South Shore Coastal Hazards Adaptation Study

Funding provided by the
District Local Technical Assistance program

Prepared for the

Towns of Duxbury, Marshfield, and Scituate

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Executive Summary

Coastal cities and towns in the Boston region enjoy access to the scenic, economic and recreational amenities of being along the ocean shores. However, there is also a unique set of challenges that these municipalities face, specifically impacts from the ocean's power both in normal and in storm conditions. Adding to these challenges is the potential for a rise in sea level and more intense storms as a result of a changing global climate.

The Scituate, Marshfield and Duxbury Coastal Hazards Adaptation Study assessed general changes in coastal hazard impacts that could occur due to climate change, primarily the impacts from sea level rise and changes in storm intensity and frequency. The project explored current and potential future coastal vulnerabilities, identified a range of possible adaptation options and provided information about resources that could support local actions and strategies. The Metropolitan Area Planning Council (MAPC) conducted the project in partnership with the Towns of Scituate, Marshfield and Duxbury and with support from the Massachusetts Office of Coastal Zone Management (CZM).

Climate change has the potential to increase the risks associated with existing natural hazards as well as introduce new changes that will alter the landscape of these three towns. By taking this first step, the towns of Scituate, Marshfield and Duxbury are laying the foundation for determining how climate change will affect public infrastructure and private property. They are also demonstrating that the three towns in collaboration with MAPC, Massachusetts CZM and others are capable of working together and bringing a regional focus to local issues. Going forward, the challenge for this work will be to educate the public about the projected impacts of sea level rise and to take action to avoid costly impacts to private and public property. There is local leadership and regional partnership on the issue of a changing climate, but a challenge will be to build a larger network of support for local action.

TASK ONE: CURRENT AND POTENTIAL FUTURE COASTAL HAZARDS

For the first task of this study, information was compiled about the shorelines of Scituate, Marshfield and Duxbury with a specific emphasis on the existing hard and soft coastal protection structures and natural coastal features. There is a review of previous coastal structure inventories, such as that performed by the State Coastal Hazards Commission (CHC), and a look at key risk factors affecting the structures and nearby public and private properties. In addition, information is provided about how identified risk factors, such as sea levels, could change in the future and their amplified impacts. In the end, a general summary of vulnerabilities will be presented in order to highlight possible opportunities for adaptation.

COASTAL PROTECTION STRUCTURES

Each of the towns has coastal protection structures (e.g., bulkhead /seawalls, revetments, groins/jetties) along their coastlines. According the CHC report, there is approximately a total of 25 miles of shoreline along these three municipalities where the coasts are exposed to open ocean waves, with the remainder having some level of protection by offshore structures or landforms. The coastal structures provide protection to private properties as well as to public infrastructure adjacent to and in the vicinity of the shorelines. However, due to a number of factors, including age, weather impacts and natural environmental processes (e.g., erosion) these structures are in varying states of decline.

Previous Studies

There have been efforts of note during the past 10-15 years to inventory the type and condition of coastal protection structures in Scituate, Marshfield and Duxbury as well as other coastal towns and cities. Multiple efforts to create a baseline and to update existing information on coastal protection structures were performed by Vine Associates, Inc. They have conducted inspection and inventories in each town, with the most recent being a 2007 update for Scituate, a 2005 update for Marshfield and a 2005 report for Duxbury.

The second effort was lead by the Coastal Hazards Commission (CHC), which was completed in 2009. The CHC, with the assistance of the Massachusetts Office of Coastal Zone Management (CZM), was charged by the Commonwealth to review existing coastal hazards practices and policies, identify gaps in data, and draft recommendations that would improve mitigation and management of

coastal hazards. As part of this work, the Infrastructure Plan Working Group performed an assessment of hard and soft coastal structures along the Massachusetts coastline.

Bulkhead /Seawalls

Groins / Jetties

Revetments

Engineered Coastal Beach

Since the CHC effort was performed across each of the three towns at the same time, the findings from the inventory and assessment are used as a base for existing conditions. The following findings were reported:

- **Scituate:** The town has approximately 12 miles of shoreline that is directly exposed to open ocean waves. There are 71 publicly-owned coastal structures in Scituate that were inventoried along the stretch of exposed shoreline, which have a length of over 30,000 feet (5.7 miles). 62 of the structures are assumed to be owned by Scituate. The amount and types of structures are noted below as are the number that were noted in either Fair or Poor condition[1].

[1] The CHC Coastal Structure Inventory and Assessment Project used a 5 level rating system that ranged from Excellent (rated A) to Critical (rated F), which indicated the extent of maintenance, repair or reconstruction needed for an assessed structure. The assessment was performed in field by an engineer who had waterfront structure assessment and design experience.

Scituate Coastal Structures Table

Structure Type	Total Number	Total Length (ft)	Number of Structures Assessed in Fair Condition	Number of Structures Assessed in Poor Condition
Bulkhead/Seawall	49	26,210	23	2
Revetments	18	116	9	3
Groin/Jetty	3	1,783	---	---
Coastal Beach	1	1,912	---	1
Total	*71*	*30,021*	*32*	*6*

It was estimated in the study that it would cost $33M[2] to bring each of structures to Condition A and $5M to address structures in Poor Condition.

- **Marshfield:** The town has approximately 12 miles of shoreline that is directly exposed to open ocean waves. There are 32 publicly-owned coastal structures in Marshfield that were inventoried along the stretch of exposed shoreline, which have a length of over 20,000 feet (3.9 miles). Each of the structures is assumed to be owned by the town. The amount and types of structures are noted below as are the number that were noted in either Fair or Poor condition.

Marshfield Coastal Structures Table

Structure Type	Total Number	Total Length (ft)	Number of Structures Assessed in Fair Condition	Number of Structures Assessed in Poor Condition
Bulkhead/Seawall	18	14,820	11	4
Revetments	8	3,390	6	2
Groin/Jetty	6	2,640	4	1
Total	*32*	*20,850*	*21*	*7*

It was estimated in the study that it would cost $22M to bring each of structures to Condition A and $12M to address structures in Poor Condition.

[2] Estimated cost is calculated based on 2006 construction costs

- **Duxbury:** The town has approximately 4.7 miles of shoreline that is directly exposed to open ocean waves. There are 13 publicly-owned coastal structures in Duxbury that were inventoried along the stretch of exposed shoreline which have a length of over 4,700 feet (0.9 miles). Each of the structures is assumed to be owned by the town. The amount and types of structures are noted below as are the number that were noted in either Fair or Critical condition (none were rated as in Poor condition).

Duxbury Coastal Structures Table

Structure Type	Total Number	Total Length (ft)	Number of Structures Assessed in Fair Condition	Number of Structures Assessed in Critical Condition
Bulkhead/Seawall	11	4,598	4	4
Revetments	2	116	1	---
Total	*13*	*4,714*	*5*	*4*

It was estimated in the study that it would cost $2.8M to bring each of structures to Condition A and $1.0M to address structures in Critical Condition.

Appendix A: Map Series 1 illustrates the location of the structures and their conditions.

Work Completed Since the Coastal Hazards Commission

Since the completion of the CHC study, the towns have made progress with improvements to their coastal protection structures. In some cases these improvements were programmed by the municipality as part of capital or maintenance plans and in other cases the improvements followed damage to the structures from storm events. Of note, the following improvements/repairs have been completed or are underway[3].

[3] Improvements are based on input from municipal representatives and available information sources.

Coastal Protection Structures Update Table

Town	Area Name	CHC Condition Rating	Type of Coastal Structure(s)
Scituate	Minot Beach	Fair – Good	Seawall/ Revetment
	Surfside Road	Fair – Good	Seawall/ Revetment
	Rebecca Road	Fair	Seawall/ Revetment
	First Cliff	Fair	Seawall/ Revetment
	Second Cliff	Fair	Revetment
	Third Cliff	Fair	Revetment
	Fourth Cliff	Poor	Revetment
Marshfield	Fieldston	Poor	Seawall/ Revetment
	Hewitt's Point	Fair	Seawall/ Revetment
	Brant Rock	Poor – Fair	Seawall/ Revetment
	Bay Avenue	Fair	Seawall/ Revetment
	Work is also scheduled for additional sections of Bay Avenue and Fieldston areas of the coastline.		

Appendix B: Map Series 2 highlights locations of improvements to the structures

EXISTING RISKS

Storm Events

Storms present a current hazard condition along the coasts of these three towns due to coastal flooding and atypical rises in sea level, known as storm surges. The storms with these impacts

generally result from either tropical (hurricanes) or ex-tropical storms (nor'easters), with the nor'easters posing the more frequent hazard since Cape Cod protects most of Boston, adjacent municipalities and areas south from the full force of most hurricanes. Nor'easters also generally last long enough to include at least one high tide, which can lead to a storm tide that combines the storm surge and diurnal tides to cause severe flooding. This can be exacerbated by the monthly phase of the moon that affects tide elevations. When these various factors occur at once (storm surge, wind direction, and spring or neap high tides), the potential for storm damage is high.

To provide an overview of how these storms have impacted the coastline in the past, three major storm events, each a winter nor'easter, are highlighted below:

- **Blizzard of 1978:** In February 1978, a storm brought blizzard conditions to New England and the other sections of the East Coast of the United States. This storm resulted in a rise of 9.82 feet relative to mean sea level (MSL) and had winds that exceeded 80 mph. Based on data for FEMA repetitive loss properties, the storm resulted in damage to 145 properties in Scituate, 28 properties in Marshfield and 9 properties in Duxbury. Claims submitted by the towns from this storm exceeded $9M.

- **Perfect Storm (1991 Nor'easter):** The October 1991 storm, also known as the Perfect Storm or No-Name Storm, hit Massachusetts in late October. The storm resulted in a rise of 8.96 feet relative to MSL and had winds up to 70 mph. Based on data for FEMA repetitive loss properties, the storm resulted in damage to 437 properties in Scituate, 132 properties in Marshfield and 39 properties in Duxbury. Submitted claims for the three towns from this storm totaled more than $40M.

- **December 2010 Storm:** Most recently, this past winter a blizzard struck coastal Massachusetts with significant force. The storm resulted in a rise of 8.45 feet relative to mean sea level MSL and had winds exceeding 30 mph. The amount of the claims for this storm was not available at the time of this report.

These storms provide a picture of the how the towns can be impacted from coastal flooding and storm surges. The repetitive loss properties and claim amounts capture impacts of the storm on both inland and coastal private properties; however they do not capture the costs that arose from damages to public facilities like roads and drainage systems. These storms also degrade and destroy roads and sidewalks, and subject the coastal protection structures to stress on the seaward side and often, the landward side.

Shoreline Change

The changes to coastal landforms can present a risk to adjacent private and public lands. Using data developed during the Massachusetts CZM South Shore Atlas project, the trends in the change of shorelines for these three towns between 1950 and 2001 can be identified. Although loss and accretion of sediment do occur naturally, shoreline structures can influence these natural processes, especially by accelerating or inhibiting movement of sediment. The table below highlights sections of Scituate and Marshfield where the shoreline change rate has been high (2' or greater per year) and whether coastal structures are present.

Shoreline Change and Coastal Structures Table

Town	Area Name	Coastal Structure(s) present	Type of Coastal Structure(s)
Scituate	Cohasset Harbor	No	---
	Peggoty Beach	Yes	Revetment/ Barrier Beach
	Mouth of North River	No	---
	Humarock Beach	Yes	Seawall
Marshfield	Ferry Street	Yes	Seawall/ Groins/ Revetment
	Brant Rock	Yes	Seawall/ Revetment
	Bay Avenue	Yes	Seawall/ Revetment
Duxbury	Duxbury Beach	No	---
	Goose Point	N/A	---

Not only can a coastal structure impact the shoreline change rate, but a loss of sediment in front of structures can also impact performance. The removal of sediment at the bottom, or toe, of seawalls and bulkheads undermines and destabilizes the structure, sometimes causing it to lean and even fall forward. This reduces the level of protection offered to facilities and properties behind the structure.

Appendix C: South Shore Coastal Hazards Characterization Atlas - Shoreline Change Maps

Sea Level

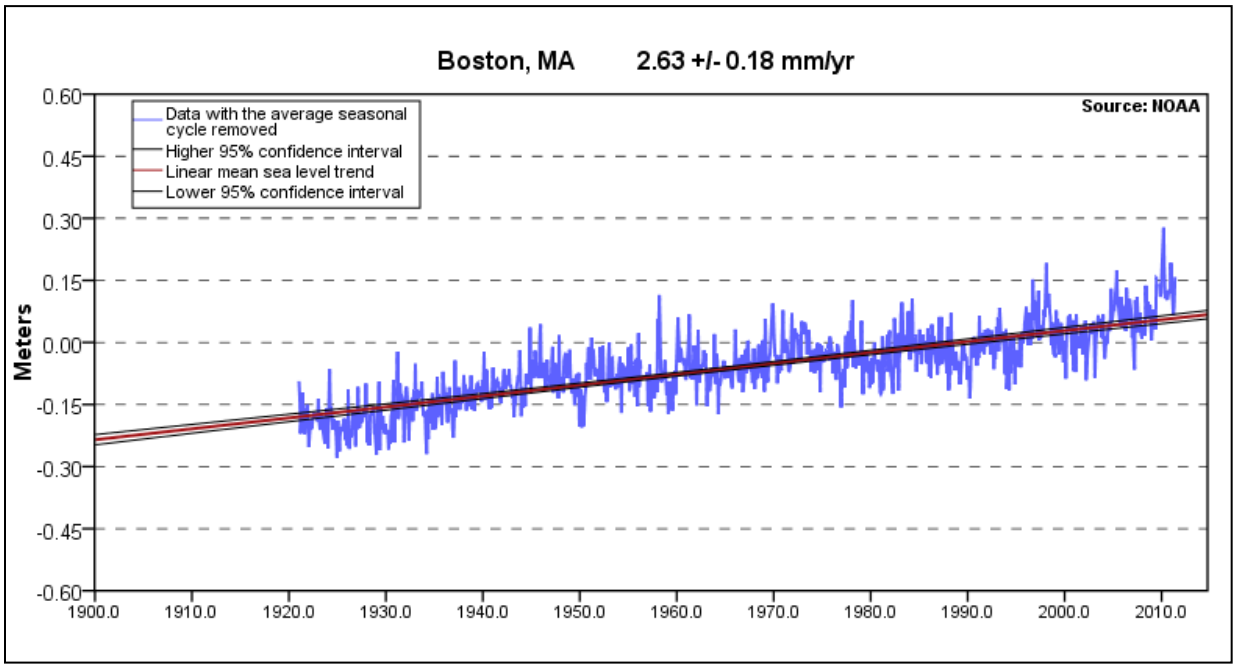
Sea level refers to the height of the ocean's surface and it is used as the basis for determining land elevation. Mean sea level (MSL) is a specific measure of the ocean's surface, representing an average of the water's surface elevation between tidal fluxuations that occur daily (e.g., diurnal and semidiurnal tides) and over the course of a year (e.g., neap and spring tides).

Tide gauges are tools that can be used to measure and track mean sea level over periods of time. For the three municipalities, there are no long term tide gauge data available, so the nearest tide gauge was identified to serve as a basis for assessing sea level change in the region. The nearest gauge is for Boston Harbor which is approximately 25 – 30 miles to the north; the nearest gauge to the south is in Woods Hole, however it is over 50 miles away. For the purpose of this report, the Boston Harbor gauge will be used.

