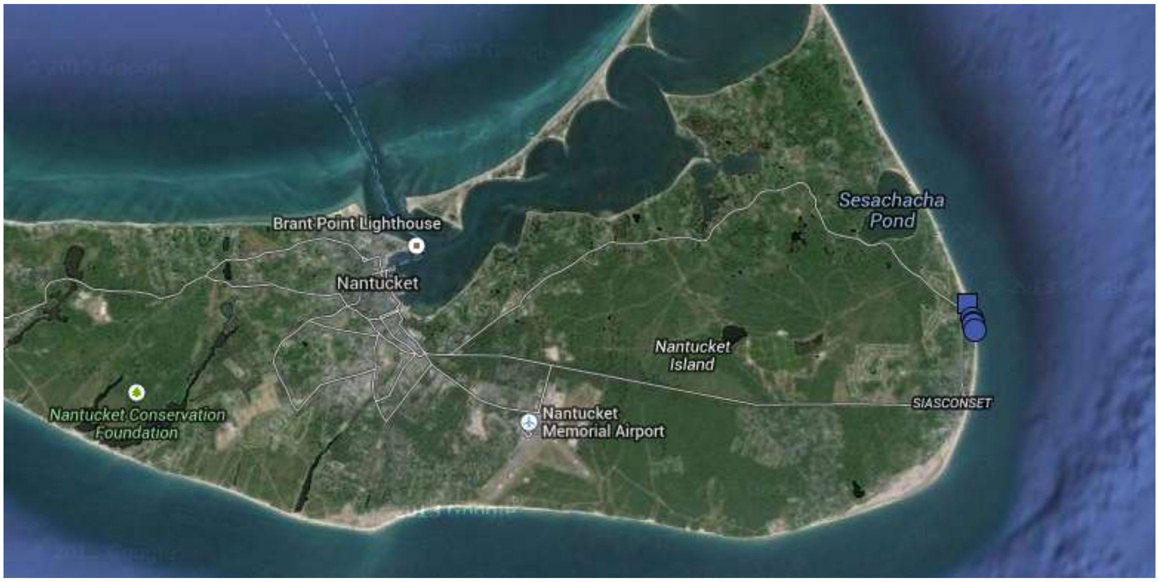

Figure 17: Siasconset Section (Google My Maps, 2014)

Structure Parcel Number(s)	Erosion	Accretion	Scouring	None/New Structure
Geotubes with Sand Nourishment 49 17	X			
Beach Grass and Jute Mesh (Soft) 49 24				X
Jute Bags (Soft) 49 27	X			
Jute Mesh and Bags (Soft) 49 30		X		
Beach Grass, Jute Mesh and Jute Bags (Soft) 49 32, 49 33	X			

Table 7: Effects of Siasconset Structures

4.1.1.3 The South Coast Section

The south coast section spans from the east end of Milestone Road then west to Smith Point. We identified five private structures across six separate properties along the southwest coast (Figure 18). All of the structures were soft structures. The south coast had sand drift fencing, zigzag fences, and beach grass plantings. Many of these structures have been in place for a long time but after multiple years of use they are now either in severe disrepair, no longer providing any protection or no longer have effects on the surrounding beach. As shown in Table 8, one structure showed signs of visible accretion of sand, two showed signs of erosion, and one showed signs of both. None of the structures showed signs of scouring, but three were so damaged that they showed no signs of any adverse impacts.

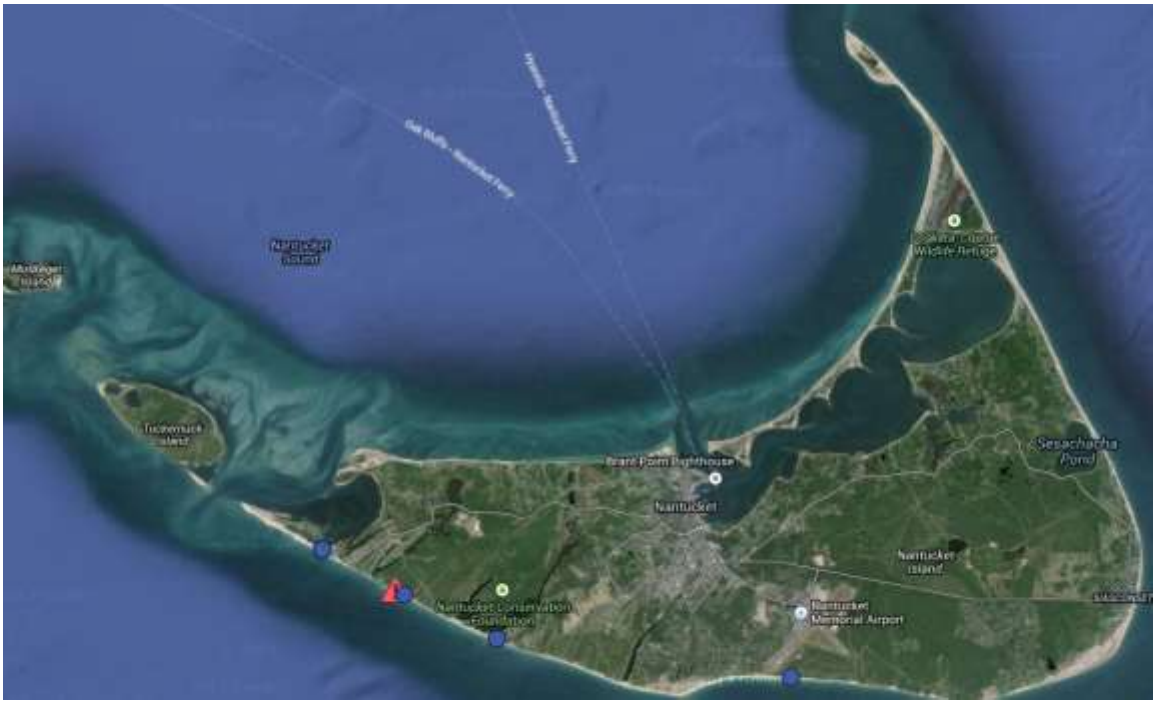

Figure 18: South Section (Google My Maps, 2014)

Structure Parcel Number(s)	Erosion	Accretion	Scouring	None/New Structure
Sand Drift Fence (Soft) 62 39.2				X
Zigzag Fence (Soft) 88 68				X
Sand Drift Fencing (Soft) 60.3.1. 15	X	X		
Sand Drift Fencing (Soft) 60.3.1 1, 60.3.4 98	X			
Zigzag Fence and Beach Grass (Soft) 83 3				X

Table 8: Effects of South Coast Structures

4.1.1.4 The Harbor Section

The harbor section spans from the Brant Point to Wauwinet and was the most densely populated area with 50 private structures across 52 separate properties (Figure 19). Since the harbor section was so densely populated, it had a variety of different types of structures including: sand fences, rock walls, wooden fences, beach grass, jute bags, beach nourishment, zigzag fence, (metal, wooden and concrete) bulkheads, windscreens, rock and wooden groins. These were all private structures with the only public erosion structure being the jetties located at Jetties Beach. As shown in Table 9, 16 (32%) of structures showed signs of visible accretion of sand but 30 (60%)

of structures showed signs of erosion. Five (10%) structures showed signs of both erosion and accretion.

