Metro Boston Regional Adaptation Climate Change Strategy

- *WORKING DRAFT* -

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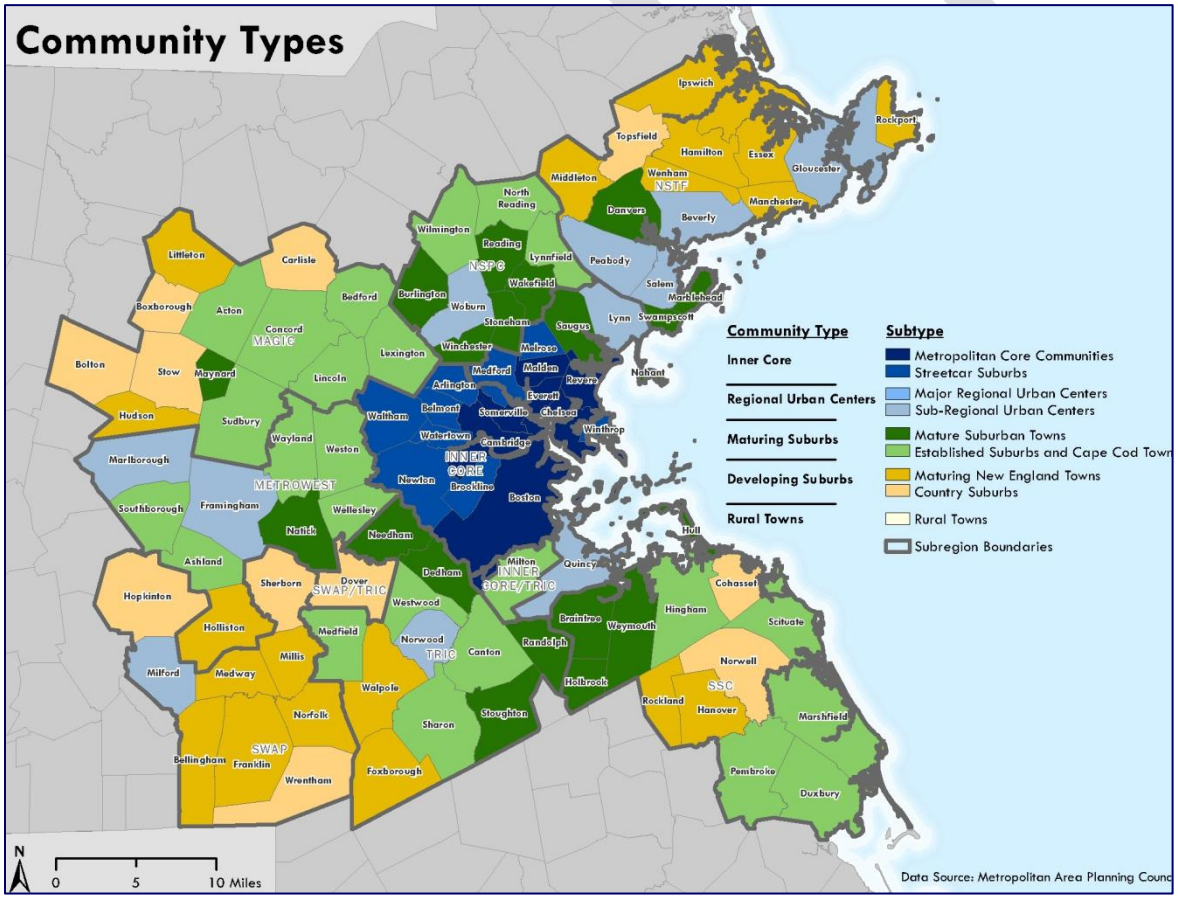
Table of Contents

I. INTRODUCTION

Given the magnitude of climate change impacts on the natural environment, development and infrastructure, economy, and public health in the region; it is imperative that climate change adaptation is adequately addressed at the regional level. The primary goal of this Strategy is to prepare recommendations for local, regional, and state action to reduce vulnerability to future hazards and impacts of climate change within Eastern Massachusetts. This Strategy builds upon findings of the *Massachusetts Climate Change Adaptation Report*[1] and other pertinent publications developed to date.