Sea level has been rising and ebbing globally for many centuries, but according to the most recent report from the Intergovernmental Panel on Climate Change (IPCC), it has not changed substantially over that period. However, starting in the late 19th century, the rate of this natural, or eustatic, rise has been increasing.

Past sea level rise was determined using data from the National Oceanic and Atmospheric Administration's (NOAA) Center for Operational Oceanographic Products and Services (CO-OPS). It is estimated that the rate of change in MSL for Boston Harbor is 2.63 millimeters/year (approx. 1"/10 years). Historic tide data was collected for the Boston Harbor for the period between January 1, 1921 and May 6, 2011. A graph showing the change in monthly MSL is included below.

Mean Sea Level Trend –Boston Harbor Coastal Station: 8443970; NOAA CO-OPS



Subsidence

Sea level rise can be attributable to an increase in the ocean's volume, but it can also be complimented by land sinking, which is referred to as subsidence. Subsidence is a natural process of the earth compacting downward and it can occur slowly as the ground settles over time, or it can occur quickly as in the case of sinkholes. When subsidence is combined with sea level rise, it is called relative sea level rise and the net result is higher mean sea level. A reference from the

Climate's Long-term Impacts on Metro Boston (CLIMB)[4] report indicates that 0.15 meters of subsidence has occurred in coastal areas of Massachusetts.

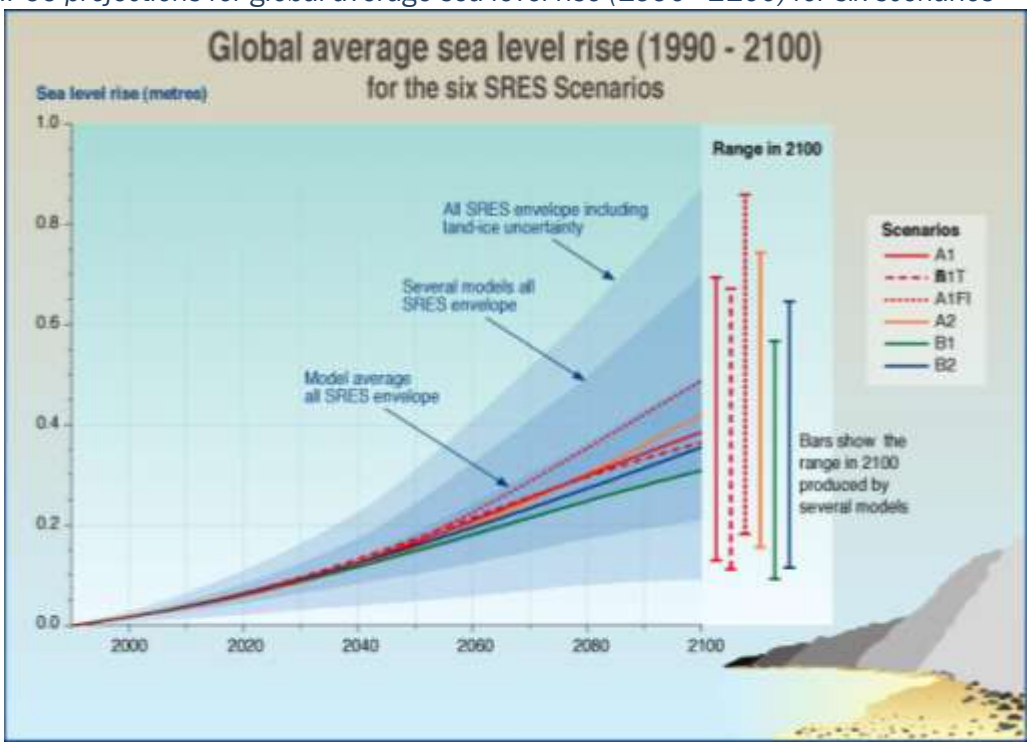
Potential Climate Change Impacts

Based on current research, there is evidence that surface temperatures around the globe have been rising. The increased temperatures are expected to affect numerous aspects of our earth's climate as well as other natural processes. Two potential threats from the changes that will likely have considerable impacts on coastal communities are sea level rise and stronger and more frequent storm events.

Future Sea Level Rise

As noted earlier, the past century has resulted in approximately 1 foot of sea level rise in the Boston region, including Scituate, Marshfield and Duxbury. Based on estimates from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), it is estimated that this rate of sea level rise will be maintained and likely increase to 2 feet per century.

IPCC projections for global average sea level rise (1990 - 2100) for six scenarios[5]



Eustatic sea level rise over the past decade is the result of melting ice deposits (e.g., polar ice sheets, glaciers, etc.) and the thermal expansion of water in the ocean as it warms. These forces will

[4] Climate's Long-term Impacts on Metro Boston (CLIMB) Final Report V1.1, 2004.
[5] The IPCC used multiple models of potential changes in emissions to project temperature and sea level changes. The B1 scenario represents the lower emission scenario and the A1F1 scenario represents the higher emission scenario.

continue contributing to sea level rise; however, it should be noted that the projections for sea level rise assume a constant rate of melting of the ice sheets. There is less understanding about the ice sheets than other factors so there is some potential for a more substantial increase in the melting rates of these sources, especially the Greenland ice sheet (the second largest land-based ice sheet on the earth). This has led some to predict a more likely estimate for future sea level rise is 3 feet per century or greater.[6]

To illustrate where 2 foot rise in sea level could impact Scituate, Marshfield and Duxbury, maps were developed using 2007 US Army Corps of Engineers (USACE) Topographic/Bathymetric Light Detection and Ranging (LiDAR) data for Massachusetts.[7]

Appendix D: Map Series 3 illustrates the location of SLR[8]

From this map series, there are some pockets of land that have potential vulnerability for a 2 foot SLR in MSL, such as Third Cliff and Fourth Cliff sections of Scituate. However, the potential new MSL will likely impact more sections of coast as high tides move farther inland and set up more exposure of coastal protection structures and unprotected land to ocean wave action.

Future Storm Events

Storms will continue to be a hazard for the coastlines, and their potential impacts could be amplified as a result of changes in the climate. These impacts would reflect projected changes in the frequency and intensity of storms. In either situation, the result would be a greater stress to the coastlines, both for the existing natural features and for man-made coastal structures.

These storms would also play out differently as their related storm surges would occur on top of a higher sea level. As noted in the CLIMB report, if the rate of sea level rise continues the trend from the past century, a typical 10 year storm[9] would have the intensity of a 100 year storm and a present 100 year storm could equal the power of a 500 year storm. For example, a USACE study (Weiner, 1993) determined that the 10-year surge elevation in Boston Harbor is 2.8 meters (approx. 9 feet) and that the 100-year surge elevation is 3.16 meters (approx. 10 feet). A rise of another foot in sea level (i.e., 0.3 meters/~1 foot) would have the effect of bringing the 10 year surge to that of the present 100 year.

To illustrate where a two-foot rise in sea level accompanied by a storm surge equal to the present 100 year storm surge (or estimated future 10-year storm) could potentially impact Scituate, Marshfield and Duxbury the following maps were developed. As a point of reference, the 100 year storm would be approximately equivalent to the 1991 nor'easter.

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[6] 'Sea-level rise and coastal change: Causes and implications for the future of coasts and low-lying regions.' Shore & Beach, Williams & Gutierrez, 2009.

[7] The 2007 USACE LiDAR only covers approximately 1 kilometer (3,280 feet) inland from shoreline.

[8] Conceptual illustration for areas that could be affected by a static rise in sea level. This does not account for other dynamic features of ocean such as wave and wind action.

[9] The 10 year storm would also be known as a storm that is 10 percent likely in any given year; the 100 year storm and 500 year storms are 1% and 0.2% likely in any given year, respectively.

Appendix E: Map Series 4 illustrates the location of SLR with a Storm Surge [10]

Under this potential storm condition, the areas along the coasts in the three towns that are likely to impact grows significantly and more private properties and public infrastructure would be at risk.

Potential Future Coastal Threats due to Climate Change Impacts

Coastal Structures

As sea level rises, the existing conditions under which most of the existing coastal structures were designed and built will no longer be applicable. For example, a sea wall is designed to protect against loss of lands along the shoreline by reducing erosion and protecting against wave and tide action. They are designed under an existing set of assumptions including shoreline type (coastal banks, sandy beach, etc.), water levels (e.g., mean water/sea level, tides, storm surge, etc.) and wave characteristics (e.g., height and periods).

Sea level rise will surpass the structural design parameters of the structures as the level of standing water and the potential level of tides, waves and storm surges will be elevated. Coastal structures may hold up under these changes, but there is the likelihood that the structures may fail in a shorter period of time than expected. This may be especially an issue in the event that predictions for more frequent and intense storms come to fruition.

Shoreline Change and Erosion

Shoreline change will continue to occur as the sea level rises. As described earlier, there are locations along the coastline of these three towns where the rates of changes are 2 feet per year or greater. With a rising sea level these rates could be exacerbated and the seaward side support for coastal protection structures could face more frequent deterioration.

Not only will there be changes in the width of the shoreline, there is a greater possibility for erosion of unprotected land along the shoreline. Erosion of this kind could affect the stability of properties that sit on or near coastal bluffs. Additionally, erosion could weaken the barrier beach locations such as Duxbury Beach and allow for a breach that would expose more area to open ocean wave action. A breach of this kind occurred in Chatham, MA.

Migration/Loss of Environmental Features

Coastal wetlands, particularly salt marshes, are a key feature along the coasts of these three towns. The salt marshes provide habitat for plants, birds, fish and other wildlife and exist through a close relationship with natural tides. They also provide an essential service for people through their ability to store floodwaters and reduce the amount of water coming from inland or ocean sources. Salt marshes and estuaries are one of the most productive ecosystems on the planet.

[10] Conceptual illustration for areas that could be affected by a static rise in sea level in combination with the elevation of a storm surge. This does not account for other dynamic features of ocean such as wave and wind action.

Source: Adapting to Sea Level Rise Presentation, Slovinsky/Lockman

Coastal wetlands and other natural features of the shorelines will be impacted by a rising sea level. The two main possibilities for these natural features will be migration inward or loss of the features entirely if there are obstacles that block migration.

Some of the factors that will influence these potential outcomes are:

- Rate of sea level change
- Adjacent land uses (open space, residential neighborhoods, etc.)
- Presence of coastal structures (sea walls, bulkheads, tides gates, culverts, etc.)
- Presence of transportation and other infrastructure (roadways, bridges, culverts, etc.)
- Soil types

As part of the BioMap2, which was an effort to identify locations essential to maintaining biodiversity in Massachusetts, specific areas where coastal wetlands may migrate as a result of sea level rise were identified. These areas are comprised of undeveloped land that is adjacent to and up to approximately 5 feet in elevation above existing mapped salt marshes. Maps have been prepared for Scituate, Marshfield and Duxbury to illustrate the results of the work on the South Shore.

Appendix F: Map Series G illustrates Potential Inland Migration of Salt Marshes

TASK TWO: ADAPTATION STRATEGIES

Having identified current and potentially increased risks to the coastlines of the three towns, Task 2 provides an inventory of recommended climate change adaptation strategies. These strategies follow the three major categories of adaptation:

- Protect – the use of measures to shield land uses from the impacts of a rising sea.
- Accommodate – the use of measures that adjust to the impacts of a rising sea while maintaining existing land uses.
- Retreat – the use of measures that accept the impacts of a rising sea and move land uses farther inward.

These strategies also reflect a No Adverse Impact (NAI) approach to adapt to present and future risks for built and environmental features. Namely, adaptation strategies should be implemented in manner that does not increase risks, actual damage to property or municipal costs relative to benefit received.

Planning and implementing adaptation measures not only helps a community plan for potential impacts, but also protects the environment; encourages sustainable development; and provides social and aesthetic benefits to the community. Specific actions are proposed for protecting the built environment including implementing regulatory changes, providing development guidelines, and strengthening coastal protection structures (e.g., bulkheads, jetties) to prevent sea level rise from inundating low-lying coastal property. A longer-term, more preventative strategy is to preserve natural resources and landscapes to ensure that high flood waters do not adversely affect infrastructure or development. Both options are described in more detail below. Although these approaches are separated within the report, there are many interrelated options, particularly when considering land use controls and land conservation. It is important to note that the strategies suggested may require changes to the built environment that will affect the grade and access to facilities, therefore, compliance with the American Disabilities Act must be considered in the design phase.

A number of terms are used to describe land near a waterbody that is flooded: *flood zone, floodplain, floodprone area,* and *riparian zone*. Although these terms are more prominently used to describe inland areas, it is important to note their subtle distinctions, as some terms are utilized within this report. Flood zones are geographic areas that the Federal Emergency Management Agency (FEMA) has defined according to varying levels of flood risk: high (100 year flood event w/ 1% annual chance of flooding and 26% chance of flooding over life of 30-year mortgage), moderate, and low chance of flooding. A floodplain is the area next to a river that experiences flooding when water comes out of the banks of the main channel. The floodprone area is an area bordering a stream that will be covered by water at a height of twice the maximum bankfull depth. A riparian zone (i.e. riverbank) is the land located immediately adjacent to a channel, and it provides the buffer between a channel and upland areas. Parts of active floodplains and riparian zones are often times the same areas of land.[11]

[11] Ward, Andy et al. *Floodplains and Streamway Setbacks*. The Ohio State University Extension. Fact Sheet # AEX-445-02. 2008.

THE BUILT ENVIRONMENT

Regulatory options presented include a range of measures to protect existing development and infrastructure, to minimize loss of life, destruction of property, environmental damage, and enable safe access for homeowners and emergency response. Depending on the level of vulnerability, alternatives can range from prescriptive, such as the prohibition of new and redeveloped structures, and/or improvements to existing structures, to reactive where work is advanced to reinforce new or redeveloped structures against climate change impacts.

Land Acquisition

Acquiring land that is vulnerable to sea level rise is an important way to reduce the risk of future disasters. Typically, the community buys private property, acquires title to it, and then clears the land of structures that would be vulnerable to rising seas and storm frequencies. FEMA includes the property acquisition (buyouts) program where funding is available to municipalities (75% of local land acquisition) to acquire vulnerable properties. The funding is administered by the State and local communities, who work together to identify areas where land acquisition is viable. By law, that property, which is now public property, must forever remain open space land. The community can use it to create public parks, wildlife refuges, etc., but it cannot sell it to private individuals nor develop it.

Regulation

Town of Nantucket amended their zoning use regulations relating to their Flood Hazard District to prohibit construction seaward of the reach of the mean high tide line and man-made alteration of sand dunes. The Rhode Island Coastal Resource Management Council took the next step by including an additional 50-ft minimum setback requirement from coastal shoreline features. Another example of setback regulation is in Hawaii. The Kauai Shoreline Setback Ordinance 863 establishes an erosion rate-based setback; a buffer zone to allow the natural dynamic cycles of erosion and accretion of beaches and dunes to occur, and to avoid armoring or hardening of the shore. Setbacks are based on the average lot depth and have been designated as described in the following tables:

Setback related to lot depth

If Average Lot Depth is:	< 100 ft or less	101 – 121 ft	121 - 140 ft	141 – 160 ft	161 -180 ft	181 - 200 ft	>200
Minimum Setback:	40 ft	50 ft	60 ft	70 ft	80 ft	90 ft	100 ft

Setback related to building footprint

For Structures with a Building Footprint that is:	Less than or equal to 5000 square feet (sq ft)	Greater than 5000 sq ft
Then the Setback Distance is:	40 feet plus 70 times the annual coastal erosion rate	40 feet plus 100 times the annual coastal erosion rate

These approaches attempt to eliminate future impacts by prohibiting construction within the highest flood hazard area.