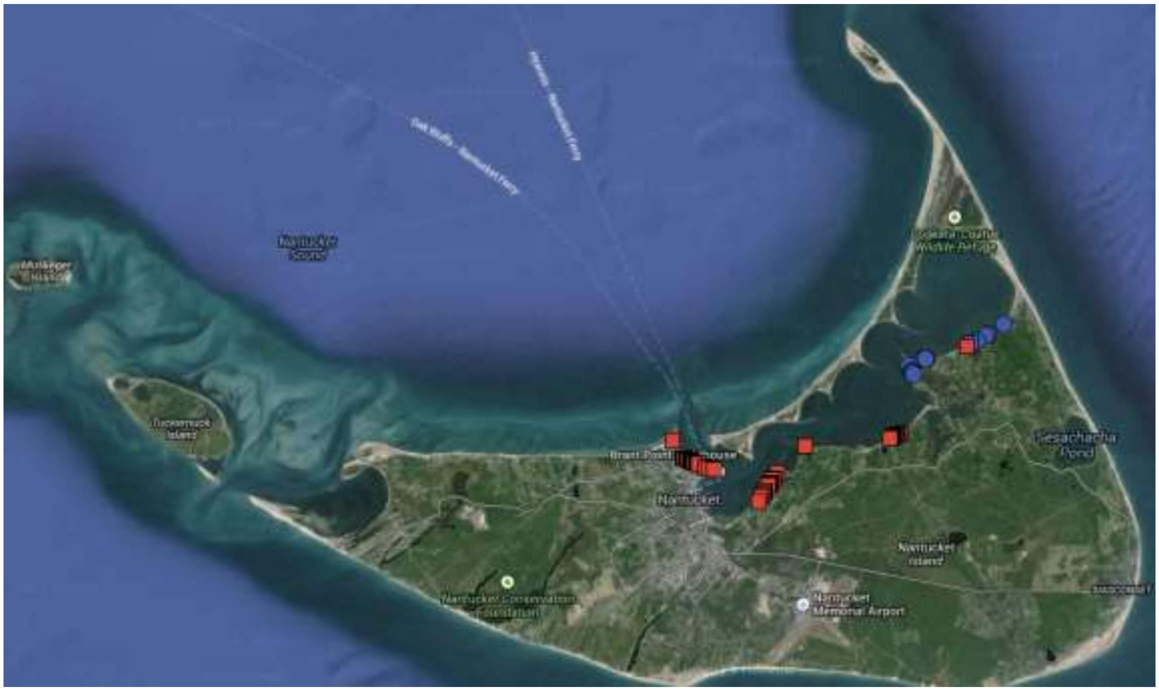

Figure 19: Harbor Section (Google My Maps, 2014)

Structure Parcel Number(s)	**Erosion**	**Accretion**	**Scouring**	**None/New Structure**
Sand Fence (Soft) 11 28				X
Rock Wall (Hard) 14 10.1	X		X	
Wooden Fence, Beach Grass, and Jute Bags (Soft) 14 14	X		X	
Zigzag Fence and Dune Nourishment (Soft) 14 15	X			
Wooden Fence and Dune Nourishment (Soft) 14 17	X		X	
Wooden Fence, Beach Nourishment, Beach Grass, and Jute Bags (Soft) 14 56.2	X		X	
Beach Nourishment and Beach Grass (Soft) 15 9				X
Sand Fencing (Soft) 15 10	X	X		
Sand Fencing (Soft) 15 11	X			
Sand Fencing (Soft) 15 12	X			

Structure Parcel Number(s)	Erosion	Accretion	Scouring	None/New Structure
Beach Grass (Soft) 15 39	X			
Wooden Fence (Soft) 15 40				X
Zigzag fence, Beach Nourishment, Beach Grass, and Sand Fencing (Soft) 15 41	X	X		
Zigzag Fence, Beach Grass and Dune Nourishment (Soft) 15 43, 15 42	X			
Metal Bulkhead and Beach Grass (Hard) 26 2	X		X	
Wooden Bulkhead and Beach Grass (Hard) 26 3	X			
Metal Bulkhead (Hard) 26 4	X			
Concrete Bulkhead, Rock Wall, and Rock Groin (Hard) 26 5			X	
Concrete Bulkhead and Rock Groin (Hard) 26 7	X		X	
Metal Bulkhead (Hard) 26 8	X			
Metal Bulkhead and Sand Nourishment (Hard) 26 11	X			
Wooden Bulkhead and Rock Groin (Hard) 26 12	X		X	
Bulkhead (Hard) 28 6				
Wooden Bulkhead (Hard) 29.2.3 6.1		X		
Windscreen Fence (Hard) 29.2.3 3		X		
Windscreen with Sacrificial Sand (Hard) 29 6, 29 7, 29 9	X			
Wooden Bulkhead with Windscreen (Hard) 29 10	X	X		
Wooden Bulkhead, Windscreen, and Groins (Hard) 29 11		X		
Wooden Bulkhead and Groins (Hard) 29 12		X		
Wooden Groins (Hard) 29 13	X	X		
Wooden Groin (Hard) 29 15		X		
Wooden Groin (Hard) 29 16		X		
Wooden Bulkhead (Hard) 29 17				X
Wooden Bulkhead and Windscreen (Hard) 29 19				X
Wooden Bulkhead (Hard) 29 20	X			

Structure Parcel Number(s)	Erosion	Accretion	Scouring	None/New Structure
Wooden Bulkhead (Hard) 29 21	X			
Wooden Bulkhead and Groin (Hard) 29 23		X		
Wooden Bulkhead (Hard) 42.1.4 6	X			
Wooden Bulkhead and Beach Grass (Hard) 43 1	X			
Sand Fence (Hard) 43 69	X	X		
Wooden Bulkhead and Rock Groin (Hard) 43 77		X		
Wooden Bulkhead (Hard) 43 81	X		X	
Wooden Groin and Bulkhead (Hard) 43 82		X		
Wooden Groin (Hard) 43 83		X		
Wooden Bulkhead (Hard) 43 84	X			
Wooden Groins, Beach Nourishment, and Beach Grass (Hard) 43 85		X		
Wooden Bulkhead, Groins, and Fence (Hard) 43 124	X			
Wooden Bulkhead and Groin (Hard) 43 125				X
Sand Fencing (Hard) 43 126				X
The Jetties (Hard)		X		

Table 9: Effects of Harbor Section

Nantucket's geography is continuously shifting due to ocean currents, wave energy, and severe weather. This means that each structure has to address its specific surroundings. For example one type of structure may be more effective in the harbor section due to its low wave energy, but will be far less effective if placed in a high wave energy location. Overall, there were numerous differences between all of the locations, their structures and their effects,

4.1.2 Quantity and Style of Structures in Nantucket

Based on Table 10, 6/12 (50%) of the structures in the northwest section were soft structures and 6/12 (50%) were hard structures. The most commonly used soft structure was fencing and beach grass and the most common hard structure was a wooden groin. In the Siasconset section as well as the south section all 5 structures in each area were soft structures. In the Siasconset section the most popular erosion structure was the jute bag and in the south section the most popular structure was sand fencing. In the harbor section out of the 50 structures, 14/50 (28%) were soft structures and 36/50 (72%) of the structures were classified as hard structures. The most common soft structure was sand fencing and most common hard structure was wooden groins

Location	Soft Structures	Hard Structures	Total Structures
Northwest Section	6	6	12
Siasconset Section	5	0	5
South Section	5	0	5
Harbor Section	14	36	50
Total	30	42	72

Table 10: Quantity of Hard vs. Soft Structures

We have observed that fencing, bulkheads and beach grass plantings reoccur the most on island. While most of the bulkheads predate 1978, the fencing and beach grass have been continuously permitted for over 30 years.