The Metropolitan Area Planning Council is a regional planning agency serving the people who live and work in the 101 cities and towns of Metro Boston. Our mission is to promote smart growth and regional collaboration. Our diverse region includes a number of varying community types from urban centers to country suburbs with rural-based agriculture, as shown in the figure below.

Figure II.1: MAPC Community Types



[1] Massachusetts Climate Change Adaptation Report, Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, September 2011.

I.A. Purpose and Vision of the Strategy

The Regional Plan for the metropolitan area, MetroFuture, indicates one goal for adaptation: ***the region will be prepared for and resilient to natural disasters and climate change.*** This goal, and numerous others included in the MetroFuture Plan, was created by the thousands of people who participated in the process in order to reflect the special character of Metro Boston and the diverse values of the people who live and work here. The MetroFuture Goals are the specific and measurable "end state" outcomes that MetroFuture seeks to achieve. Objectives are specific quantitative targets or milestones, generally based on available data, which can be used to determine whether a goal has been achieved. Unless otherwise noted, the time horizon for most objectives is the year 2030. Strategies have been developed to achieve the goals and objectives of the MetroFuture Plan. The Regional Climate Change Adaptation Strategy (Strategy) is the most recent addition to the MetroFuture Plan, as fully described in this report.

The primary purpose of this Strategy is to outline specific sub-strategies and recommendations to fulfill the stated adaptation goal and associated objectives (explained in Section 2). The overarching public purpose of the Strategy is to reduce the impacts of climate change through effective risk management. The Strategy is intended as a proactive approach in response to the findings of the vulnerability assessment conducted for the Metro Boston Region. A primary planning recommendation of the Strategy is the integration of information about emerging climate change risks into current disaster planning systems and arrangements at the community and regional level, as appropriate. Such a strategy is urgently needed because any increase in the number or intensity of disasters due to climate change will adversely impact quality of life and economic development in the region. Ideally, the Strategy can significantly limit the adverse effect of climatic hazards on public health and safety, critical infrastructure and development, and the region's natural resources and ecosystems. This in turn will reduce the disruption of the local economy, lessen the costs of post-disaster response, and increase the ability of the region to bounce-back more quickly and completely

The underlying vision for the Strategy is climate-resilient communities, businesses, and ecosystems across the 101 cities and towns of Metro Boston. This will require a clear framework for adaptive, flexible, phased, and decisive actions to reduce climate change risks across households and businesses in partnerships ranging from the municipal to regional level and ultimately to the state and national level. Due to the complexities of adaptation and the need to make immediate and longer-term changes, the vision includes measures that can be implemented under the following time horizons:

1. Near-Term (2015-2020): Development of an enabling environment for adaptation that cuts across key sectors, institutions, and administrative divisions in the MAPC region. This involves the development of action measures that incorporate risk management and suggest financing mechanisms, as well as establishing regional coordination mechanisms. An important characteristic of near-term adaptation actions is that they include the adjustment of existing local planning mechanisms that will fulfill both mitigation and resiliency goals.

2. Mid-Term (2021-2030): Implementation of action measures that are focused on the key vulnerable sectors identified in the vulnerability assessment: natural resources, coastal zone, built environment and infrastructure, public health and welfare, and local economy. Mid-term measures include planned investments in specific measures and technologies, as well as the introduction of new practices that build disaster-resilient communities and systems across the region.

3. Long-Term (i.e., 2031-2050): Iterative adaptation and risk management modifications in light of information that emerges from monitoring and evaluation of mid-term strategies. These actions are not included in the current Strategy, as the Strategy will evolve through time and information collected.

I.B. Vision Guiding Principles

The Strategy's vision was guided in part by the following four principles:

1. The Strategy will be a holistic, multi-hazard approach that integrates climate change risks and focuses on prevention, preparedness, response and recovery, with an emphasis on prevention and preparedness measures.

2. Effective regional partnerships, state government, and private sector engagement are essential building blocks. The Strategy will include a focus on strengthening existing networks that are already making progress in order to advance regional cooperation and take advantage of risk reduction synergies. It will propose mechanisms to improve communication of risks and opportunities in order to increase awareness among state and federal lawmakers.