The Cape Cod Commission's *Model Bylaw for Effectively Managing Coastal Floodplain Development* recommends that communities prohibit all new or expanded non-water dependent structures in the coastal high hazard zone. The overall intent of the model bylaw is to restrict or prohibit development and uses on Land Subject to Coastal Storm Flowage (100-year coastal floodplain) and its buffer zones. As with many other examples, it begins with the establishment of a Coastal Floodplain District (an overlay district) serving as an expansion of the regulatory scope of the underlying district, applying more restrictive regulation.

The Town of Oak Bluffs' Rules and Regulations for the Floodplain Overlay Zoning District include uniform procedures for the Board of Appeals (ZBA) in managing the floodplain overlay district. The ZBA serves as the special permit granting authority for the overlay district, as established under Section 8.1 of their Zoning Bylaw. The regulations outline the special permit review process and requirements including development submission requirements, as well as design criteria and performance standards.

The creation of setback areas in the floodplain is also essential to protecting the built environment. A study by the U.S. Environmental Protection Agency (EPA) indicates that in order to effectively remove nutrients and sediments, a buffer of at least 100 feet is needed. Furthermore, a floodplain protection plan should have the main goal of providing enough space for the waterbody to adjust and maintain itself in a state of equilibrium. One of the best examples of a development setback in coastal areas can be found in the Maine Shoreline Zoning Handbook for Shoreland Owners; stating that "all structures, except those which are water dependent, must be set back from the normal high-water line of a water body (including tributary streams) or the upland edge of a wetland." This typically results in a 100 foot setback.

Development/Building Guidelines

Incorporating development review guidelines is critical to protecting the built environment and ensuring that redevelopment proposals consider possible climate change impacts. Zoning changes may be necessary to accommodate design considerations to protect the built environment. It is important to account for interdependent changes such as mandating floodproofing and accommodating increased building height associated with elevated buildings. The Towns of Hull and Rockport have recently dealt with this issue.

Increasing the existing floodplain area (above FEMA regulation and based on increased storm frequency and flood potential) or creating floodplain zoning are significant first steps to climate change adaptation.

Floodproofing

The revised Massachusetts State Building Code, Appendix 120.G which includes the following:

- National Flood Insurance Program (NFIP) conformity,
- Post Hurricane Katrina FEMA recommendations, and
- Consistency between the Massachusetts Building Code and the Massachusetts Wetlands Protection Act regulations and permit approvals.

However, the building code does not account for potential increased flooding frequency and intensity caused by climate change. Therefore, municipalities should consider establishing minimum building design standards within existing flood zone areas, as well as adjacent areas that could be impacted. FEMA produces Technical Bulletins for floodproofing (e.g. FEMA Technical Bulletin 3-93: Non-Residential Floodproofing), which can be used as a guide for establishing local guidelines. Municipalities that participate in the NFIP must adopt minimum building standards of the NFIP regulations; 44 CFR 66.3. However, cities and towns are currently only encouraged to adopt and enforce floodplain management ordinances or laws more stringent than the minimum requirements. Municipalities should consider including the following building specifications within all flood zones to reduce climate change impacts:

- Elevation of the lowest floor (including basement mechanical and utility equipment, and ductwork) two feet above the Base Flood Elevation (BFE). Although the state building code prevents municipalities from regulating this change outside of velocity zones (V-Zones), local incentives can be provided to encourage property owners to elevate in other flood prone areas.
- Allow floodwaters to pass through basements and breakaway panels.
- Watertight to the floodproof design elevation (at least the BFE). Floodproofing to any elevation less than one foot to two feet above the BFE will have a serious negative impact on the flood insurance rating for the building.
- Walls that are "substantially impermeable to the passage of water" (U.S. Army Corps of Engineers Flood Proofing Regulations).
- Foundations and structural components having the capability of resisting hydrostatic and hydrodynamic loads and the effects of buoyancy. This requirement would allow the municipality to receive CRS Credit Points for higher regulatory standards (CRS Credit for Higher Regulatory Standards).
- Minimum design elements from FEMA's Flood-Resistant Materials Requirements, Technical Bulletin 2-93 including:
    - Moisture entrapment within walls and floors that impact structural integrity and cause biological and chemical contamination,
    - One-way valves permanently fitted in drains and sewage pipes to prevent backflow,
    - Concrete, vinyl and ceramic tiles,
    - Pressure-treated timber,
    - Glass block.
- Requiring a FEMA Floodproofing Certificate for all non-residential buildings to ensure proper floodproofing (FEMA technical Bulletin 3-93: Non-Residential Floodproofing).
- Utilities and sanitary facilities, including heating, air conditioning, electrical, water supply, and sanitary sewage services, in new and redeveloped sites should be located above the base flood elevation and be completely enclosed within the building's watertight walls, or made watertight and capable of resisting damage during flood conditions. All of the building's structural components should be capable of resisting specific flood-related forces, as described in *Technical Bulletin 3-93*.

Other design and siting considerations outlined in the Coastal Construction Manual, which can assist in the protection of buildings from sea level rise include:

- Use of corrosion-resistant structural connectors including wooden connectors, heavy gauge galvanized connectors, and stainless steel connectors, to avoid compromising structural integrity and building failures.
- Breakaway walls in enclosures below elevated buildings are designed to collapse under flood loads and act independently from the elevated building, leaving the foundation intact (not recommended in Coastal A Zones, rather open areas).
- Buildings should be located landward of both the long-term erosion setback and the limit of base flood storm erosion, rather than simply landward of the reach of mean high tide.
- Decks, pads, and patios should be designed to minimize the creation of large debris in the event of failure.

Infrastructure Protection

Infrastructure enhancements for climate change adaptation include a range of actions from altering engineering structures that affect water bodies and coastal locations to limiting where hazardous and polluting structures can be built (including landfills and chemical facilities).

Coastal Infrastructure

Shoreline armoring is the protection of land and buildings from erosion and flooding using man-made structures such as jetties, seawalls, and bulkheads. These structures are also intended to hold shorelines in place. It is important to note, however, that these hard structures restrict the movement of wetlands and contribute greatly to beach erosion as they deprive the beach of natural deposition of sediment. Additionally, new shoreline armoring is not recommended by CZM or U.S. EPA and is only considered under extreme conditions.

The issue of armoring becomes prominent with respect to adaptation as it has a role in both protecting existing uses like buildings and roads and giving way to accommodating sea level rise. In the short term, the need to repair and reconstruct these structures will be critical. People's homes and businesses would be exposed to greater risks if these structures were not present and public facilities like roads could damaged, severing vital transportation links for municipalities. In the long term, though, these structures will potentially experience forces that will hasten their deterioration and reduce their ability to protect the property behind them. Furthermore the remaining beaches and coastal landforms on the seaward side of the structures will be lost. An issue that will also be involved with these structures is ownership, specifically determining if the structures are privately or publicly owned.

Adaptation strategies for coastal protection structures will be an evolving process to determine where the costs to rebuild a structure will be weighed against the costs and outcomes from removal. The process will rely on the constant collection of data, such as MSL, mean high water (MHW) lines and storm costs, and the evaluation of this information to guide decision-making. A framework to help organize this process is called Adaptive Management. This framework addresses issues that involve uncertainty and relies on iterative processes that utilize continuous monitoring and assessment to inform policies and implementation. The Massachusetts Department of Fish and Game has developed a webpage about Adaptive Management and how the department is using it to advance climate change adaptation in the state.

Water Infrastructure

Wastewater collection and treatment systems could be adversely affected by climate change in a number of ways. Changes in temperature will lead to increased temperature for wastewater effluent discharged to cold water fisheries. Increased sea level could cause inundation to septic systems, damage to sewer lines, and treatment facilities located in coastal areas and adjacent to embayments. Methods for protecting wastewater facilities include: installing protective walls, raising pump stations, developing new/relocating existing facilities away from flood zones, and implementing increased effluent treatment to address increasing surface water temperature increases. It is also important for communities to eliminate combined sewer overflow (CSO) systems, which could increasingly overflow due to increased storm events and intensity. EPA estimates the costs associated with these adaptation strategies (capital and operation and maintenance) in the Northeast to range from $31 to 61 billion. Therefore, positioning wastewater management to assist with increasing potable water supply challenges (e.g., reusing treated wastewater for irrigation) will become a critical, sustainable method for municipalities to employ.

According to the United Nations – Water Publication Climate Change Adaptation: The Pivotal Role of Water, "Water is the primary medium through which climate change influences Earth's ecosystem and thus the livelihood and well-being of societies." Adaptation measures relating to water supply can be classified, as follows:

- Planning and making investments (e.g., capacity expansions; local, sustainable water supplies; additional wastewater treatment and/or reuse; and ecosystem restoration).
- Monitoring and regulating existing systems to accommodate new uses (e.g., ecological monitoring and protection, pollution control, monitoring population growth).
- Maintaining, rehabilitating and re-engineering existing systems (e.g., dams, pumps, tide gauges, streams/beds, and wetlands).
- Modifying demands for existing systems (e.g., rainwater harvesting, water conservation, pricing, regulation, basin planning, funding for ecosystem services, stakeholder participation, consumer education and awareness).
- Introducing new, efficient technologies (e.g., desalination, biotechnology, and wastewater reuse and recycling).

Protection of drinking water sources and infrastructure from floodwaters and increased heat is a critical measure to ensure public health. Drinking water sources can easily become adversely affected by decreased or increased precipitation (which reduces water availability), salt water intrusion into groundwater and/or inundation of coastal facilities, and increased flooding. Strategies to adapt to these changes include additional treatment and filtering, protective walls around key infrastructure and treatment facilities. EPA cost estimates associated with these protective measures in the Northeast ranges from $70 to 90 billion. Therefore, it is recommended that municipalities consider a long-term integrated water management (IWM) approach to protecting water resources, as discussed in the Association of Metropolitan Water Agencies' *Confronting Climate Change: An Early Analysis of Water and Wastewater Adaptation Costs*. IWM includes looking holistically at drinking water, stormwater and wastewater systems along with water resource management to maintain watershed integrity and waterbodies natural flood protection functions. Integrated adaptation strategies should include:

- Water Conservation and Greywater Reuse
- New Water Conveyance and Storage
- Desalination
- Wastewater Reuse

- Riparian Restoration (reduces water temperatures and protects habitat)
- Green Infrastructure (natural stormwater systems to reduce flooding, recharge and treat water locally)

Stormwater management is in the forefront of municipal leaders' minds because it represents the initial stages of climate change impacts. As described in the report, storm frequency and intensity could lead to additional flooding in the three towns. Stormwater systems are generally the first system to be impacted by the flooding, along with the roadways they serve. It's more important that municipal officials embrace low impact development (LID) stormwater techniques, reusing rainwater and managing stormwater at the site (rather than through a piped system). Fortunately, there currently are numerous resources available to municipalities regarding retrofitting existing stormwater systems and alternative techniques employed at redevelopment/new development sites. Designing for the 100-year storm at higher frequency, maintaining the hydrologic system, recharging groundwater are most critical elements of climate change adaptation. Further information can be found on the EPA's LID Website, Massachusetts Smart Growth/Smart Energy Toolkit website and in the MAPC LID online toolkit. MAPC is also developing a Stormwater Utility Starter Kit, which should be completed in mid to late 2012.

Transportation

Protection of low lying transportation facilities is an important aspect of adaptation planning. Roadways, bridges and other transportation infrastructure can be flooded on a reoccurring basis, and these facilities can be damaged significantly by powerful storm events. Loss of access to these roads and bridges can result in economic losses and reduce capabilities for emergency services. An example of this risk can be seen in the impacts to Vermont towns as a result of Tropical Storm Irene.

As coastal transportation facilities are evaluated for repair, reconstruction and re-design, their proximity to the coastline and elevation should be carefully reviewed. If the facility is within an area that could be impacted by sea level rise and flooding from storm events, alternatives such as relocation or enhanced drainage systems should be explored. In other cases, increased maintenance to coastal structures that protect these facilities may be necessary. A related consideration is the integration of roadway reconstruction with wetlands restoration, as culverts can be widened to improve the flow of water below a roadway. This would allow more water to be sent into wetlands and adjacent water bodies.

Natural Resources

The preservation of green space and proactive water resource management is one of the most important components of protecting natural resource functions for climate change adaptation. Planning for linked open spaces that provide co-benefits (ecological, recreational, and flood storage),restoring wetlands, protecting and increasing tree canopy, and preserving natural land for floodwater absorption are critical actions for local climate change adaptation.

Wetlands

Protecting and restoring salt marshes and inland wetlands are extremely effective climate adaptation strategies. Wetlands function as sponges, as buffers against storms, as sources of fresh water and food. Another important function of wetlands is its natural function as carbon sequester.

Depending upon the wetland's make-up, they can hold up to up to five times the carbon stored in tropical forests.

The development of, or revision of an existing, Wetlands Bylaw that accounts for sea-level rise in the resource delineation methods is useful to ensure that these valuable resources are protected. These regulations should also allow for wetland expansion and migration, as necessary to accommodate higher tides and floodwaters. (*See Potential Salt Marsh Inland Migration map series from Task 1*). One of the study towns, Scituate, is already advancing this in practice through their coastal wetland bylaw, which is described in the Regulation section.

Restoring existing wetlands should become a municipal planning and investment priority. The Massachusetts Division of Ecological Restoration (DER) has developed the South Shore Tidal Restriction Atlas[12], which identifies wetland resources and potential restoration opportunities and funding mechanisms. Specific restoration methods provided by DER are as follows:

- Redesign and/or remove impediments to tidal flow and sediment supply, such as dams on coastal rivers, tide gates, and culverts to restore natural tidal range, sediment supply, and habitat migration potential.
- Remove obstructions and protect coastal lands upgradient of tidal wetlands to facilitate inland migration of salt marsh and other coastal habitats.
- Adopt flexible regulations, planning policies, and land use laws to promote coastal wetland restoration and increase protective buffers.

Shoreline

Restoring the immediate shoreline to a state that will accept the fluctuations of rising tides and storm surges is critical to climate change adaptation. According to EPA's Climate Ready Estuaries program, "soft" measures to maintain shoreline features aim to develop living shorelines through beach nourishment, planting dune grasses, marsh creation, and planting submerged aquatic vegetation. The Climate Ready Estuaries website provides a list of soft measures along with examples across the country. Massachusetts CZM StormSmart Coasts program also describes a number of ways to protect and restore shoreline areas:

- Renourishing beaches and dunes to prevent sea level rise from inundating low-lying coastal property, eroding beaches, or worsen flooding (see Massachusetts Department of Environmental Protection, Beach Nourishment guidance and CZM's Barrier Beach Management in Massachusetts).

- Re-vegetating/stabilizing shorelines and/or riparian (river) corridors with native plants. See CZM's Coastal Landscaping website and UMass Extension's brochure Selection and Maintenance of Plant Materials for Coastal Landscapes.

Municipalities can also consider developing a shoreline protection bylaw. The State of Maine has established a Coastal Sand Dune Rule that prohibits new construction in frontal dunes, with some minor exceptions (e.g. elevated boardwalks, fire escapes, handicapped access).

[12] An electronic copy of this document can be requested from MAPC.