4.1.3 Structures and Their Effectiveness

After analyzing all the data and information we gathered, there are no specific criteria necessary for a structure to follow to be considered "effective." This is in part due to there being many outside factors such as wave energy, tidal patterns, and up shore and down shore drifts. Due to these varying forces, there were many examples where the same type of structure worked differently in one location than it did in another. For this reason, it is difficult to accurately evaluate effectiveness. As discussed in the methodology chapter, we established a list of guidelines to help provide us with a simple set of tests to rate each structure's effectiveness. Our ratings on effectiveness are preliminary as there is currently no concrete way to determine a structure's effectiveness. With our preliminary ratings, site visits, and permit data, our database is the most comprehensive collection of data concerning coastal erosion structures on Nantucket. Our effectives rating scales address the conditions of the structures, the surrounding properties, and the beach in front of the structures. By rating each category a 0 (meaning poor), 1 (meaning fair), or a 2 (meaning good) we developed a system that would provide us with a numerical answer. The following table 11 is the list of structures that we were able to rate the effectiveness of.

Location	Score of 5 or Higher	Score of 3 or 4	Score of 2 or below
Northwest Section	6	6	0
Siasconset Section	4	1	0
South Section	0	2	2
Harbor Section	21	27	2
Total	31	36	4

Table 11: Effectiveness and Location

If a structure was given a score of 5 or better, then it would be considered an effective coastal erosion structure. If it was rated a 3 or 4 it is considered an adequate structure. Any structure rated a 2 or below is considered an ineffective structure.

We also looked at the differences in whether or not hard structures or soft structures received a more effective rating. These findings are shown below in table 12.

	Effective	Adequate	Ineffective
Hard	20	21	1
Soft	11	15	3

Table 12: Effectiveness of Hard vs. Soft

Hard and soft structures had 50% and 52% respectively of adequate structures. Soft structures had 38% effective and 10% ineffective. Hard structures had 48% effective and 2% ineffective. Soft structures are designed to fail in high energy situations so that may be a possible explanation for why we found more of them in an ineffective state.

4.2 Structure types and proximal impacts

In addition to the patterns observed from the aggregate data on coastal erosion structures, we also observed other patterns at the individual structures or locations.

4.2.1 Groins

A groin focuses on trapping and retaining sand through longshore drift to mitigate erosion. Sediment collects on the up-drift side of the groin and is eroded on the down-drift side. Groins are often set up in groups called groin fields and on Nantucket we noticed that the groins were typically set up in groin fields in conjunction with a seawall. There were two major types of groins installed on the island; timber groins and rock groins. Figure 20 below shows an example of a pair of timber groins at Shimmo Pond Road and Figure 21 shows an example of a field of rock groins on Quaise Road. In both cases they are joined to a seawall. Location also has an impact of how an effective a groin field works. If wave energy is too high the groins become deteriorated and the sediment is washed away before it can accumulate. Figure 22 shows a close up view on the wear of the rock groins in Figure 21 where they connect with the bulkhead.

Figure 20: Timber Groins Along Shimmo Pond Road, Nantucket harbor

Figure 21: Rock Groin Field, Quaise Road, Nantucket Harbor

Figure 22: Close up View of Rock Groins, Quaise Road

While most of the groins we observed had effects of scouring and accretion near the groin itself, one groin field on Hulbert Avenue had a significant impact. The half mile stretch of coastline along Hulbert Avenue just inside the harbor is lined with timber bulkheads and groins that were installed prior to 1978; hence they did not undergo the permitting process. The groins appear to have been successful in trapping sediment and this entire stretch of coast has signs of accretion. Figure 23 below shows a photograph from 1981 that was found in the permit for the wooden bulkhead repair and Figure 24 shows a picture we took in 2014.

Figure 23: Hulbert Avenue, 1981

Figure 24: Hulbert Avenue, 2014

Figure 25 shows an aerial photograph of Hulbert Avenue with a smaller section of the shoreline expanded to show a current and past image. From these images, we deduce that the direction of natural beach sand transport runs right to left in the photo. The 2014 photo indicates substantial sand accretion along the shore in the right between the groins to the left in the photo. We infer that the accretion is a result of the groins, although it is possible that accretion might have occurred without the emplacement of the groins.

When we visited the sites along Hulbert Ave most of the groins are just visible above the sand and many had sand accretion along the bases of the timber bulkheads. The purpose of a groin is to trap sediment from longshore drift and this section appears to be successful since it shows signs of accretion.

Figure 25: Hulbert Avenue Aerial Photographs (Google, 2014)

4.2.2 Seawalls

Some of the largest structures on the island that predate 1978 are located along the northwest shore. These structures consist of large hard armoring and seawalls. There are a total of four seawalls; two large rock walls, a timber bulkhead, and a metal bulkhead. While each of these structures shows signs of success in preventing the land behind it from being washed away, they also show adverse impacts similar to those documented in the research literature. When wave energy hits a shoreline it is absorbed by the dune and as a result sand is released to replenish sand that is lost. When wave energy hits a seawall, the energy has nowhere to go so some of it is deflected downwards into the beach below. This can be seen in Figure 26 along East Tristram Avenue where one of the dilapidated groins is still attached to the rock wall. The energy results in vertical scouring and beach is lost at the base of the seawall. Since the seawall is locked in place there is no source of sand to replenish the sand that was lost. The dark line along the rock wall shows the reach of the recent high water line.

Figure 26: Rock Wall, East Tristram Ave, Nantucket Northwest shore

Along with vertical scouring, we also observed regular scouring at the four seawalls we visited. The energy that isn't deflected downward is deflected to the side and results in increased energy at the end of the seawalls. The seawall at East Tristram Avenue (Figure 26) has suffered some of the most severe scouring we observed on the island Figure 27 below shows the location of the seawall in relation to Jetties Beach and the inset photos show the extent of scouring over 13 years.

Figure 27: Aerial Photographs, East Tristram Ave, Nantucket Northwest shore (Google, 2014)

Any structure that was built before 1978 can be rebuilt or repaired in the same way that it was originally created; however it cannot be expanded upon or moved. This poses a problem for seawalls that have experienced effects of scouring since the seawall cannot be expanded to compensate for the lost land. Homeowners however may apply for a separate permit that allows them to implement a soft structure to mitigate the effects of the scouring. As highlighted in Figure 26 by the red arrow, a zig-zag fence has been added at the end of the rock wall to try to limit scouring.