3. The continued development of accurate information on present and future climate risks is a necessary prerequisite for effective adaptation. The improvement of relevant data and information, including the access to climate change modeling information at the scales relevant for the region is a resource on which to base decision-making and action.

4. Strengthened communication is needed across institutions and communities. Apart from a general sense that action is needed in metro Boston, there still remain persistent gaps between the results of climate risk studies and the ability of elected and appointed officials to interpret and react to such information with specific measures.

I.C. Report Structure

This Report provides a summary of the entire project resulting in the Regional Climate Change Adaptation Strategy to be established for the region. The Strategy Report includes the following sections, which are designed to also be utilized as stand-alone data and guidance:

1. Executive Summary

2. Vulnerability Assessment

3. Goals and Objectives

4. Adaptation Strategies

Each section of the Strategy Report, as well as the analysis behind it, is organized topically; addressing five major sectors:

5. Natural Resources and Habitat

6. Coastal Zone

7. Developed Areas and Key Infrastructure

8. Human Health and Welfare

9. Local Economy and Government

These five Sectors are the same used within the Massachusetts Climate Change Adaptation Report. MAPC maintained this categorization for consistency with the statewide report in order to ensure synergy between local, regional, and state analysis and recommendations.

I.D. Definitions

Due to the wide range of climate change topics, as well as the complexities within these topics, a series of key terms and their definitions have been provided below. These terms have been utilized throughout the Report.

Base Flood Elevation: The flood having a one percent chance of being equaled or exceeded in any given year. This is the regulatory standard also referred to as the "100-year flood." The base flood is the national standard used by the National Flood Insurance Program (NFIP) and all Federal agencies for the purposes of requiring the purchase of flood insurance and regulating new development. Base Flood Elevations (BFEs) are typically shown on Flood Insurance Rate Maps (FIRMs).

Bankfull Depth: The volume of flow, and the flow width or depth associated with the bankfull elevation: that point where water fills the channel just before beginning to spill onto the flood plain.

Climate Change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.[2]

Climate Change Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Climate Change Mitigation: Efforts to reduce or prevent emission of greenhouse gases. Mitigation includes the use of new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behavior.

Climate Resiliency: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.[3]

Floodplain: Also sometimes called the "floodway," is the area next to a river that experiences flooding when water comes out of the banks of the main channel. Floodplain is the term FEMA used to include: "any land area susceptible to being inundated by flood waters from any source." Therefore, generally this is the term used within the Strategy unless also describing the areas listed below.

[2] Intergovernmental Panel on Climate Change Fifth Assessment Report (http://www.ipcc.ch/report/ar5/index.shtml)
[3] IPCC Fifth Assessment Report

Floodprone Area: Is an area bordering a stream that will be covered by water at a height of twice the maximum bankfull depth.

Special Flood Hazard Area (SFHA): are areas designated by FEMA as "having special flood, mudflow, or flood-related erosion hazards, and shown on a Flood Hazard Boundary Map or a Flood Insurance Rate Map (Zone A, AO, A1-A30, AE, A99, AH, AR, AR/A, AR/AE, AR/AH, AR/AO, AR/A1-A30, V1-V30, VE, or V)." NOTE: in determining Community Rating System premium discounts AR and A99 zones are treated as non-SFHAs.)

Green Infrastructure: An approach to infrastructure and natural resource management that includes sustainable water infrastructure, preserving and protecting natural or "green" systems, decentralized solutions, or other innovative approaches and technologies that provides multiple benefits. Techniques include but are not limited to: decentralized wastewater systems; water conservation and reuse, stormwater recharge (bioretention, rain gardens, tree boxes), porous pavement, green roofs, water efficient landscaping, preservation and restoration of natural landscape buffers (i.e. forests, floodplains, and wetlands); restoration of natural stream channels.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.

Impact: Effects on natural and human systems. In this report, the term *impact* is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system.

Low Impact Development (LID): This is a development process that begins with smart growth-based best site planning practices to identify critical natural resource areas for preservation and uses Green Infrastructure to maintain natural drainage flow paths and reduce impervious surfaces. LID also includes a specific set of innovative strategies to treat stormwater management at the site level, ensuring that water is managed locally rather than engineering the discharge of water away from its source.