Regulation

There is a number of varying regulatory options available to municipalities to ensure that natural resources, which can minimize natural hazards from climate change, are protected or enhanced. Methods include development of zoning changes and/or overlay districts for flood protection, development/revision of wetlands and shoreline protection bylaws, the use of land use restrictions such as easements and establishing transfer/purchase of development rights.

Wetland Regulations

Wetland Ordinances/Bylaws and Regulations can be strengthened to include sea level rise and landward migration of the wetland resource area (typically Land Subject to Coastal Storm Flowage) in design considerations. For example, the Scituate Wetlands Regulations include the 100 year flood elevation plus a factor of one foot (historic rate of relative sea level rise in Massachusetts) to accommodate sea level rise in design. Designers must set the top of the foundation one foot above base flood elevation, at a minimum, unless a higher elevation is determined by the Commission.

Land Subject to Coastal Storm Flowage

The Massachusetts Coastal Hazards Commission (CHC) recommended that the state and municipalities revise their wetlands regulations to include best management practices or performance standards for Land Subject to Coastal Storm Flowage (LSCSF).

LSCSF are defined within the state Wetlands Protection Act as "land subject to any inundation caused by coastal storms up to and including that caused by the 100-year storm, surge of record or storm of record, whichever is greater" (i.e. coastal floodplain). These areas are significant to storm damage prevention and flood control, protection of wildlife habitat and the prevention of water pollution. Generally, LSCSF contains areas where the water table is close to the surface, therefore, pollutants in a flood plain, including contents of septic systems and fuel tanks, could affect public health and water supplies, groundwater quality, wildlife, fisheries and shellfish during a storm. Currently, there are no performance standards within the state regulations.

The Town of Duxbury has revised their wetlands regulations to include LSCSF performance standards that include, but are not limited to:

- A proposed project shall not cause any adverse effect or cumulative adverse effect upon the wetland values of LSCSF.
- When LSCSF is significant to protection of wildlife habitat, a proposed activity shall not impair the capacity of LSCSF to provide important wildlife habitat functions.
- When LSCSF is significant to pollution prevention, a proposed activity shall not cause ground, surface or salt water pollution triggered by coastal storm flowage or flooding. For those areas within at least 100 feet of another Resource Area, activities shall minimize adverse effects in order to maintain the capability to remove suspended solids and other contaminants from runoff before it enters other Resource Areas.
- For activities proposed in A-zones, the historic rate of relative sea level rise in Massachusetts of 1 foot per 100 years shall be incorporated into the project design and construction.

Their regulations pertaining to LSCSF prohibit new construction or placement of new structures, new or proposed expansions of coastal engineering structures, and new or expanded septic systems.

Floodplain Management

Current FEMA floodplain mapping does not take climate change and sea level rise impacts into account. Therefore, municipalities would have to map vulnerable areas that would not be included in the standard floodplain maps available, such as the Federal Insurance Rate Map (FIRM), for their own communities. Mapping and regulating an area outside the FIRM is critical to protecting natural flood resistant areas as well as built areas. The National Flood Insurance Rate Program (NIFP) has developed a Model Floodplain Ordinance, which includes a more prescriptive mapping effort resulting in a larger regulatory floodplain area. Municipalities can also receive credit through the Community Rating System of the NIFP for including habitat protection within a floodplain management ordinance, as described in the *CRS Credit for Habitat Protection* guidebook. The guidebook reviews the many good floodplain management practices that can protect habitat and help reduce and prevent flood damage.

Conservancy District

Although sometimes a challenging approach, one of the most prescriptive methods for climate change adaptation is establishing a Conservancy District. This district can be established as an overlay zoning district for built and/or natural areas in order to prohibit future development on existing parcels and with the intent of establishing a long-term buffer between flood-prone areas.

The Town of Chatham has set a primary example with the establishment of a Conservancy District and associated changes to its zoning bylaw. These changes prohibit construction of residences in certain areas known to flood (including the entire 100-year floodplain as mapped on their FIRMs). The bylaw was challenged, but upheld by the Massachusetts Supreme Judicial Court. The Cape Cod Commission has a Model Bylaw for Effectively Managing Coastal Floodplain Development, which recommends that communities prohibit all new or expanded non-water dependant structures in the coastal high hazard zone. The model also contains a technical report to support its higher standards.

Land Use Restrictions

Conserving land in coastal areas can be accomplished by removing or limiting development potential through acquisition, conservation easements, and the Purchase and Transfer of Development Rights.

Conservation Easements

A conservation easement - restriction on the use of one's property – can protect land against future development and maintain the land's natural functions for flood control. It is a recorded deed restriction, and the right to enforce the restriction is typically given to a tax-exempt charitable organization or a government agency. The Nature Conservancy has used conservation easements for years to preserve natural lands from development.

Rolling Easements

Rolling easements essentially are a set of approaches that are structured to allow the inward migration of wetlands and beaches as sea level rises. The rolling easement recognizes the natural inland migration of these features and focuses on retaining public access to the shoreline by: prohibiting the use of coastal protection structures that obstruct this movement and establishing a

clear set of regulations about the upper boundary of publicly accessible shoreline. The result is a clear set of expectations of how buildings, roads and other structures will be expected to retreat over time as they are inundated in order to allow the shoreline and related features to maintain their natural processes. A Rolling Easements primer has been developed through the EPA's Climate Ready Estuaries program.

Transfer of Development Rights

Transfer of Development Rights (TDR) includes a similar principle of preserving natural areas for flood protection, except the method for doing so includes the identification of specific "sending areas" (preservation areas) and "receiving areas" (development districts), as described in full on the Commonwealth's Smart Growth/Smart Energy Toolkit. Once areas are identified, zoning amendments can be adopted that authorize landowners in the sending areas to sell their development rights to landowners in the receiving areas. This approach allows market forces to enter into the transaction and requires land owners to negotiate the final value of development rights.

To ensure that land protection can occur, even if there is no immediate market for development, a development rights bank could be established by a municipality, similar to that done in New York. The municipality establishes a "bank" or account that acquires and retains development rights from a sending area. Development rights are held until there is demand for them to be used within the receiving area.

Purchase of Development Rights

Purchase of Development Rights (PDR) is a system by which owners are allowed to sell their rights to develop their properties (versus transfer) while retaining their property ownership. In Montgomery County Maryland, local governments and land trusts have purchased development rights and have the land protected through a conservation (agricultural) easement. Municipalities can adopt the Community Preservation Act (CPA) and use Community Preservation funds to acquire properties at risk of sea-level rise and storm surge.

Land Acquisition

In addition to the methods described above, municipal acquisition of natural open space areas, potentially through the Community Preservation Act Funds, would certainly ensure the permanent protection of natural areas for the purposes of climate change adaptation. Also, acquisition of inland wetland buffer zones will provide an opportunity for wetlands to migrate inland, which is an important component to wetland adaptation to increasing flood waters.

Outreach and Education

Moving forward with climate change adaptation will likely involve a catalog of strategies. How to identify and position resources for this are addressed in the following section, however the role of citizens, businesses, local officials and other partners deserves highlighting as well because of the key role they will play in the process. Below is a brief description of how outreach and support building could begin with specific stakeholder groups.

Municipal

Municipal officials play a key role in climate change adaptation; in not only establishing local planning and regulatory changes, but to educate both their elected and volunteer officials and the general public about climate change and local effects. The information provided in this report will provide a good first glance at the types of issues these coastal communities are facing. Internal and public presentations can be created from this information. Tailored information regarding education for local emergency responders, department of public works, and water/wastewater operators should be considered, as these officials will likely have the most implementation responsibilities (e.g., building/repairing protective structures, retrofitting municipal facilities, etc.). In addition, planning staff/board and the local health agent/board will have critical roles to play in terms of generating regulatory change and protecting public health from climate change impacts (e.g. illnesses from mold exposure, increased heat-related illnesses).

Residents and Local Businesses

General climate change and adaptation education should be provided to residents and local businesses to provide context and assist officials in their efforts to adapt to climate change impacts. Furthermore, it is important that community members have a sense of responsibility and stewardship in adaptation actions since these actions may move forward on a parcel-by-parcel basis. Information to homeowners and small businesses should be focused on minimizing adverse effects from high flood waters, increased storms and frequencies, sea level rise and increased heat. As described above, specific, site-level measures can include floodproofing, heat reduction measures (e.g., shade trees and retrofitting, setbacks from natural areas), natural landscaping, and land conservation. This information does not have to be daunting, rather, it could provide homeowners with an opportunity to make improvements to their property, and possibly receive credits for doing so. A guide for educating homeowners and creating local floodproofing programs has been created by the U.S. Army Corps of Engineers. Resources regarding natural landscaping can be found on the Greenscapes Massachusetts website, of which the North and South Rivers Watershed Association is a partner.

Real Estate Agents

Real Estate Agents provide the first introduction to homeownership when an interested party seeks a new home or business location. This provides a realtor with a great deal of power with regard to what information is provided. Information regarding location within a FEMA flood zone or the community's flood hazard area should come from realtors, as many potential homebuyers are not familiar with what questions to ask the Town or information to research. Furthermore, realtors could provide the Town with a direct vehicle by which to provide additional information to homeowners such as water conservation and reuse, natural landscaping, and even residential floodproofing strategies (see outreach to Residents and Local Businesses).

Developers/Engineers

Education for developers regarding their critical role in adaptation and development strategies for adaptation is an important outreach component. Developers, contractors, and engineers work directly with the structures and facilities that will be affected by sea level rise and climate change impacts. Their actions could provide benefits to the community in the future, or could lead to

economic losses. Training for developers and contractors is something municipalities could consider. Hosting and coordinating programs to ensure that development is conducted in a sensitive manner that protects community assets and vulnerabilities identified in this report. FEMA provides training courses regarding floodproofing.

Regional Outreach

Participating and cultivating a regional outreach program would be the next step to developing and implementing a South Shore adaptation plan. Since climate change is more than a local issue, regional approaches are warranted for discussion. South Shore Communities could engage with MAPC and other regional partners such as the South Shore Chamber of Commerce, the North and South Rivers Watershed Association, and the MAPC South Shore Coalition (SSC) to devise a regional outreach program regarding the development of adaptation plans and mitigation planning.

TASK THREE: FUNDING OPTIONS TO SUPPORT ADAPTATION

For the third task, MAPC worked to identify existing funding sources that could be re-purposed or re-directed to support adaptation strategies. However, there will likely be new resources needed to support municipal actions. For example, in the short-term, the huge projected costs to maintain crumbling sea walls, revetments and bulkheads, are expected to push the limits of current State and municipal funding sources. New alternatives will need to be outside current governmental fiscal regulatory constraints. This section provides background and guidance on utilizing existing resources while identifying possibilities for new resources to support adaptation strategies.

REVIEW OF THE NATIONAL FLOOD INSURANCE PROGRAM AND EXISTING GRANTS FOR CLIMATE CHANGE

Existing funding that can be focused toward mitigation of natural hazards and management of climate change vulnerabilities includes grants and technical assistance from: Federal Emergency Management Agency (FEMA), National Oceanic and Atmospheric Administration (NOAA), the Massachusetts Division of Conservation Services (DCS), and the Executive Office of Housing and Economic Development, among others. Details on these programs are provided below.

Federal Emergency Management (FEMA)

- Community Rating System: The National Flood Insurance Program's (NFIP) Community Rating System (CRS) is a voluntary incentive program under FEMA that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. As a result, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from the community actions meeting the three goals of the CRS: 1) Reduce flood losses; 2) Facilitate accurate insurance rating; and 3) Promote the awareness of flood insurance. The CRS could be an effective tool for reducing community costs in coordination with reducing climate change risk exposure. Marshfield and Scituate currently participate in CRS and are designated as Class 8 communities, which provide properties in the towns a 5-10% discount in flood insurance premiums.

- Hazard Mitigation Grant Program: The Hazard Mitigation Grant Program (HMGP) provides grants to States and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. Locations impacted currently by a natural disaster can often be candidates for potential impacts from climate change. As a funding resource used in the part by Scituate and Marshfield, new grant proposals should explore opportunities to build climate change considerations into the new mitigation measures should be explored.

- Pre-Disaster Mitigation Grants: The Pre-Disaster Mitigation (PDM) grants provide funds on an annual basis for hazard mitigation planning and the implementation of mitigation projects prior

to a disaster. The goal of the PDM program is to reduce overall risk to the population and structures, while at the same time, also reducing reliance on Federal funding from actual disaster declarations. Although not currently required by FEMA, climate change can be included in the hazard mitigation planning to identify future, as well as past, risks.

- Flood Mitigation Assistance: Flood Mitigation Assistance (FMA) provides funds on an annual basis so that measures can be taken to reduce or eliminate risk of flood damage to buildings insured under the National Flood Insurance Program (NFIP). With the threat of sea level rise and higher levels of flooding, there may be opportunities to build in these considerations when addressing building elevations and heights. FEMA is currently conducting a review of the entire National Flood Insurance Program. While the NFIP was actually designed to discourage the unwise occupancy of flood prone areas, occupancy of these areas has actually increased since 1968 and providing coverage has become much more costly, preventing many from purchasing the insurance. In an era of growing climate volatility, FEMA is seeking to optimize the NFIP to balance fiscal soundness, affordability of insurance, floodplain management, economic development, and individual freedoms.

- Repetitive Flood Claims: Repetitive Flood Claims (RFC) provides funds on an annual basis to reduce the risk of flood damage to individual properties insured under the NFIP that have had one or more claim payments for flood damages. RFC provides up to 100% federal funding for projects in communities that meet the reduced capacity requirements. Up to $10 million is available annually for FEMA to provide RFC funds to assist States and communities to reduce flood damages to insured properties that have had one or more claims to the National Flood Insurance Program (NFIP).

  There is a direct link to climate preparedness as it relates to flooding and sea level rise as grants are given the following mitigation activities:
  - Acquisition of properties, and either demolition or relocation of flood-prone structures, where the property is deed restricted for open space uses in perpetuity
  - Elevations
  - Dry floodproofing of non-residential structures
  - Minor localized flood control projects (funding limited to $1 million per project)

- Severe Repetitive Loss: The Severe Repetitive Loss (SRL) program provides funds on an annual basis to reduce the risk of flood damage to residential structures insured under the NFIP that are qualified as severe repetitive loss structures. SRL provides up to 90% federal funding for eligible projects designed to reduce or eliminate the long term risk of flood damage to severe repetitive loss structures, which are directly impacted by flooding and storm events aggravated by increased storm event intensity and frequency, as well as rising sea level. Grant awards can be used on SLR properties for the same mitigation activities identified with RFC.

  The federal government will generally cover 75% with a state cost share of 25%. Up to 90% Federal cost-share funding can be achieved for projects approved in states, territories, and federally-recognized Indian tribes with FEMA-approved Standard or Enhanced Mitigation Plans or Indian tribal plans that include a strategy for mitigating existing and future SRL properties.

National Oceanic and Atmospheric Administration (NOAA)

- Center for Sponsored Coastal Ocean Research: NOAA's CSCOR, which is part of the National Centers for Coastal Ocean Science, provides scientific information to assist decision makers in

meeting the challenges of managing the nation's coastal resources. Through its funding opportunities, the Coastal Ocean Program is making significant strides toward finding the solutions that will protect coastal resources and ensure their availability and well-being for future generations. The CSCOR's Ecological Effects of Sea Level Rise Program brings together University and NOAA scientists to help coastal managers and planners better prepare for change in coastal ecosystems and their economic impacts due to sea level rise, coastal storms, land subsidence, and erosion.