4.2.3 Soft Structures

After the Town imposed a ban on hard structures there was a shift to the use of soft structures. Hard structures may still be permitted for buildings that predate 1978 if a soft method cannot be proven to be a viable option. Beach grass plantings, sand nourishment, jute bags, and sand fences are now the preferred methods permitted by the Conservation Commission. Soft structures are more versatile and can be adapted to each location. They have less of a dramatic impact on the natural environment and are designed to fail in cases of extreme wave energy. In most cases we saw the use of a jute mesh to stabilize the bank until the beach grass seedlings had a chance to take root and grow and then the use of jute bags or a fence to stabilize the toe of a bluff. Figure 28 shows a section of the Siasconset bluff that was permitted with a soft structure. Along this section the beach grass had a chance to stabilize and grow and the base is supported by rows of jute bags.

Figure 28: Jute Bags and Beach Grass, Siasconset Bluff Nantucket

Figure 29 shows the use of a zig-zag wooden fence with sand nourishment behind the fence and beach grass plantings at Pocomo Road. Along the bank of the dune sections of sand drift fence have been used to trap sediment blowing over the dune. Figure 30 shows an example of a linear wooden fence at Coskata with a dune that has a section of well-rooted beach grass plantings. The section of dune was lined with a jute mesh before the seedlings were planted.

Figure 29: Zig-zag Fence, Beach Nourishment, Beach Grass, Pocomo Road Nantucket

Figure 30: Linear Fence, Beach Grass Plantings, Jute Mesh, Coskata Course Way Nantucket

To stabilize the section of dune behind a seawall or bulkhead we also observed in many cases the use of soft structures to prevent runoff erosion and wave energy that may crest the seawall. Figure 31 below shows an example of jute mesh and beach grass plantings that stabilizes the bank behind a seawall at Quaise Road in the harbor section of Nantucket.

Figure 31: Wooden Bulkhead with Beach Grass and Jute Mesh, Quaise Road Nantucket

4.2.4 Idiosyncratic Structures

While most structures on the island conform to those described in the research literature, we also found a few structures that were idiosyncratic combinations of approaches to erosion control. One of these structures was located at 11 Lauretta Lane. This location was permitted for sand fencing, coir jute bags, sand nourishment, and beach grass plantings. The structure was assembled from materials permitted for a soft structure but it actually functions in a similar way to hard armoring. As seen in Figure 32 the fencing is layered in such a way with the jute bags that it prevents sand from passing through it. As a result, the fence acts as a solid structure like a sea wall and blocks the source of sediment for the beach directly in front. Figure 33 shows the resultant loss of beach in front of the fencing.

Figure 32: Right View of Lauretta Lane, Nantucket

Figure 33: Left View of Lauretta Lane, Nantucket

Another example of idiosyncratic structures is the series of seawalls and groins along Quaise Road. This section has a combination of seawalls (wooden, cement, metal, and rock), rock groins, beach grass, and beach nourishment. From the permits we looked at, the different structures were installed one after another after the first installation of hard armoring. This is visible from the transitions in the styles of bulkheads along the road. After the first few installations of hard armoring the neighboring houses began experiencing the effects of scouring on their own property so they then installed their own bulkheads and groins. Figure 34 shows an aerial photograph with four images of the different style of bulkheads used.

Figure 34: Aerial View of Quaise Road, Nantucket Harbor

At this location we also observed the effects that seawalls have on the beach directly in front of them. The erosion and wear, also known as vertical scouring, in front of the seawall shown in Figure 35 is a result from a lack of sediment to replace the sand that is lost from wave energy.

While most of the structures we looked at relied on one style of erosion structure the section along Quaise Road used a combination of many different styles of hard armoring and soft structures.

Figure 35: Vertical Scouring at Seawall, Quaise Road

4.3 Stakeholder Perspectives

Our group had the opportunity to interact with multiple people and organizations throughout the duration of the project. We interviewed a small number of people to gauge some of the primary stakeholder concerns. We intended to interview many more, including property owners, but did not have time. The results of the few interactions varied between each occurrence. We found that we obtained more in-depth information and explanations from individual people than from an organization overall. Given the information from these interviews, we got an idea of the different stances regarding the anti-erosion efforts on the island. In one instance, one person we spoke with lived close to an eroding bluff, but opposed the ongoing erosion project. He was made aware when he purchased his property that there was a possibility that his land would one day shrink, or even disappear. After analyzing the information from the interactions, and what the data in the database showed, we came to the conclusion that the situation is very unique, as it is extremely complicated and the topic is very controversial. Due to the nature of the topic, we could not find a simple solution to recommend the town. This section details the interactions first by individual people, then with organizations. The table from Methodology Section 3.2 is copied below with a complete list of people and groups we contacted (Table 13).

List of Interviews Name	Affiliation	Date of Interview
Natural Resources Department	Natural Resources Department	October-December 2014
Nantucket Coastal Conservancy	Nantucket Coastal Conservancy	11/10/2014
John Merson	Baxter Road Resident	11/11/2014
Josh Posner	President, SBPF	12/7/2014
Harvey Young	Young's Bicycle Shop	12/11/2014

Table 13: Table of Interviews

Within the time frame of the project, we were able to interact with multiple people and interest groups. Building on our review of the literature, we interviewed Jeff Carlson, Director of NRD, to determine more clearly the permitting process. We learned that in order to obtain a permit a homeowner must first complete the permitting process as described in the Literature Review.

While working on our project, we also attended three Conservation Commission meetings on October 29, November 12, and December 3, 2014. We were able to witness how the Conservation Commission hears a project, discusses it, and votes on the project and approves, denies, or continues the discussion to the following meeting. The hearing process consisted of the Conservation Commission beginning with their opening statements and then went on to hear each case, first for Notice Of Intents, then Determinations of Applicability, Minor Modifications, Certificates of Compliance, Orders of Conditions, (when applicable) Emergency Certifications, and then final concerns from the public. With each case that was brought before the board, the Conservation Commission and public were allowed to ask questions regarding the project and any group or person with concerns had the opportunity to raise their concerns in front of the board. During one of the two meetings we attended, we were given insight into how contentious projects on, in or near resource areas are. In one case, although not erosion related, the discussion went back and forth between the engineer, lawyer, Conservation Commission, and opposing groups for fifteen minutes. During this one instance, the homeowner wished to implement an access walkway on their property which would be placed through a resource area. A simple walkway led to a lengthy discussion about alternatives, the possibility that it would set precedents for other homeowners wishing to do the same, and the possible impacts it would have on the vegetation and animal life.

One of the organizations our group was in contact with was the Nantucket Coastal Conservancy. We were invited to attend a meeting and present information regarding our project to the Conservancy, explaining what our IQP was about. After giving a brief presentation of the data we had collected, presenting our preliminary database, and further explaining what our project's primary focus was, we took questions regarding our project from the members of the Conservancy. We found that some were interested in the statistical data our database could give, such as percentage of hard or soft structures, for example. Most of the question regarded what our project would include and exclude and the deliverable items we would give the town, which include a database on the structures, a pictorial database to accompany it, pamphlets describing our methods for obtaining data, and the criteria we used to evaluate the effectiveness as best we could. We found that, in the group’s opinion, the deliverables and the information within the database was much needed for the town, as there were no current, digital locations with all the data on the structures around the island. What data did exist, were in hard copy permit form and the critical information had to be extracted from these files. In their opinion, our project would directly and immediately impact the town in a positive way, as anyone who would be interested in information regarding coastal erosion and coastal erosion structures on the island would have access to the database.