Non-Potable Water: Water that has not been examined, properly treated, nor approved by appropriate authorities as being safe for consumption.

Potable Water: Water suitable for drinking.

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.[4]

Stream Crossings: A stabilized area designed to cross a stream to provide a travel way for people, livestock, equipment, or vehicles.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

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

II. Vulnerability Assessment

One of the primary tasks of developing the Strategy was to first conduct a vulnerability assessment of climate impacts across the region. The vulnerability assessment provides a conceptual overview and introduction to climate change vulnerabilities and describes historical climate trends and the range of projected future climate changes that are expected over coming decades for this region. Climate change and related impacts are expected to continue to intensify within the region for many decades. Following the lead of the statewide Massachusetts Climate Change Adaptation Report (MA EOEEA, 2011), the current assessment considers two future time periods: mid-century around 2050 and end of the century (2100).

For each sector the assessment includes a discussion of baseline conditions that reflect current circumstances and resource endowments, followed by a description of current response strategies and an analysis of the sector's vulnerabilities to various impacts of future climate change.

II.A. Background on Climate Changes

There is now wide consensus in the scientific community that human-induced greenhouse gas emissions contribute to global climate change. The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. In 2014 the IPCC produced their fifth assessment report (AR5)[5], which included a summary of global climate change observations seen thus far, as well as projections for what we should anticipate in the future. The primary difference between the AR5 and all past IPCC reports is that the AR5 assesses a substantially larger knowledge base of relevant scientific, technical, and socioeconomic literature across a broader set of topics and sectors. The AR5 also included expanded coverage of human systems, adaptation, and the ocean. One of the most important items of note in the AR5 is that "climate-change impacts are strongest and most comprehensive for natural systems."[6] This makes an even stronger case for natural resource protection and restoration, as they are also the primary sources of "defense" from impacts to development.

In summary, global mean surface temperatures have increased by .85° C (1.53°F) since the late 1800s with most of this warming having occurred in the last 50 years. Further, the AR5 reported environmental trends including sea level rise, increases in greenhouse gas emissions, surface ozone variations, ocean acidification and low-oxygen, increases in precipitation levels more intense precipitation patterns, decreases in sea ice cover, and increases in the flow off of the Greenland and West Antarctic ice sheets. Further observations include increased precipitation levels, simultaneously more intense precipitation patterns that result in more droughts, damaging rainfall and more variable climate patterns. These observations capture a global shift in weather patterns that are anticipated to continue further in the future, though the magnitude of these changes remains uncertain and is largely dependent on global emission rates.

As we prepare for these anticipated changes, it's important to note that there are significant variations in climate change impacts. For example, sea level rise has not been uniform globally and will have greater rates of change in the future as well. Uneven sea level rise is caused by a number of factors. One is that thermal expansion is a driving force behind sea level rise, therefore uneven changes in ocean temperatures lead to different rates of thermal expansion. Other factors

[5] Intergovernmental Panel on Climate Change, *Fifth Assessment Report: Climate Change 2014*. (https://www.ipcc.ch/report/ar5/index.shtml)
[6] IPCC *WGII AR5 Summary for Policymakers* (https://www.ipcc.ch/report/ar5/wg2/)

contributing to uneven sea level rise include the changes in gravitational forces as ice sheets melt and redistribute mass across the globe, changes in wind patterns, as well as land subsidence, which has had dramatic affects in certain parts of the United States. While some places, such as along the Massachusetts coastline, have seen increases of 15-20cm (6 to 8 inches) over the past 50 years, other locations, such as some coastal regions in Alaska; have actually seen decreases in sea level. Variations also exist for other climate change impacts and in this report we explore the anticipated regional impacts for the Boston Metropolitan Area. We first consider climate changes anticipated over the coming decades as well as the long term (100 year) outlook. We then look at how these trends are expected to impact key sectors in the region over this period.

II.B. Observed Regional Climate Conditions to Date

Due to the wide-ranging geographic scale of climate changes, observed changes for the Metropolitan Boston Region are similar to those described in the Massachusetts Climate Change Adaptation Report (September 2011). After all, the region comprises a significant portion of the geography of the Commonwealth with 101 municipalities and home to approximately half of the state's population. However, there are regional variations that will be explored throughout this assessment, in an effort to highlight and, ultimately, prioritize strategies for implementation.