- Community-Based Restoration Program: The NOAA Restoration Center has developed the Community-Based Restoration Program web page to disseminate information about grant opportunities offered through its funding partnerships. Grant opportunities are posted, on an ongoing basis, as partnerships are developed and funding becomes available.

- **The Estuary Restoration Act**: NOAA's National Ocean Service and National Marine Fisheries Service, in cooperation with Restore America's Estuaries, developed A National Strategy to Restore Coastal and Estuarine Habitat. The program has included funding opportunities to support restoration projects. Estuaries are likely to be key coastal features in relation to climate change since they can provide storm and tidal storage benefits, but at the same time can be severely impacted by higher sea levels.

- Coastal Estuarine Land Conservation Program**:** The Coastal and Estuarine Land Conservation Program (CELCP) was established by Congress in 2002 "for the purpose of protecting important coastal and estuarine areas that have significant conservation, recreation, ecological, historical, or aesthetic values, or that are threatened by conversion from their natural or recreational state to other uses," giving priority to lands that can be effectively managed and protected and that have significant ecological value. Congress directed the National Oceanic and Atmospheric Administration (NOAA) to administer this program and to establish guidelines that would make CELCP project selection an objective and nationally competitive process. To meet this directive, NOAA developed CELCP guidelines that require states wanting to participate in this voluntary program to first prepare a Coastal and Estuarine Land Conservation Plan (CELC Plan). NOAA is expected at some future date to require approval of a CELC Plan for a state to be eligible to nominate grant applications to NOAA under the CELCP.

- **MIT and Woods Hole Sea Grant Programs:** These grants sponsor a wide variety of marine research, through an annual funding competition open to Massachusetts university-based researchers. In-house research includes the work of the Autonomous Underwater Vehicle (AUV) Lab, and the Design Lab for naval architecture and systems. The MIT Sea Grant Marine Advisory Services group conducts research in marine bio-invasions, water quality, climate change, fishing communities and policy, and offers innovative, hands-on marine science education programs. The Woods Hole Sea Grant program, based at the Woods Hole Oceanographic Institution (WHOI), supports research, education, and extension projects that encourage environmental stewardship, long-term economic development, and responsible use of the nation's coastal and ocean resources.

- Coastal and Ocean Climate Applications (COCA): Formerly the coastal portfolio of the Sectoral Applications Research Program (SARP), the Coastal and Ocean Climate Applications (COCA) program under NOAA addresses the needs of specific stakeholder(s) grappling with pressing climate-related issues in coastal and marine environments. This program will strengthen existing initiatives developed under SARP focused on supporting interdisciplinary applications research in the coastal zone, and will expand efforts to include coastal and marine ecosystems.

Other Federal Funding and Technical Assistance Resources

- Catalog of Federal Funding Sources for Watershed Protection: The Environmental Protection Agency's (EPA) Catalog of Federal Funding Sources for Watershed Protection is a searchable database. The database highlights federal grants and loans that may be used at the local level to support watershed projects, including coastal waters, conservation, and pollution prevention, and contains references to other publications and Web sites on funding and technical assistance.

- National Estuary Programs (NEP): The EPA National Estuary Program (NEP) Funding Mechanisms Web page contains information about the EPA's Environmental Finance Program, funding wetland protection through the Clean Water state revolving fund, and funding for nonpoint source/estuary enhancement projects.

  The EPA Climate Ready Estuaries program works with the National Estuary Programs and other coastal managers to: 1) assess climate change vulnerabilities, 2) develop and implement adaptation strategies, 3) engage and educate stakeholders, and 4) share the lessons learned with other coastal managers. Projects included the following examples:

  - The Casco Bay Estuary Partnership is working with EPA in developing a climate change stakeholder outreach plan that targets local decision makers and integrates consideration of ecosystem resilience into broader messages about climate change. These outreach and stakeholder engagement efforts will help inform the development of a climate change adaptation plan for the estuary.
  - In 2008, The Piscataqua Region Estuaries Partnership launched a project to identify road culverts that are susceptible to failure in the face of increasingly severe storms and from hydrological modifications related to development in the watershed.

- *Coastal Adaptation to Sea Level Rise Tool (COAST):* The New England Environmental Finance Center has developed the *Coastal Adaptation to Sea Level Rise Tool (COAST)* that is able to show the location-specific avoided costs associated with making particular adaptations, along with the costs associated by implementing those actions, to help coastal communities model and analyze various adaption cost scenarios. This tool works graphically at the parcel-based level and can present single-event scenarios as well as cumulative damage and costs over a multi-decade period.

  The City of Portland, Maine and the towns of Hampton and Seabrook, NH area are partnering with the Casco Bay Estuary Partnership (CBEP), Piscataqua Region Estuaries Partnership (PREP), and New Hampshire Climate Adaptation Workgroup (NHCAW) under the EPA Climate Ready Estuaries Program to use COAST to show climate change impact cost and to model the cost of various adaptation scenarios.

- The National Fish and Wildlife Foundation Grant Program: This program is a private, nonprofit, 501(c)(3) tax-exempt organization, established by Congress to address environmental education, natural resource management, habitat protection and restoration, and conservation policy development. The foundation creates partnerships between the public and private sectors to offer such grant programs as the Chesapeake Bay Small Watershed, Community Salmon Fund, Coral Reef Conservation, Five Star Restoration Challenge, Gulf Conservation Challenge, International Sea Turtle Conservation, Pacific Grassroots Salmon Initiative, Shell Marine Habitat Program, the Pathways to Nature Conservation Fund, and many more.

Massachusetts Division of Conservation Services

- Landscape Partnership Program: This program will offer competitive grants to municipalities, non-profit organizations and EEA agencies to help fund partnership projects that permanently protect a minimum of 500 acres of land. The Landscape Partnership Program seeks to preserve large, un-fragmented, high value conservation landscapes including working forests and farms, expand state-municipal-private partnerships, increase leveraging of state dollars, enhance stewardship of conservation land, and provide public access opportunities.

- Conservation Appraisals/Open Space and Recreation Plans for Small Communities Grant Program: This program provides reimbursement funding for Open Space & Recreation Plans (OSRPs) and/or appraisals contracted in order to apply to the LAND grant program. This program is available to all communities with a population of fewer than 5,000 people. Funding is non-competitive; all eligible applicants receive contracts on a rolling basis until all available funding is allocated.

- MA Land and Water Conservation Fund: The Federal Land & Water Conservation Fund (P.L. 88-578) provides up to 50% of the total project cost for the acquisition, development and renovation of park, recreation or conservation areas. Municipalities, special districts and state agencies are eligible to apply. Nearly 4000 acres have been acquired and hundreds of parks renovated using the $95.6 million that Massachusetts has received from the state side portion of the federal program since 1965.

- MA Local Acquisitions for Natural Diversity (LAND) Program: The LAND Program (formerly the Self-Help Program) was established in 1961 to assist municipal conservation commissions acquiring land for natural resource and passive outdoor recreation purposes. Lands acquired may include wildlife, habitat, trails, unique natural, historic or cultural resources, water resources, forest, and farm land.

Executive Office of Housing and Economic Development

- MassWorks Infrastructure Program: The MassWorks Program provides a one-stop shop for municipalities and other eligible public entities seeking public infrastructure funding to support economic development and job creation. The Program represents an administrative consolidation of six former grant programs:
    - Public Works Economic Development (PWED)
    - Community Development Action Grant (CDAG)
    - Growth Districts Initiative (GDI) Grant Program
    - Massachusetts Opportunity Relocation and Expansion Program (MORE)
    - Small Town Rural Assistance Program (STRAP)
    - Transit Oriented Development (TOD) Program

  The MassWorks Infrastructure Program provides public infrastructure grants that support four project types:

    - Housing development at density of at least 4 units to the acre (both market and affordable units)
    - Transportation improvements to enhance safety in small, rural communities

- Community revitalization and sustainable development
- Economic development and job creation and retention

- District Local Technical Assistance Program (DLTA): The DLTA funds are distributed among the state's 13 Regional Planning Agencies (RPAs) to provide cities and towns with technical assistance to help move municipalities forward in the Commonwealth's key initiatives, including regional collaboration, promoting economic development, best practices in zoning, and protecting the environment. This funding is essential to assist cities and towns in regionalizing service as diverse as public health, fire safety, emergency dispatch, special education, emergency medical services, and disaster planning. This study was funded by a DLTA grant.

LOCAL RESOURCES AND PROGRAMS

Many communities feel financially constrained when it comes to acting on climate change adaptation. Local staff is asked to juggle multiple issues of immediate importance, making it difficult to take on new issues such as climate change preparedness. Financial, technical and staffing issues often constrain a community's perceived ability to act.

In response, steps to address climate change preparedness are already being taken as towns and cities address existing high priority management issues that will be exacerbated by climate change such as: water supply, stormwater management, road operations and maintenance, parks and forest management, coastal resources management, agriculture and public health.

Some degree of climate change planning can be integrated into a community work plan using existing budget, technical and human resources. Incorporating stronger climate change preparedness options into local master plans, zoning and subdivision controls, stormwater regulations and natural hazard mitigation plans are examples of non-structural options for climate preparedness. The handbook *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*, Chapters 5 and 6, developed by King County, Washington offers excellent guidance on how municipalities can work within existing programs when planning for climate change.

- **Develop a Capital Investment Program (CIP):** A Capital Investment Program (CIP) contains projects that may have been identified in the municipal comprehensive plan as essential to achieve the "vision" of a town or city by a certain year. Some of the projects will be to meet state mandates, some may accommodate growth and others support an improved local quality of life. The projects in the CIP are expected to occur during the planning period identified, but timelines may be revised as the plan is reviewed and updated. These plans are developed regularly by many municipalities and can be modified to include costs for climate change adaptation measures that occur individually or as part of a larger project. Each project within the CIP typically includes an estimated cost, potential funding source and relative priority. Most data will be taken from known estimates for various upgrades, such as for re-sizing culverts or re-building seawalls.

- **General Taxes, Fees, Revenue Bonding, and Sink Funding:** General fund support, revenue bonds and sink funding may be carefully considered as sources of funding to address infrastructure upgrades. Success in procuring those funds will be increased to the degree that accurate information can be provided on the costs of the adaptation methods or upgrades being considered, probability of inundation events that can be expected, and costs to infrastructure, real estate, local economic activity and natural system functions that would result in no action being taken. Using tools such as COAST, described above in Section 1.1.1, accurate information

and costs can be generated to help support the use of taxes and revenue and sink funding as being cost effective and necessary.

- **General Taxes and Fees:** Taxes generally go into general funds for state and local governments. Fee revenues will often go into enterprise accounts specifically targeted to certain accounts such as parking meter fees being used to maintain and clean downtown parking areas, or water bill user fees to help maintain the town or district water distribution system. If pursuing general funds to prepare for climate adaptation measures, it may be helpful to frame the question as one of infrastructure, public safety and public health rather than only as an environmental issue. Avoided costs, generated through the COAST process, can also help secure funding.

- **General Revenue Bonding**: Bonds represent the most widely used mechanism used to help pay for climate preparedness projects. Encompassing repayments of principal and interest, a bond represents the seller's promise to repay borrowed money on a fixed schedule and timeline. Revenue bonds usually refer to bonds on which debt service payable mainly from the revenue is generated through the operation of the project, or from other non-property sources. Revenue bonds are widely issued by state and local governments, authorities, commissions, or special districts and account for the majority of municipal bonds used to finance water, stormwater and infrastructure projects. They are usually tax exempt and do not count against debt ceilings but they are accounted for under financial analyses conducted by national financial rating agencies. Examples include State Revolving Fund bonds, private-activity industrial development bonds, and mortgage lease-backed bonds.

- **Sink Fund:** A fund into which an organization sets aside money over time, in order to retire its financial obligations, such as bond agreements. In the case of bonds, incremental payments into the sinking fund can soften the financial impact at maturity. Investors prefer bonds and debentures backed by sinking funds because there is less risk of a default. A sink fund can also be used to prepare for large anticipated expenses by setting aside dollars which can be used later for purchasing new assets or set aside as a "rainy day" fund.

- **Coastal Infrastructure Utility Fund**: Investigate the option of creating a locally funded coastal infrastructure utility funding mechanism similar to a stormwater utility to assist with paying for coastal infrastructure costs.

- **Local Improvement Districts:** The Local Improvement District is a method of using betterments and assessments to fund public type improvements benefiting property owners in one section of a municipality while charging the cost of the improvements to the same property owners. The use of these districts is allowed by 35 states and proposed in Massachusetts in 2007 as Chapter T legislation. Legislation has not yet been enacted, but highlights include:
    - A special charge is assessed on property owners in a geographical area to finance needed infrastructure.
    - A "Development Zone" is designated that includes the real estate benefiting from, and paying for, the proposed infrastructure improvements. Assessment payments are used to repay debt issued to fund infrastructure.
    - First used to finance street and drain construction in New York in 1961. Now widely used to finance services, infrastructure and facilities within a defined geographical area, e.g. parks, roads, recreational facilities, utilities, and water and sanitary faculties.
    - See Chapter 40T for more information.

- **Revolving Loan Fund:** Support the creation of establishing a state revolving loan fund to help finance coastal resource infrastructure projects. House Bill 217, filed by Rep. Ayers of Quincy would establish a Coastal Protection and Harbor Maintenance Revolving Fund.

- **Community Preservation Act Funding for Coastal Infrastructure**: Rep. James Cantwell of Marshfield sponsored House Bill 220 that would allow for the use of Community Preservation Act Funds for coastal infrastructure work.

Consolidate Local and Regional resources

Assign a single climate municipal change preparedness "point person" rather than a municipal team to save staff time, coordinate preparedness and seek outside help. That person can be an existing municipal staff member or newly hired individual to carry out the task. The "point person" for climate preparedness needs to have a wide range of authority and skills in order to be effective including:

- The ability to set meetings across departments, require information updates and accomplishment of assigned tasks;
- Technical competence or ability to learn mission and practices of a wide range of departments;
- Access to and relationship with the city or town top leadership to be able to advise and outline plan actions;
- Ability to research, write and communicate about regional climate adaptation and community vulnerabilities;
- A passion for doing climate adaptation work;
- Resourcefulness in finding outside resources to create an adaptation agenda and implement it.

Leverage Local Resources through Partnerships with Institutions and Non-Governmental Organizations

Partnerships between governments, non-governmental organizations, universities and businesses to get data and other resources can assist communities dealing with climate change preparedness. Examples of these partnerships include Antioch New England, Cornell, Columbia, Rutgers, Manomet Center for Conservation Studies, the Nature Conservancy, ICLEI and Clean Air/ Cool Planet.

For example, on the North Shore of Massachusetts, the six communities of Marblehead, Salem, Peabody, Danvers, Beverly, and Manchester-by-the-Sea, worked with Salem Sound Coastwatch, a non-profit coastal watershed organization, and Tufts University in 2008 to assist Salem Sound communities to understand anticipated climate change impacts and begin to develop strategies and tools to make the communities more climate resilient to climate change. See *Climate Change: Ready or Not- Climate Change Impacts, Vulnerability, Risk and Adaptation Strategies for the Salem Sound Area of Massachusetts*.

As a Regional Coordinator for the Mass Bays Program, Salem Sound Coastwatch is a partner in EPA's Climate Ready Estuaries pilot program with the Massachusetts Bays National Estuary Program.