Additionally, our group met with, and interviewed John Merson, a homeowner on Baxter Road in Siasconset. He maintains a relatively neutral stance on most of the projects that are in place along the bluff, although has opposed the geotube system and other hard armoring projects. He does however, maintains an open line of communication with supporting parties as he believes there will be a need for a compromise. To support his personal position he has done a significant amount of research regarding erosion. In his research he discovered that “most of the techniques that are used to prevent erosion end up destroying beaches in the name of protecting houses and that the basic problem is that we are building too close to the beach...people want to protect what they built and Baxter road is a really good example” (Merson 11/11/14). Some of the more critical infrastructure, not including the numerous homes that have been or are in danger of being lost to the ocean, that is in danger of being jeopardized by erosion includes the airport runway and water treatment plants. In his opinion, the town is going to "need to come up with an island-wide solution" (Merson 11/11/12).

From the research Mr. Merson has done, from the information he shared with us, and backed by our experience on the island, we learned that people are still unsure how exactly to proceed with the erosion problem, as it is still difficult to "understand how the ocean moves sand up and down the beach. So we are not sure what it is going to take to counteract it" (Merson 11/11/14). Mr. Merson described one of the biggest problems with erosion and trying to implement a structure when he said erosion is like an "unknown unknown" or something that we don't realize we don't know. He states that he thinks "that often comes into play when we look at erosion. The science of beach erosion and rock revetments and some of the other techniques, tells us what's likely to happen but we can still completely miss on what the natural world is going to do" (Merson 11/11/14) meaning we can study and research beaches, erosion, and different structures, but we cannot fully know what part nature will play. We found that this statement was very true, as weather is not completely predictable and the effects of a storm, or wind, or water runoff cannot be precisely pin-pointed.

Our team also met with Josh Posner, who represented the Siasconset Beach Preservation Fund (SBPF). Mr. Posner has a long familial history on the island, going back over 50 years to when his family used to spend their summers on the island. For this reason, we learned Mr. Posner has a personal attachment to the island and its history. Through our interview with Mr. Posner, we learned that the SBPF was founded in the 1990s. In the 1990s erosion was becoming more of a visible problem and families began moving their houses back on their lots away from the water. The mission of the SBPF is to "Identify ways to protect and preserve 'Sconset Beach and Bluff that are environmentally responsible, carried out collaboratively and help Nantucket adapt to climate change and rising sea levels that threaten its very existence" (Sconsetbeach.org). We learned from Mr. Posner that in the past, the SBPF has made several attempts to mitigate erosion. One of the first attempts was to install a dewatering system along the edge of certain sections of the beach. The group had researched the method thoroughly and received approval from the Conservation Commission. The supporting theory was that sand would build up along the areas of beach where the dewatering was taking place. However, despite the research, the method was not successful, although, according to Mr. Posner, "there's sort of an area where it might have worked… Cod Fish Park did experience a major buildup of beach at the same time as the dewatering was functioning" (Posner 12/7/14). We found that the group made several other attempts to get permits for experimental mitigation projects after the dewatering system failed, including beach nourishment, which when project opponents put a referendum question on the ballot in 2008 was shot down 85 percent to 15 percent. We learned from this interview that some believe the town should be more receptive to trying different methods on an experimental basis as long as any effects are reversible if the methods do not work, they are being paid for by those who would benefit and not the general taxpayers, and they are at no harm to anyone else or any other beaches and properties. "I don't think that all erosion should be stopped, but I do think there are places where erosion harms historic communities and it's totally reasonable if you can do it to do something to offset that as long as you're not hurting anyone else" (Posner 12/7/14).

We also learned through talking with Mr. Posner about current efforts in Siasconset. We learned that when Baxter Road became threatened by the heavy erosion, the original plan for the beach parallel to Baxter Road was proposed as a 4000 foot long rock revetment, which was taking so long to get approved that SBPF put the application on hold and applied in conjunction with the town for the current geotube system which was installed between December 2013 and January 2014 along a 900 foot section where the road was deemed most threatened. We also learned that approximately $100,000,000 of property value has been lost due to the severe erosion in Siasconset. When asked more about the cost of the geotube project Mr. Posner stated that "even though the costs of the project are in excess of $5 million, the value that is being protected and restored is many times greater. That's not counting the personal history many people want to protect and the whole idea of eventually protecting the village of 'Sconset itself" (Posner 12/7/14).

In addition to the erosion at the toe of the cliffs, throughout our project we found that there are other contributing factors, one of which is road run off, where after a storm, storm water drains down the side of the cliff and cause additional erosion. In order to manage the excess water from storms, during one of the Conservation Commission meetings we attended, the town, which has "a legal responsibility to deal with this storm water" (Posner 12/7/14) brought a storm water management system to the Conservation Commission. Whether the erosion is happening due to the water run off or the high wave energy or the high winds, we found that there is still a lot to learn when it comes to erosion.

Our team also took a trip to Great Point with Mr. Harvey Young to learn more about the natural transport and deposition of sand. Harvey young has been a long time resident of the island and owns a bike and jeep rental shop in town. He has taken many trips out to Great Point and he has watched the changes of this coastline that occur over time. During our trip, Mr. Young pointed out various interesting things. One of these things was the size of the dunes along the beaches up to Great Point. He told us that at any given point, the dunes could appear to be taller or shorter, due to the amount of sand on the beach. When the beach is accreting, the dunes appear to be relatively short, and one can see over top. However after a storm, the dunes sometimes appear to be much larger and the beach side of the dune becomes more of a shear face. The dunes are continuously shifting and rebuilding with each storm period.

He also pointed out to us that this stretch of coastline is one of the longest and naturally uninterrupted beaches on Nantucket except for in one location. Next to Coskata Pond there is a section of hard material, as seen in Figure 36, which he suspects was deposited when the island was formed by the glaciers. This section of hard land is the only interruption that occurs along the stretch of dunes out to Great Point. Over the years he has seen this piece of land act in similar ways to a naturally forming bulkhead or seawall. In large storms the wave energy is concentrated on the end of the hard land and will often break through the adjacent dune spilling into the sand marsh as seen in Figure 37.

Figure 38 shows the stretch of coastline out to Great point with the land mass expanded to show detail. The red rectangle shows the section where this hard dirt is located and the red arrow points out the location next to it where the dune has been broken. This naturally occurring bulkhead has effects similar to a manmade bulkhead. The interruption of the natural dune causes increased energy at the end of this hard structure and causes scouring.

Figure 36: View of Natural Clay Deposit, Great Point Nantucket

Figure 37: View of Scouring Effects from Natural Bulkhead

Figure 38: Aerial Photograph of the Natural Clay Deposit at Great Point

5. Conclusions and Recommendations

Extensive land and property loss as a result of coastal erosion has been a problem facing the United States and Nantucket in particular since homes were built along the coast. Large amounts of money, time, and other resources have been invested in developing coastal erosion structures to mitigate shoreline loss. While some have been successful, others have caused detrimental effects to the coastline surrounding the structure. Before 1978 on Nantucket, structures were not required to go through a permitting process, creating many discrepancies in the historical documentation as well as resulting in structures that were ineffective or had unintended impacts. Stricter regulations, policies and procedures regarding the installation and permitting of structures, are intended to ensure that structures are more likely to be effective at erosion control and less likely to cause unintended adverse impacts to properties and the environment.