Potential Partnerships with Federal/ State Agencies and Regional Planning Agencies/Councils of Government

Collaborating towns and cities that have identified climate change preparedness issues, or individual communities, should contact relevant state agencies and RPAs to help them support, facilitate and fund climate preparedness planning. See District Local Technical Assistance Program grant source above.

The EPA Climate Ready Estuaries Program offers information on climate change impacts to different estuary regions, access to tools and resources to monitor changes, and information to help managers develop adaptation plans for estuaries and coastal communities.

The StormSmart Coasts program is designed to help coastal communities address the challenges arising from storms, floods, sea level rise, and climate change, and provides a menu of tools for successful coastal floodplain management.

Shared Networks and Staff

Augmenting shared strategic partnerships among the public and private sectors with regional networks can further leverage climate change resources, planning and implementation. Examples of how this can be executed include technical assistance circuit rider programs, North Shore Conservation Commission Network, North Shore Public Health Network and Green Neighborhoods Program.

As with this study, additional work to create and implement a regional coastal and climate adaptation initiative can occur through technical assistance planning programs. Regional planning agencies (RPAs) with coastal community clients could work to organize a circuit rider type of assistance program where an experienced coastal planning professional could provide focused assistance on coastal planning issues to municipal staff and boards.

TASK FOUR: PUBLIC WORKSHOP

For the final task, a public workshop was organized to share information about the study process and key outcomes. It was also framed as an opportunity to improve awareness of the current and potential future impacts to the coastlines from natural hazards and climate change (i.e., sea level rise and increased storm intensity/frequency) and to provide a forum to seek community feedback during the planning process.

The workshop was held on the evening of October 27, 2011 at the Marshfield Senior Center and over 60 people attended, with participants from the three towns and other municipalities on the South Shore. The workshop included a set of panel presentations that featured:

- Jim O'Connell, a former coastal processes specialist with the Woods Hole Oceanographic Institution Sea Grant Program and Cape Cod Cooperative Extension, and now the Conservation Agent for Scituate, on changes to coastal landforms, geology and sea level rise that have occurred from the past and up to the present.
- Julia Knisel, from the MA Office of Coastal Zone Management, on the recently released Massachusetts State Climate Change Adaptation Report.
- Anne Herbst, the Conservation Agent for the Town of Hull, on a coastal inundation study conducted for Hull which looked at how possible sea level rise scenarios could impact public facilities.

MAPC concluded the workshop with a presentation about the study and its findings, and brought together many of the key themes of the other panelists: how the coastline continues to change, how storms and sea level rise present challenges to vulnerable locations, and how to plan for the future in a manner that makes the towns more resilient. In addition, keypad questions were used during the presentation to find out about participants' knowledge of coastal changes, climate change and adaptation strategies. Results of the keypad questions included:

- 70% of participants responded that they have noticed changes such as movement in the high tide line or stronger ocean waves.
- Nearly 90% of participants responded that they have observed changes such as changes in the beach profile or changes to the land in front of sea walls.
- 71% of participants responded that they are very familiar with the potential impacts of a changing climate along the coastlines.
- 84% of participants responded that they think the potential impacts of Climate Change could be very significant along the coastlines
- 73% of participants responded that mixtures of the adaptation strategies (e.g., Build stronger seawalls, elevate roads and buildings, purchase open space and undeveloped land, and move roads and buildings back from vulnerable areas) are the most appropriate approach to addressing climate change impacts along the coastlines.

The workshop was a positive event with 67% of participants indicating that the workshop increased their understanding of how climate change could impact coastlines in their towns. As with this study, the workshop was another step in building a working collaboration to advance climate change adaptation strategies on the South Shore and the surrounding region.

APPENDIX

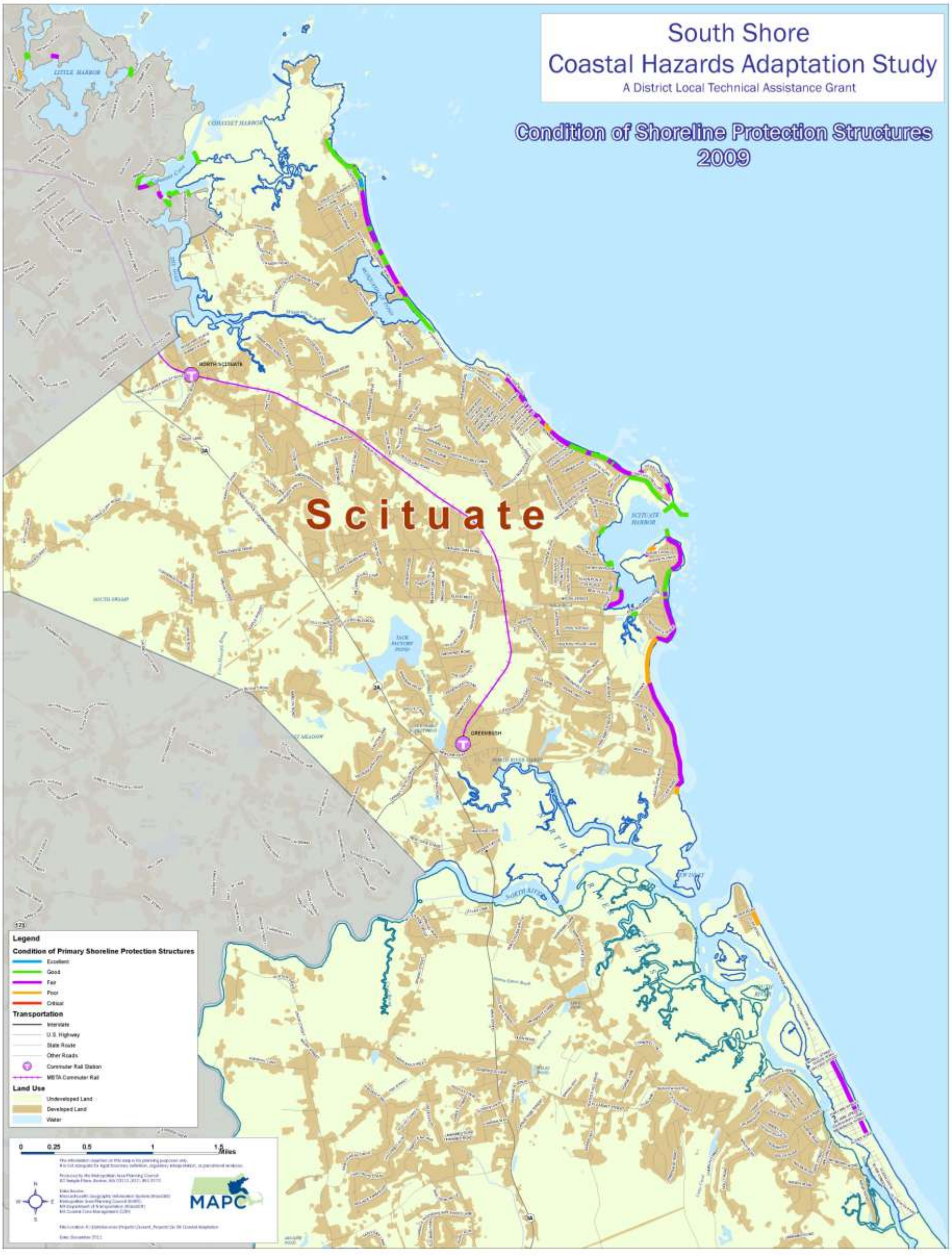
APPENDIX A

CONDITION OF COASTAL PROTECTION STRUCTURES 2009

South Shore
Coastal Hazards Adaptation Study

A District Local Technical Assistance Grant

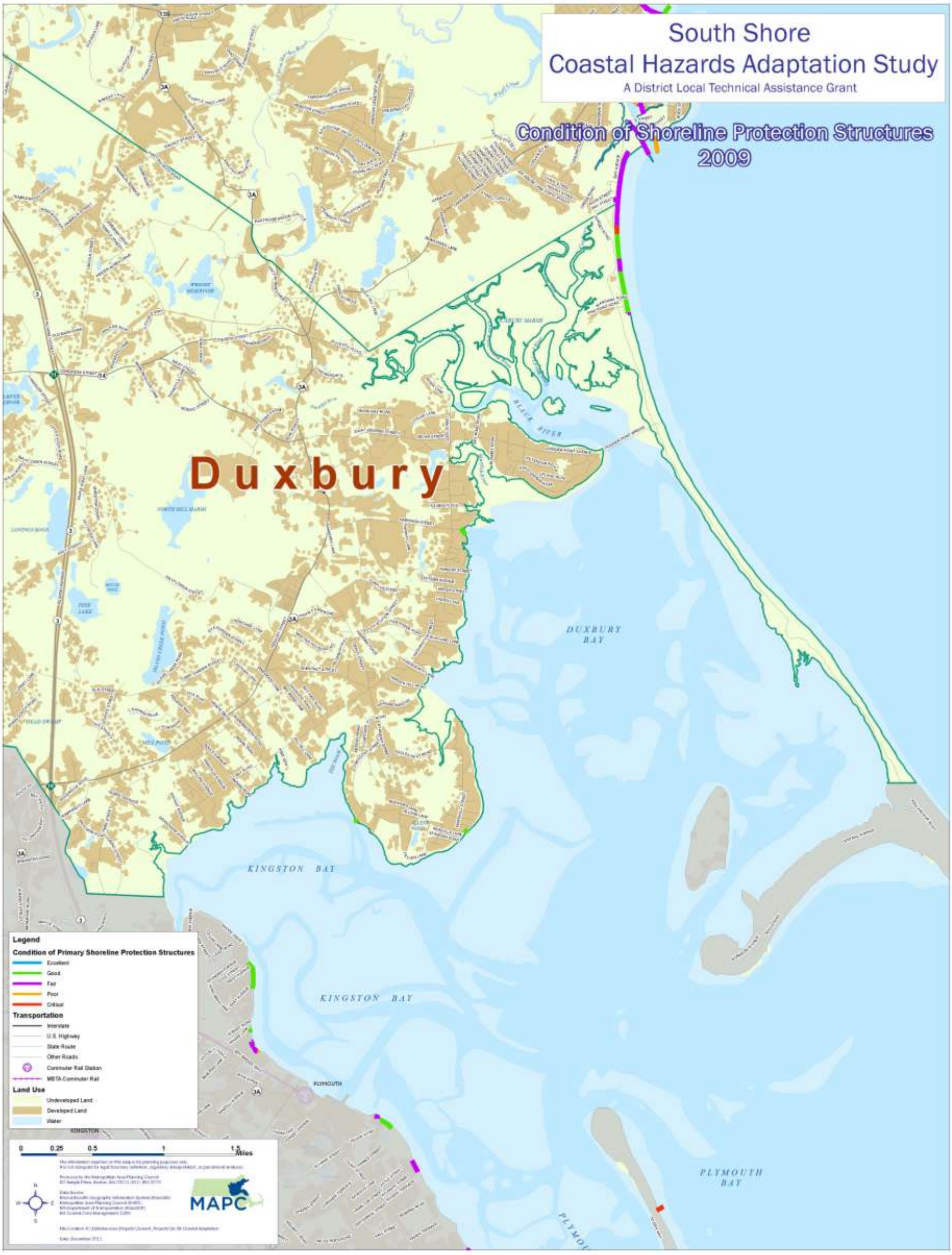
Condition of Shoreline Protection Structures
2009



South Shore
Coastal Hazards Adaptation Study

A District Local Technical Assistance Grant

Condition of Shoreline Protection Structures 2009


South Shore
Coastal Hazards Adaptation Study
A District Local Technical Assistance Grant
Condition of Shoreline Protection Structures
2009
Duxbury
DUXBURY BAY
KINGSTON BAY
KINGSTON BAY
PLYMOUTH BAY
PLYMOUTH
KINGSTON
Legend
Condition of Primary Shoreline Protection Structures
Excellent
Good
Fair
Poor
Critical
Transportation
Interstate
U.S. Highway
State Route
Other Roads
Commuter Rail Station
MBTA Commuter Rail
Land Use
Undeveloped Land
Developed Land
Water
0
0.25
0.5
1
1.5
Miles
N
W
E
S
MAPC

APPENDIX B

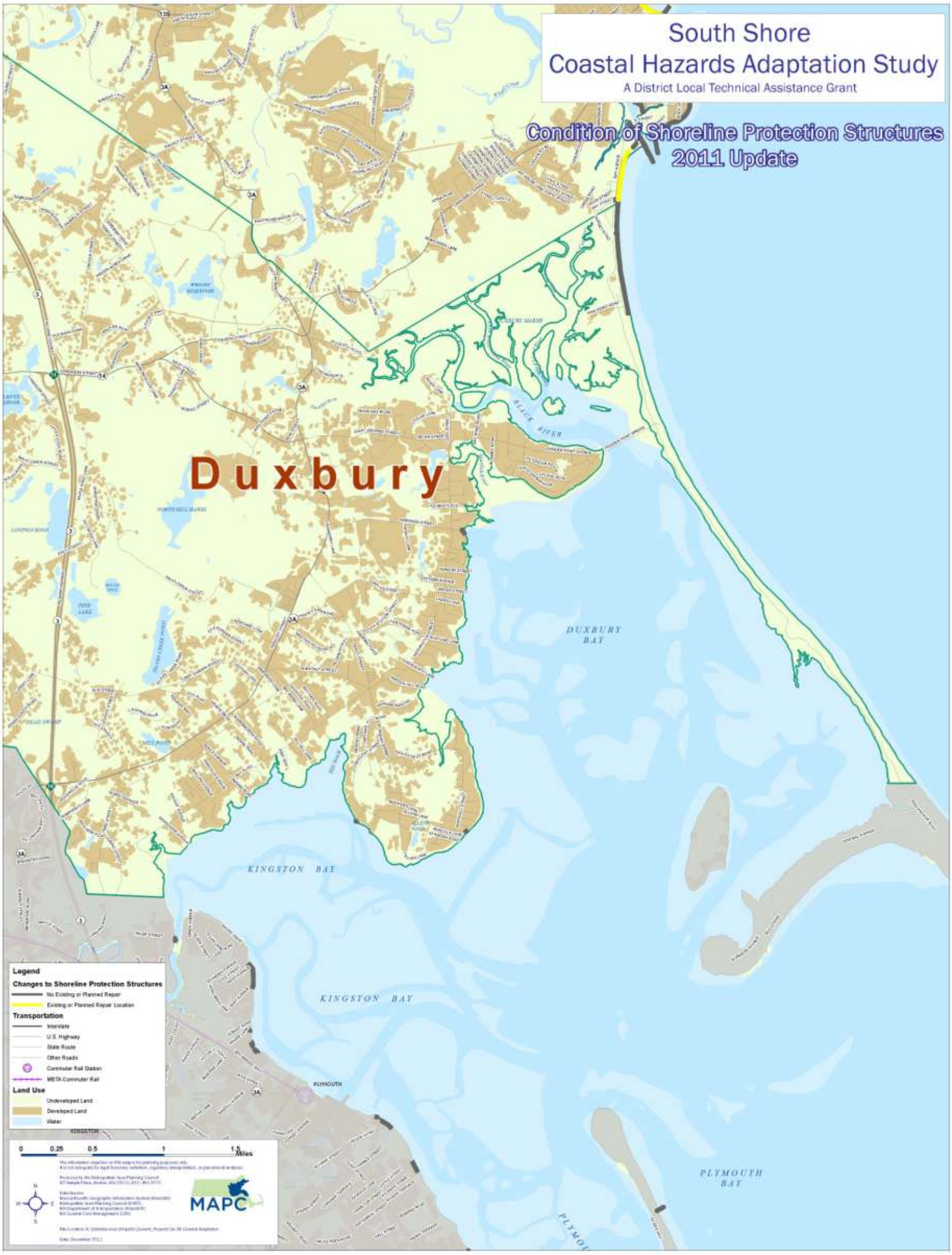
DLTA UPDATE ON CONDITION OF COASTAL PROTECTION STRUCTURES


South Shore
Coastal Hazards Adaptation Study
A District Local Technical Assistance Grant
Condition of Shoreline Protection Structures
2011 Update
Scituate
Legend
Changes to Shoreline Protection Structures
No Existing or Planned Repair
Existing or Planned Repair Location
Transportation
Interstate
U.S. Highway
State Route
Other Roads
Commuter Rail Station
MBTA Commuter Rail
Land Use
Undeveloped Land
Developed Land
Water
0 0.25 0.5 1 1.5 Miles
MAPC

South Shore
Coastal Hazards Adaptation Study
A District Local Technical Assistance Grant

Scituate Marshfield

Condition of Shoreline Protection Structures
2011 Update


South Shore
Coastal Hazards Adaptation Study
A District Local Technical Assistance Grant
Condition of Shoreline Protection Structures
2011 Update
Duxbury
DUXBURY BAY
KINGSTON BAY
KINGSTON BAY
PLYMOUTH BAY
PLYMOUTH
KINGSTON
Legend
Changes to Shoreline Protection Structures
No Existing or Planned Repair
Existing or Planned Repair Location
Transportation
Interstate
U.S. Highway
State Route
Other Roads
Commuter Rail Station
MBTA Commuter Rail
Land Use
Undeveloped Land
Developed Land
Water
0
0.25
0.5
1
1.5
Miles
MAPC

APPENDIX C

SOUTH SHORE COASTAL HAZARDS CHARACTERIZATION ATLAS - SHORELINE CHANGE MAPS

Historical Shoreline Change Rate

Cohasset Harbor to Mann Hill Beach

(1950 to 2001, in feet/year)

< -5

-2

-0.6 to + 0.6

+2

> +5

(+ = accretion, - = erosion)

N

W E

S

0 0.25 0.5

Miles

Length of colored bars illustrates relative magnitude of shoreline change.