Based on our site visits and analysis of Natural Resource Department files we identified 72 permitted erosion control structures on the island (See figure 39 below), including 42 that we classified as hard structures (red squares) and 30 soft structures (blue circles). The geotubes that have been put in place in Siasconset are indicated with a blue square since they were permitted as emergency structures. Evidently, most of the structures are located in the harbor (50 structures) and northwest sections of the coastline (12 structures), although we also identified 5 structures in Siasconset and 5 on the south shore. We should note that the size, type and complexity of structures vary substantially across the island.

Figure 39: Overview of Structures on Nantucket (Google My Maps, 2014)

The concentration of structures on the north coast probably reflects the higher density of population and the large number of houses that were built directly on beachfront property. For example, the majority of structures along Hulbert Avenue belonged to homes that were less than 100 yards from the beach. Records are incomplete, but it appears that many of the soft structures on the island were built more recently, reflecting the shift in emphasis from hard to soft structures that has been a predominant pattern nationally and along the east coast. Twenty-three of the hard structures we identified were definitively documented as being built prior to 1978 when more stringent oversight and regulations came into effect.

The database includes a broad array of information on each of these 72 structures, including:

- Map and parcel number;
- The date and time we visited the structure;
- Town address;
- If the structure was permitted ;
- If the structure has a Chapter 91 license;
- The date the structure was installed;
- The most recent date that it was updated;
- How it was maintained;
- The name of property owner;
- If the structure is private or public;
- The condition of the structure;
- Permit and, site visit notes;
- MORIS transect value; and our
- Effectiveness rating values.

Because some of the structures span more than one property the database includes 85 individual entries covering the 72 structures.

Measuring the effectiveness of coastal erosion structures is extremely complicated. We developed a relatively simple set of measures that we could apply in the field and these were summarized in the database. Based on our observations and measurements, we found that 31 out of the 72 structures scored a 5-6 on our rating scale and were deemed *effective*; we rated 36 structures as *adequate* since they scored between 3-4 and only 4 structures as *ineffective* with a score of less than 2. Surprisingly, we found that 48% of the hard structures were effectives, while only 38% of the soft structures were effective. This is surprising because the Army Corps of Engineers, Nantucket Conservation Commission and others have been moving toward greater use of soft structures in preference to hard structures in the past three decades. This may be because our effectiveness rating scale focuses inordinately on the proximal effects of coastal erosion structures coastal erosion structures on the immediate areas in front, behind, and to the sides of the structures and does not try to assess more distant impacts up and down the coast or offshore. It may also reflect the relatively narrow time horizon for our evaluation. Indeed, there are few traces of many structures that have been built in the past because they have been entirely destroyed by storm and wave action; such structures are by definition ineffective, but are not included in our assessment or database.

A preliminary assessment of structures suggests that the advantages and disadvantages of hard and soft structures are not so easily discernible, depending on the type of structure, its method of construction, and location. Soft structures may be successful at decreasing erosion and encouraging accretion while being a more environmentally friendly alternative; however they require more maintenance and upkeep. If a soft structure such as a sand fence is layered in such a way with a jute mesh bag that it forms a solid structure it may act more like a hard structure similar to a seawall. Hard structures may effectively protect the land immediately behind them; however they can cause scouring, the loss of beaches, and other distant impacts by limiting replenishing sand. Hard and soft erosion structures may inhibit erosion in the short term over a limited spatial extent, but effectiveness varies dramatically by location and many structures have unintended proximal impacts. We have observed structures here on island that use a combination of both hard and soft structures to try and make the best out of both techniques and we classified these structures as hard or soft by their primary feature.

From our observations we have made several recommendations to the town to help with the ongoing situation in regards to developing and maintaining coastal erosion structures. The information in our database was limited by time to what we deemed were the most important fields for evaluation.

- **We recommend that the town continue to inspect structures on the island.** This allows for the town to monitor them for quality and to check they function as expected and are not having any detrimental effects. This also allows the town to limit the construction of unauthorized structures.

- **We recommend that the town maintain and develop the database to include more comprehensive assessments of impacts and effectiveness.** We believe that based off the research and interviews we have conducted, as a future IQP project on the island that an IQP team use our database as a launching point and continue to add critical information such as longitudinal and latitudinal locations to create a new GIS layer for the town GIS system, measurements of the structures (length and height). This data should also include information about measurements of the beach and cliff (when applicable) as a baseline for measuring effects more accurately than can be inferred from transects along pictures. It is important that the database be updated on a regular basis to ensure the information regarding all structures is accurate, while also including information on all new structures.
- **We recommend that the photographic database on the Google My Maps be maintained.** This acts as a user-friendly location for the public to view the structures we found, along with a description of the structure and pictures from site visits. It is critical this be maintained to aid in tracking the upkeep of structures and conditions of the structure, surrounding land, and beaches.
- Due to the Conservation Commission's more recent style of requiring maintenance plans as part of the Order of Conditions, a permitted structure requires the periodic submission of updates on how it is performing. **We recommend that as a future IQP, a group create a system for submitting maintenance information online.** This would consist of a form, filled out by the engineer updating the structure information, along with a separate form filled out by the homeowners, or property trustees, submitting pictures to document the maintenance and structural updates for archival purposes. These forms would then need to be sent to the Natural Resources Department, accepted, and then made immediately publicly available. This maintenance data is also recommended to be included in the updating of the databases we provide.
- Due to the preliminary nature of our rating scale, **we recommend that our evaluation scale be further developed and refined**, specified to specific structure types (e.g. sand drift fencing and groins, which would each have their respective scales), so future ratings are more accurate and consistent.

- **We recommend that the Conservation Commission continue to work with homeowners to better design well-functioning erosion structures.** They should continue to work together in a positive manner to find a solution that suits the need of the homeowner to protect their property while adhering to the Conservation Commission requirements on protecting the surrounding environment. It is important the Commission maintains an open line of communication when permitting structures to ensure homeowners meet the requirements of the Commission's and environmental needs, while also getting the most effective structure for their property.
- Finally, **we recommend that when evaluating a structure's effectiveness that there is a minimum of three people doing separate evaluations and then comparing their results for discrepancies.** This prevents any bias that may occur if only one person were to use the evaluation scale.

Coastlines are a constant dynamic system and it is extremely difficult to predict how a structure may function and perform when it is installed in a certain location. Because of this dynamic system, it is difficult to evaluate whether or not a coastal erosion structure is effective or to identify the proximate and more distant impacts. Opinions about effectiveness and the 'success' of erosion structures vary substantially among stakeholders. A homeowner may consider a structure effective if it adequately holds back the land in front of their house. However a beach goer may view the structure as ineffective if that same structure destroys the beach in front of it and damages the coastline next to it. While we attempted to evaluate effectiveness and generated a preliminary scale, there is always room for the scale to be improved and more specific to certain types of structures. Erosion will continue to be a prominent debate in future years with no foreseeable, universal solution.