White lines represent town boundaries and
dashed black lines show littoral cell boundaries.

Littoral Cell 3

Littoral Cell 4

Scituate Neck

Cohasset Harbor

Scituate

Cohasset

Atlantic Ocean

Mann Hill Beach

This map is from the South Shore Coastal Hazards Characterization Atlas, published by the Massachusetts Office of Coastal Zone Management (CZM). CZM makes no representations or warranties with respect to the definitiveness of the data presented. Prepared by Applied Coastal Research and Engineering, Inc., December 2005.

IV-b

IV-a

Historical Shoreline Change Rate

Mann Hill Beach to Rivermoor Marsh

(1950/52 to 2001, in feet/year)

< -5

-2

-0.6 to + 0.6

+2

> +5

(+ = accretion, - = erosion)

N

W E

S

0 0.25 0.5

Miles

Length of colored bars illustrates relative magnitude of shoreline change.

White lines represent town boundaries and
dashed black lines show littoral cell boundaries.

Mann Hill Beach

Cedar Point

Scituate Harbor

Littoral Cell 4

Littoral Cell 5

Scituate

Atlantic Ocean

Rivermoor Marsh

Littoral Cell 5

Littoral Cell 6

North River

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V-4

Historical Shoreline Change Rate

Rivermoor Marsh to Humarock Beach

(1951/52 to 2001, in feet/year)

< -5

-2

-0.6 to + 0.6

+2

> +5

(+ = accretion, - = erosion)

N

W E

S

0 0.25 0.5

Miles

Length of colored bars illustrates relative magnitude of shoreline change.

White lines represent town boundaries and
dashed black lines show littoral cell boundaries.

Rivermoor Marsh

Scituate

Littoral Cell 5

Littoral Cell 6

North River

Marshfield

Scituate

South River

Atlantic Ocean

Humarock Beach

Marshfield

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VI-b

Historical Shoreline Change Rate

Humarock Beach to Brant Rock

(1951/52 to 2001, in feet/year)

< -5

-2

-0.6 to + 0.6

+2

> +5

(+ = accretion, - = erosion)

N

W E

S

0 0.25 0.5

Miles

Length of colored bars illustrates relative magnitude of shoreline change.

White lines represent town boundaries and
dashed black lines show littoral cell boundaries.

Humarock Beach

Scituate

Marshfield

Atlantic Ocean

Littoral Cell 6

Littoral Cell 7

Brant Rock

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Historical Shoreline Change Rate

Brant Rock to Duxbury Beach

(1951/52 to 2001, in feet/year)

< -5

-2

-0.6 to + 0.6

+2

> +5

(+ = accretion, - = erosion)

N

W E

S

0 0.25 0.5

Miles

Length of colored bars illustrates relative magnitude of shoreline change.

White lines represent town boundaries and
dashed black lines show littoral cell boundaries.

Brant Rock

Marshfield

Duxbury

Powder Point

Littoral Cell 7

Atlantic Ocean

Duxbury Bay

Duxbury Beach

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Historical Shoreline Change Rate
Duxbury Beach to Saquish Beach
(1951 to 2001, in feet/year)

< -5
-2
-0.6 to + 0.6
+2
> +5
(+ = accretion, - = erosion)

N
W E
S

0 0.2 0.4
Miles

Length of colored bars illustrates relative magnitude of shoreline change.

White lines represent town boundaries and
dashed black lines show littoral cell boundaries.

Duxbury Beach

Duxbury Bay

Atlantic Ocean

Duxbury

Plymouth

Clarks Island

Gurnet Point

Littoral Cell 7

Littoral Cell 8

Saquish Beach

Littoral Cell 8

Littoral Cell 9

Plymouth Bay

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IX-b

Historical Shoreline Change Rate
Powder Point to Rocky Nook
(1951 to 2001, in feet/year)

< -5

-2

-0.6 to + 0.6

+2

> +5

(+ = accretion, - = erosion)

N

W E

S

0 0.25 0.5

Miles

Length of colored bars illustrates relative magnitude of shoreline change.

White lines represent town boundaries.

Powder Point

Duxbury Bay

Duxbury

Kingston Bay

Goose Point

Kingston

Rocky Nook

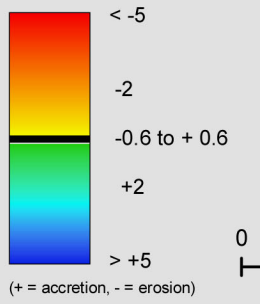
This map is from the South Shore Coastal Hazards Characterization Atlas, published by the Massachusetts Office of Coastal Zone Management (CZM). CZM makes no representations or warranties with respect to the definitiveness of the data presented. Prepared by Applied Coastal Research and Engineering, Inc., December 2005.

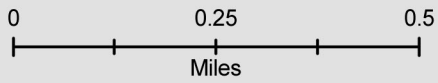
X-b

Historical Shoreline Change Rate

Rocky Nook to Plymouth Beach

(1951 to 2001, in feet/year)





Length of colored bars illustrates relative magnitude of shoreline change.

White lines represent town boundaries.

Goose Point

Duxbury

Kingston Bay

Rocky Nook

Kingston

Plymouth

Plymouth Beach

Plymouth Harbor

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XI-b

APPENDIX D

2 FOOT SEA LEVEL RISE MAPS FOR SCITUATE, MARSHFIELD AND DUXBURY

Scituate, Marshfield and Duxbury Coastal Hazards Adaptation Study

A District Local Technical Assistance Grant

Potential Sea Level Rise - 2 Feet

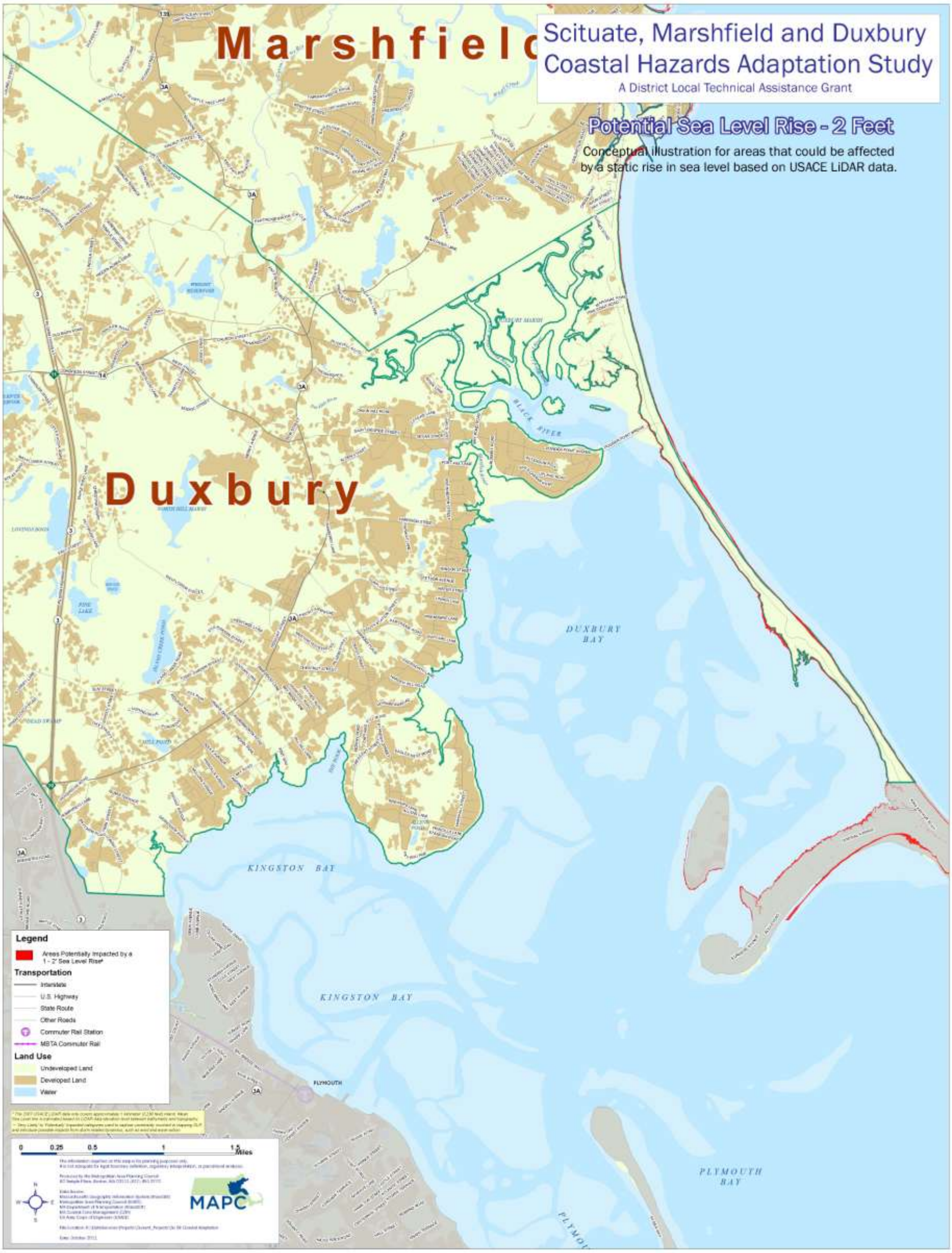
Conceptual illustration for areas that could be affected by a static rise in sea level based on USACE LiDAR data.

Scituate, Marshfield and Duxbury Coastal Hazards Adaptation Study

A District Local Technical Assistance Grant

Potential Sea Level Rise - 2 Feet

Conceptual illustration for areas that could be affected by a static rise in sea level based on USACE LiDAR data.


Marshfield
Scituate, Marshfield and Duxbury
Coastal Hazards Adaptation Study
A District Local Technical Assistance Grant
Potential Sea Level Rise - 2 Feet
Conceptual illustration for areas that could be affected by a static rise in sea level based on USACE LiDAR data.
Duxbury
DUXBURY BAY
KINGSTON BAY
KINGSTON BAY
PLYMOUTH
PLYMOUTH BAY
Legend
Areas Potentially Impacted by a 1 - 2' Sea Level Rise*
Transportation
Interstate
U.S. Highway
State Route
Other Roads
Commuter Rail Station
MBTA Commuter Rail
Land Use
Undeveloped Land
Developed Land
Water
0 0.25 0.5 1 1.5 Miles
MAPC

APPENDIX E

2 FOOT SEA LEVEL RISE WITH POTENTIAL STORM SURGE INUNDATION MAPS FOR SCITUATE, MARSHFIELD AND DUXBURY

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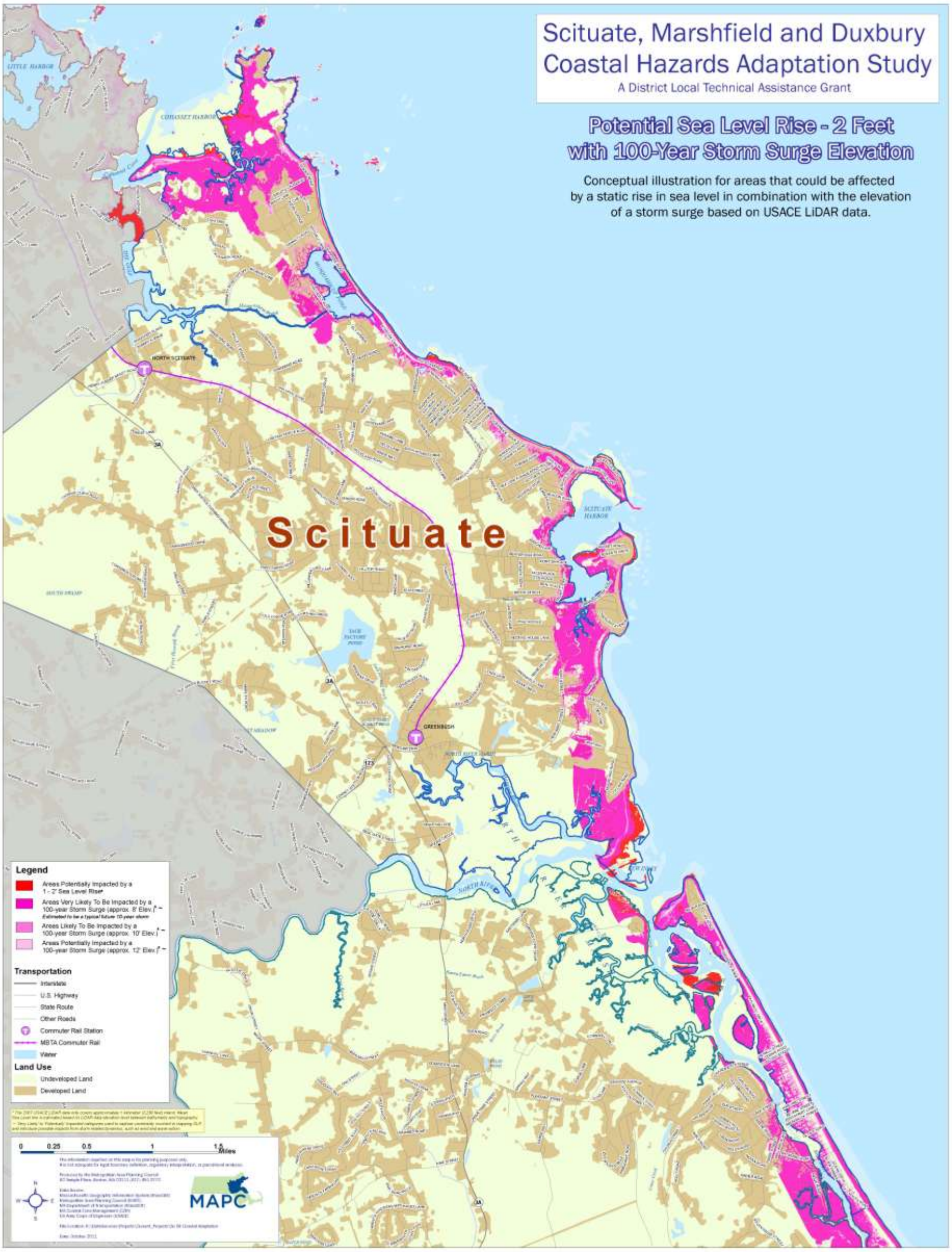
Potential Sea Level Rise - 2 Feet with 100-Year Storm Surge Elevation

Conceptual illustration for areas that could be affected by a static rise in sea level in combination with the elevation of a storm surge based on USACE LiDAR data.



Scituate, Marshfield and Duxbury Coastal Hazards Adaptation Study

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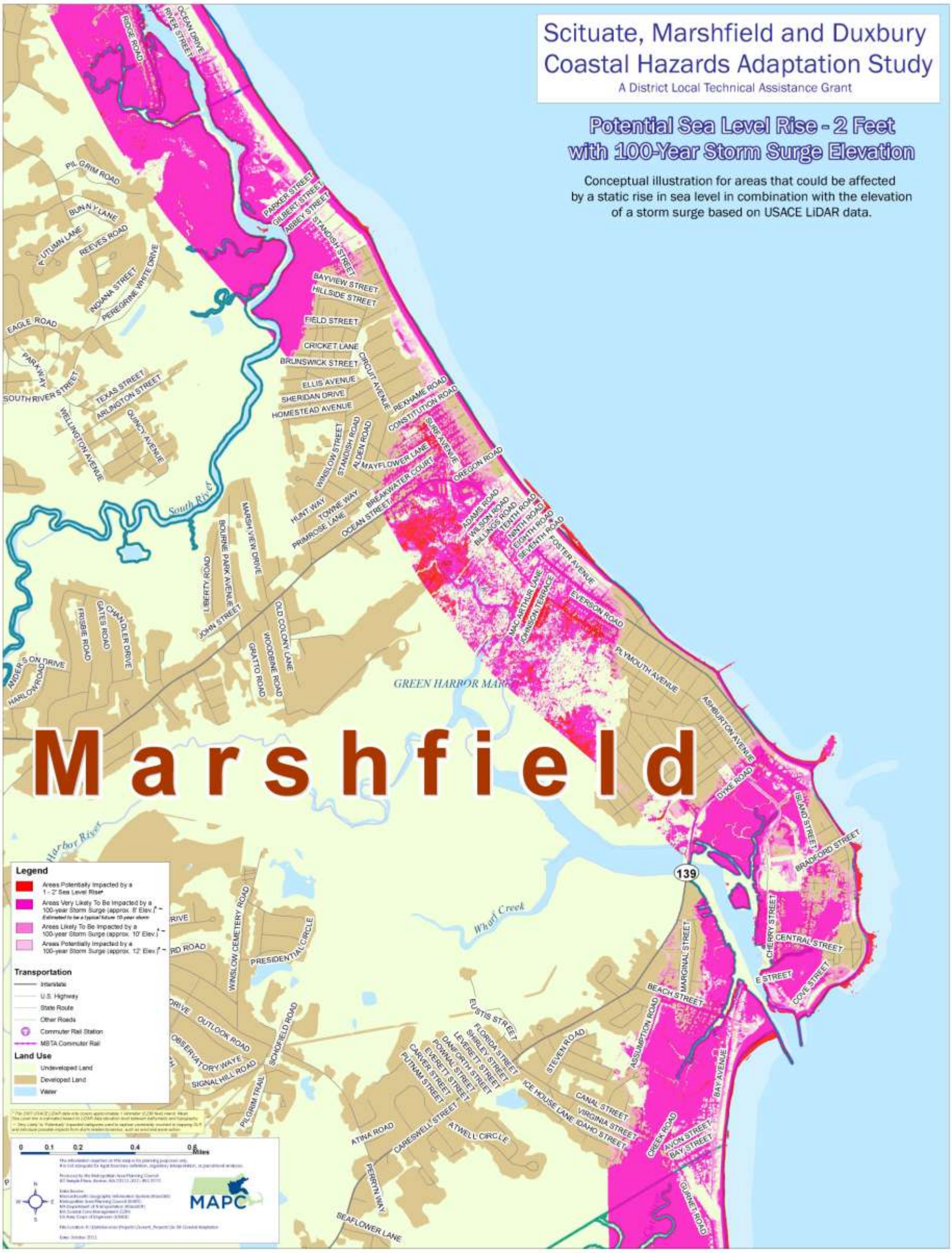
Potential Sea Level Rise - 2 Feet with 100-Year Storm Surge Elevation

Conceptual illustration for areas that could be affected by a static rise in sea level in combination with the elevation of a storm surge based on USACE LiDAR data.




Marshfiel
Scituate, Marshfield and Duxbury
Coastal Hazards Adaptation Study
A District Local Technical Assistance Grant
Potential Sea Level Rise - 2 Feet
with 100-Year Storm Surge Elevation
Conceptual illustration for areas that could be affected by a static rise in sea level in combination with the elevation of a storm surge based on USACE LiDAR data.
Duxbury
DUXBURY BAY
KINGSTON BAY
Legend
Areas Potentially Impacted by a 1 - 2' Sea Level Rise
Areas Very Likely To Be Impacted by a 100-year Storm Surge (approx. 9' Elev.)*
Estimated to be a typical future 10-year storm
Areas Likely To Be Impacted by a 100-year Storm Surge (approx. 10' Elev.)*
Areas Potentially Impacted by a 100-year Storm Surge (approx. 12' Elev.)*
Transportation
Interstate
U.S. Highway
State Route
Other Roads
Commuter Rail Station
MBTA Commuter Rail
Water
Land Use
Undeveloped Land
Developed Land
0
0.225
0.45
0.9
1.35
Miles
MAPC

APPENDIX F

POTENTIAL INLAND MIGRATION OF SALT MARSHES MAPS FOR SCITUATE, MARSHFIELD AND DUXBURY

Scituate, Marshfield and Duxbury Coastal Hazards Adaptation Study

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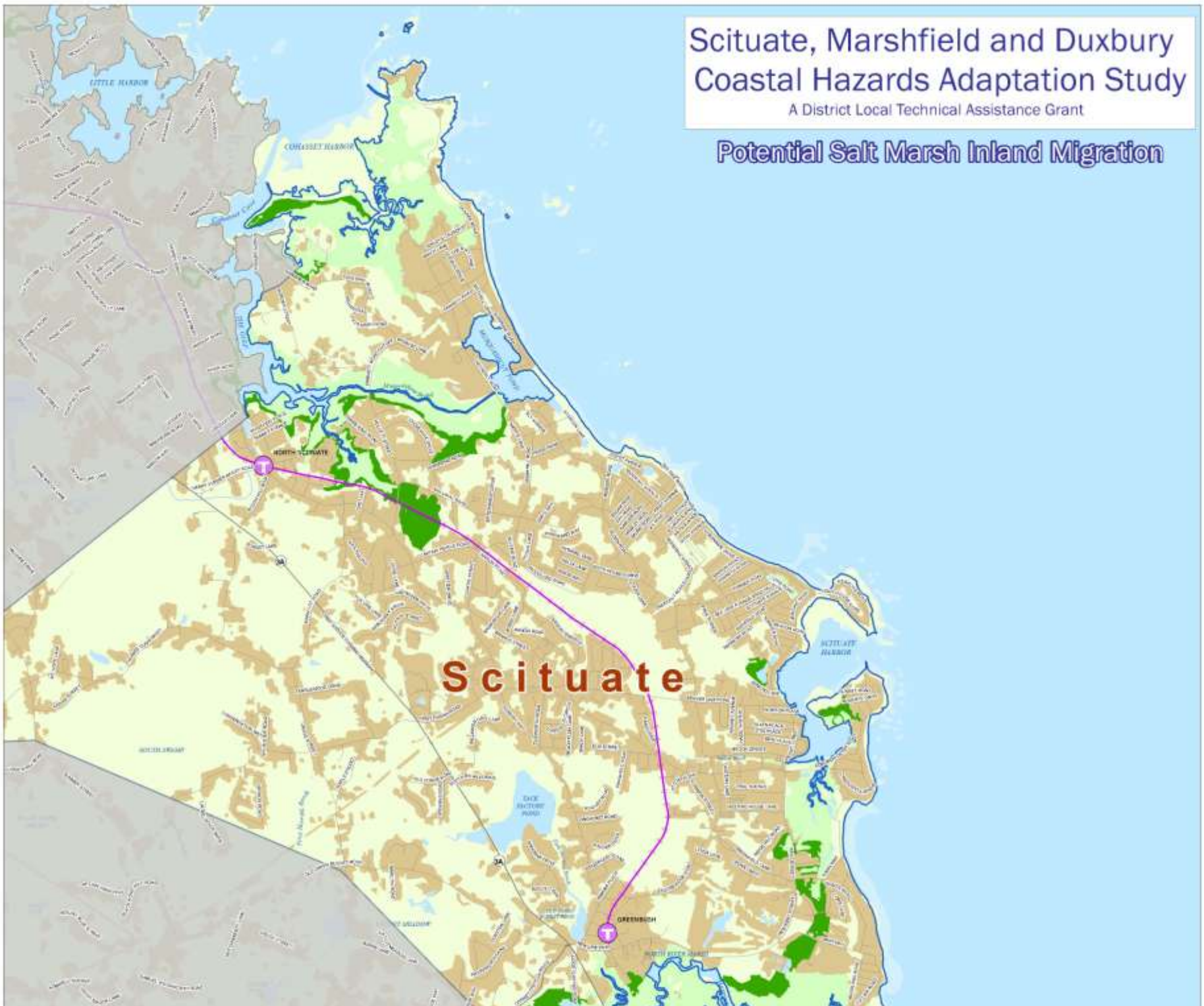
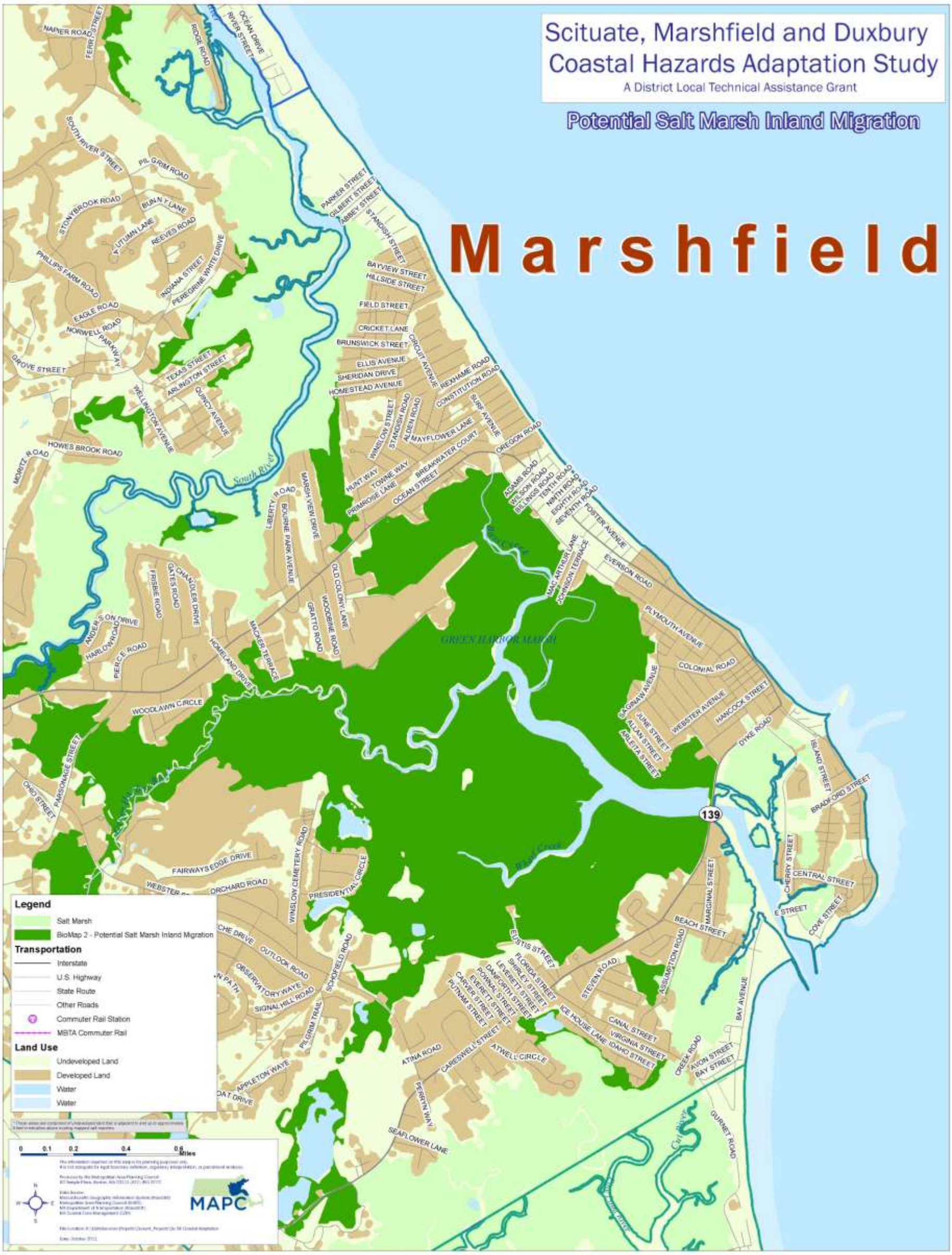
Potential Salt Marsh Inland Migration




Scituate, Marshfield and Duxbury
Coastal Hazards Adaptation Study
A District Local Technical Assistance Grant
Potential Salt Marsh Inland Migration
Marshfield
Legend
Salt Marsh
BioMap 2 - Potential Salt Marsh Inland Migration
Transportation
Interstate
U.S. Highway
State Route
Other Roads
Commuter Rail Station
MBTA Commuter Rail
Land Use
Undeveloped Land
Developed Land
Water
Water
0 0.1 0.2 0.4 0.6 Miles
MAPC
South River
GREEN HARBOR MARSH
139


Scituate, Marshfield and Duxbury
Coastal Hazards Adaptation Study
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Potential Salt Marsh Inland Migration
Duxbury
DUXBURY BAY
KINGSTON BAY
KINGSTON BAY
PLYMOUTH
PLYMOUTH BAY
BLACK RIVER
Legend
Salt Marsh
BioMap 2 - Potential Salt Marsh Inland Migration
Transportation
Interstate
U.S. Highway
State Route
Other Roads
Commuter Rail Station
MBTA Commuter Rail
Land Use
Undeveloped Land
Developed Land
Water
Water
0 0.175 0.35 0.7 1.05 Miles
MAPC