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Appendix A: Coastal Erosion Structure Evaluation Checklist

1. Date evaluated (Include time of day (high or low tide))

2. Who evaluated it (group member)

3. Location (longitude and latitude, and actual address)

4. Type of Structure

5. Property owner

6. Name of person who put it in place

7. Date it was constructed

8. What was it proposed to do?

9. Privately built or publicly?

10. Photos (taken by our group) of structure

11. Type of material used. Cost of implementing it

13. Size of structure (in ft.) (Length, width, height)

14. Method of construction

15. Why was the structure required? Are there any specific past/present erosion rates? Any previous photos taken?

16. What is the long-term maintenance program?

17. Maintained? (Privately or town? Has it been maintained at all?

18. What is the rate of erosion before and after?

19. Distance to nearest building

20. Distance to water's edge (high and low tide)

21. List of homeowners directly affected (maybe around 500 square foot area)

22. Overall appearance of structure (evaluate on scale of 1-5, 5 being the best)

· Appearance of structure

· Surrounding area

Appendix B: Interview Preamble and Questions

Preamble:

Hello, my name is ___ and as mentioned in the phone call/email I am part of a team of students from WPI conducting research on coastal erosion structures on Nantucket. It's nice to meet you and as a part of our project I would like to ask you a few questions that should take 30 minutes or so. Your input will be valuable in our research and we would like to be able to quote you in our final report if that's okay? We will send you a draft of our report to review before we publish it. If you prefer, we could anonymize your responses, or not quote them at all. Do you have any questions for us before we begin?

Sample Questions:

What has been your involvement on the island in regards to coastal erosion?

What are your thoughts on the topic?

What is your opinion on what the island has done so far to prevent coastal erosion? Are there any projects that you think we should take a closer look at on the island? Is there any additional information on them that you could provide us?

What do you think are the biggest risks when implementing coastal erosion structures? Do you think soft, hard, or hybrid engineering solutions are best for the island?

How do you view the town's role in approving coastal erosion projects? Is there anything you think that should be modified or changed?

What erosion structures do you have on your property? How did you get them approved and when were they installed? How often do you have to maintain them? How effective do you think it has been thus far and would you have done anything differently when you installed it?

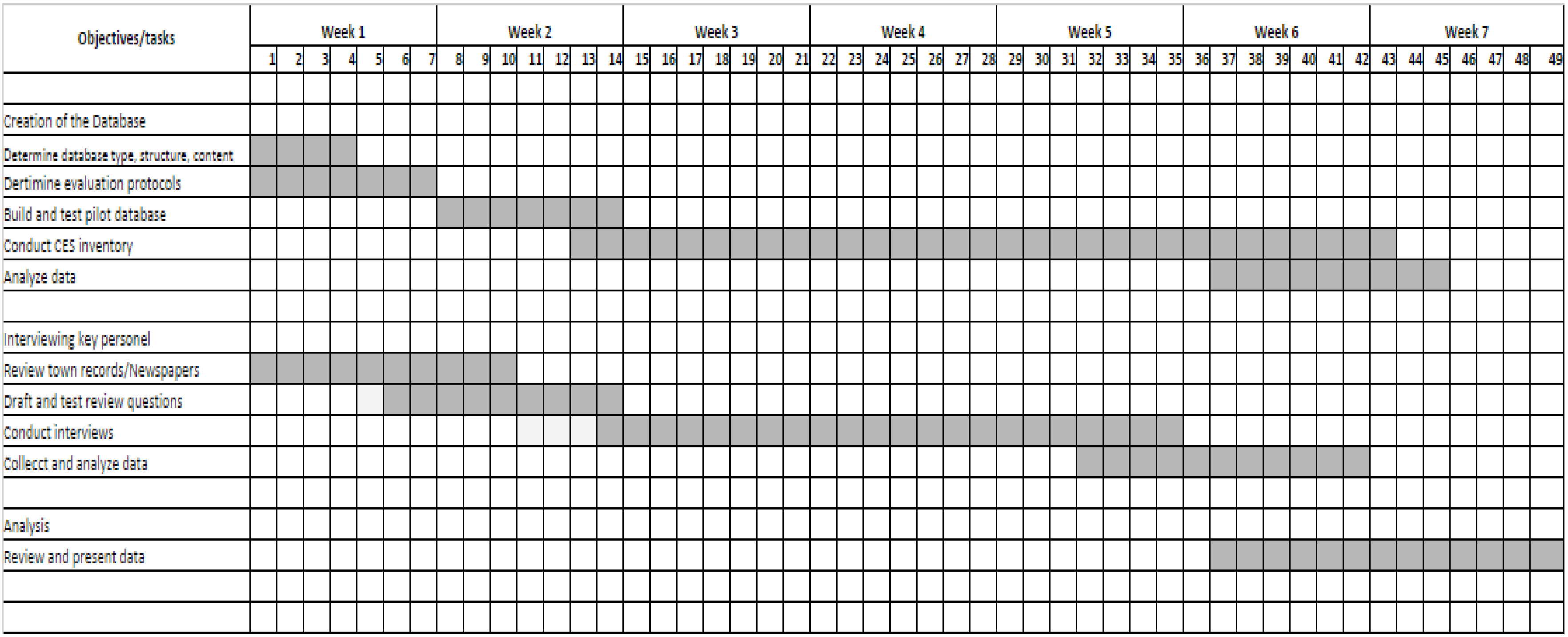
What do you think needs to be done in the future in order to help protect Nantucket's coastline?

Appendix C: Steps That Section 404 Permit Applicants Can Take to Help Assure Compliance

Follow 404(b)(1) sequence	• To the maximum extent practicable, minimize unavoidable adverse impacts of the preferred alternative; • Prepare a compensatory mitigation plan necessary to replace the wetland functions that would be lost as a result of unavoidable adverse impacts.
Prepare acceptable mitigation plan and include in permit application	• Submit conceptual compensatory mitigation plan with permit application. • Prepare detailed plan that is negotiated with the agencies. Plan must provide in-kind functional replacement for habitat functions lost as a result of unavoidable adverse impacts.
Determine project purpose and need	• This is a critical element in USACE evaluation for compliance with the 404 (b) (1) Guidelines of the CWA, and guides the scope of review.
Single point of contact with USACE	• Identify a single point of contact for purposes of coordinating with the USACE. This will improve communication and • Facilitate the orderly processing of the permit.
Assemble a project team	• Form a team including certified project manager, various experts and specialists, meetings coordinator, and an attorney. • The team should be able to address the highly complex concerns and issues raised by public and governmental agencies during permit review. • Team should include experts on NEPA, 404, WRP, and NHPA.
Develop organized record keeping system	Record should include • The permit application and supporting documentation including jurisdictional • Wetland determinations • Notice of Intent to prepare EIS for purposes of the Federal Register, or • Public Notice • Correspondence • Written comments during the public interest process • Responses by the applicant to public interest issues • Alternatives analysis incorporating the CWA 404 (b)(1), NEPA and NHPA • Regulations using a scientific and analytical basis for findings • Agency written comments and reports • Environmental impact analysis reports addressing the direct, secondary and • Cumulative impacts by subject matter • NHPA documentation including Memorandum of Agreements, if required

	• Meetings and public hearing reports or transcripts • Zoning and land use documents • Letters of certification and permitting issued by other agencies or governmental departments • Including the Section 401 Water Quality certification • Mitigation Plan and restrictive covenants if required • EA and/or EIS • Technical reports, studies, drawings and computer modeling data • Other topics as needed.
Provide information to the public	• Designate a point of contact and a location for purposes of providing information to the public. • Establish procedures for public viewing of studies and reports. Consider establishing an Internet web site.
Complete permit application	• Submit a complete permit application, especially addressing all issues and concerns raised during public scoping and at the pre-application meeting.

Appendix D: Tentative Project Timeline



Appendix E: Effectiveness Rating Scale

Effectiveness Rating Scale:
Coastal Erosion Structures

The following documents are rating scales that allow the effectiveness of a coastal erosion structure, the surrounding land and property, and beach to be calculated and given a numerical value. The rating scale gives a score based on physical characteristics of the property and will award each a value accordingly. There are three effectiveness tests that will award a point value between 0 and 2. The highest rating a total property can achieve is 6 points with the lowest being 0 points. In order to have a property in "good standing" or to be considered an effective coastal erosion structure, said structure must score either a 5 or better. An adequate structure will score between a 3 and 4 and an ineffective structure will score a 2 or below.

Effectiveness Scale for Coastal Erosion **Structures** Only

Coastal erosion structures will be evaluated on a series of conditions based on the structure only. Each structure will be awarded a numerical value between 0 and 2, with a 2 being the best score.

Good: The Current Coastal Erosion Structures in Good Condition
This means:

- Appears to be structurally sound, with either no or only minor wear from the elements
- Has prevented the land from erosion with no significant loss
- Property in completely intact and not currently threatened

Having a rating of “Good” will be awarded a score of 2 points.

Fair: The Current Coastal Erosion Structures in Fair Condition
This means:

- Structure has a moderate amount of damage and wear due to the elements
- Has only prevented some erosion to the land
- Property is intact or has been moved but threatened by slow rate of erosion

Having a rating of “Fair” will be awarded a score of 1 point.

Poor: The Current Coastal Erosion Structures in Poor Condition
This means:

- Structure has a severe amount of damage and wear due to the elements
- Has not prevented any erosion to the land or is making erosion worse
- Property is not intact and/or not existent

Having a rating of “Poor” will be awarded a score of 0 points.

Effectiveness Scale for the **Land** Surrounding the Coastal Erosion Structure Only

The land in the immediate area (300 ft either side and behind) around a coastal erosion structures will be evaluated on a series of conditions based on the land only. Each will be awarded a numerical value between 0 and 2, with a 2 being the best score.

Good: The Land Around a Coastal Erosion Structure is in Good Condition
This means:

- No significant amount of land has been lost from erosion from wave energy
- No significant amount of land has been lost due to structural inadequacies
- Property in completely intact and not currently threatened

Having a rating of “Good” will be awarded a score of 2 points.

Fair: The Land Around a Coastal Erosion Structure is in Fair Condition
This means:

- A portion of the land has been lost from erosion from wave energy
- A portion of the land has been lost due to structural inadequacies
- Property is intact, hasn’t been moved, but threatened

Having a rating of “Fair” will be awarded a score of 1 point.

Poor: The Land Around a Coastal Erosion Structure is in Poor Condition
This means:

- A severe amount of land has been lost from erosion from wave energy
- A severe amount of land has been lost due to structural inadequacies
- Property is not intact and/or not existent

Having a rating of “Poor” will be awarded a score of 0 points.

Effectiveness Scale for the **Beach** Surrounding the Coastal Erosion Structure Only

The beach in front of a coastal erosion structures will be evaluated on a series of conditions based on beach appearance only. This is based on a high tide schedule. Each will be awarded a numerical value between 0 and 2, with a 2 being the best score.

Good: The Beach in Front of a Coastal Erosion Structures in Good Condition
This means:

- Significant amount of beach is present during both high and low tides
- Allows for adequate water run off
- Structure is supported by beach in front

Having a rating of “Good” will be awarded a score of 2 points.

Fair: The Beach in Front of a Coastal Erosion Structures in Fair Condition
This means:

- Beach in front of structure in diminishing due to structure
- Allows for moderate water runoff, with few water pools
- The coastal erosion structure is intact but threatened by vertical erosion or scouring

Having a rating of “Fair” will be awarded a score of 1 point.

Poor: The Beach in Front of a Coastal Erosion Structures in Poor Condition
This means:

- No or very little amount of beach is present during both high and low tides
- Allows for no water runoff, with significant water pools
- Minimal beach and structure is severely threatened

Having a rating of “Poor” will be awarded a score of 0 points.

Appendix F: 'How to' Field Manual

How To:
Evaluate a Coastal Erosion Structure
Field Manual

Evaluating a coastal erosion structure (CES) is not the most straight-forward task. There are a variety of structures and each one comes with its own challenges for evaluations. While part of the evaluation comes from reading through paperwork, the other key part comes from effectively and efficiently conducting site visits. This guide will give you the key steps in thoroughly evaluating a CES.

Permits

The first part of any CES installation surrounds the permitting stage. Evaluating a permit can be difficult on its own, as there are lots of details to sort through. The following are some steps to take to find the important information from a permit.

1) Take note of:
   a) The **address** noted on the file and/or permit papers.
   b) Name of **property owner**, or **trustee name** if property belongs to a trust. (This information can also be found on the Nantucket Town MapGeo GIS system.)

   c) The **parcel number** of the property (This can be found using the Nantucket MapGeo GIS system if the property owner, exact address, or street are known.

   d) The **type** of structure described in the Notice of Intent. (Compare to type of structure on land during site visit.)
   e) If there is a **permit** (**Order of Conditions**).
   f) If the project required a **Chapter 91 License.**
   g) Date of **earliest permit,** or when available, date of **installation.**
   h) Date of **most recent permit.**
   i) If the structure is **maintained**. (Infer from number of permits regarding updating, repairing, and/or replacing parts, or all of, a structure.)
   j) Whether or not the structure is **private** or **public.** (Inferred from whether or not the address is a town owned location or a private residence.)
   k) The description on the **file folder tab** in case the permit needs to be pulled at a later time.
   l) Any interesting **notes** from the permits and other documents in the file.
2) Input these pieces of information into **corresponding column** in the Excel database.

Site Visits

The second part to evaluating any structure is to conduct a site visit. These on-site evaluations are important as only with on-site visits can it be determined if the structure is effective, ineffective, or destructive. Key things to look for and note during an evaluation in the field include:

1) Inspect:
   a) The **date and time** of site visit.
   b) The **tide**, high or low.
   c) The **type** of structure. (Compare to what is permitted, if permitted.)
   d) The immediate, visible **condition** the structure and surrounding land appear to be in.
      i) Include **condition** of structure
      ii) The visible **effects** on the immediately surrounding land
      iii) Effects to the **beach front**
   e) The **effectiveness** of the structure based on accompanying scale
   f) Any important or additional **notes of interest** from the site visit.
2) Enter data into **corresponding columns** in the database.