Massachusetts has experienced higher impacts than global averages for several climate change indicators. *The Massachusetts Climate Change Adaptation Report* presents research concluding that temperature change in Massachusetts has been more severe than global averages, with about 1°C (1.8°F) warming occurring since 1970, and winters warming more dramatically by 0.72°C (1.3°F) per decade.[7] Massachusetts now experiences an average of 12 days per summer season above 32°C (90°F), and this number has been rising. Regional sea level increases have been more extreme in Massachusetts with a 2.6mm (.1 inches) per year sea level increase since 1921 compared to the global average of 1.7mm (.07 inches) per year. In the report, the increased rate of sea level rise is attributed to subsidence, which is estimated to be at a rate of 1mm (.04 inches) per year. Regional precipitation has increased by about 10 percent in Massachusetts over the last 50 years, with most of this increase in the form of rain in the winter months. Massachusetts' lake ice has been thawing earlier in the spring with the "ice-out" days being now between 9 and 16 days earlier in the spring. The frequency of severe storms has also been increasing. What was once a one in 100-year event is now predicted to occur 2 to 5 times as often.

Massachusetts has also been especially vulnerable to extreme weather conditions that may be linked to increasingly variable global weather patterns. During the winter of 2013/2014 record low temperatures caused by fluctuations in the North Polar Vortex caused extreme weather and heavy snowfall in much of the northern United States. Hurricanes Irene (2011) and Sandy (2012) devastated both coastal and inland Northeastern regions; and while Massachusetts experienced minimal flooding and damages compared with other states, these events suggest the potential impacts of future weather occurrences. While evidence lacks in conclusively linking extreme weather to climate change impacts, the coastlines and inlands of Massachusetts are vulnerable to these events.

[7] Massachusetts EOEEA. (2011). Massachusetts Climate Change Adaptation Report. Retrieved May 28, 2014 from http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-firstpart.pdf.

The IPCC estimated a range of anticipated changes based on two emissions scenarios: the "B1", or "Low Emissions Scenario" where Carbon Dioxide ($CO_{2)}$ concentrations level off at 550 parts per million (ppm), and the "A1F1" scenario where concentrations level off at 970 ppm. The *Massachusetts Climate Change Adaptation Report,* and therefore; this Regional Strategy, builds its estimations from these scenarios. It should be noted, however, that most climate scientists now believe that stabilizing CO_2 levels at 550 ppm is no longer feasible.

As summarized in Table 1, climate conditions in Massachusetts are expected to change considerably over the course of the next several decades. Projected changes include: significant increases in temperature, both in summer and winter; increased annual average precipitation, though with important seasonal differences; a significant rise in sea level; earlier peak spring streamflow; more frequent droughts; and a longer growing season.

Table II.1: Projected Climate Changes in Massachusetts

Parameter	Average Historical Conditions (1961-1990)	Predicted Range of Change by 2050	Predicted Range of Change by 2100
Annual temperature (°C/°F)	8 / 46	2 to 3 / 4 to 5	3 to 5 / 5 to 10*
Winter temperature (°C/°F)	-5 / 23	1 to 3 / 2 to 5	2 to 5 / 4 to 10
Summer temperature (°C/°F)	20 / 68	2 to 3 / 4 to 5	2 to 6 / 4 to 10
Annual precipitation (cm/in)	103 / 41	5% to 8%	7% to 14%*
Winter precipitation (cm/in)	21 / 8	6% to 16%	12% to 30%*
Summer precipitation (cm/in)	28 / 11	-1% to -3%	-1% to 0%*
Droughts lasting 1-3 months (#/30 yrs)	13	5 to 7	3 to 10*
Length of growing season (days/yr)	184	12 to 27	29 to 43
Streamflow-spring peak flow (days following Jan. 1)	85	-5 to -8	-11 to -13*
Annual sea surface temp. (°C/°F)	12 / 53	2 / 3	4 / 8
Sea-level rise (cm/in)**	8 / 3	20 to 40 / 8 to 16	50 to 201 / 20 to 79

Source: Adapted from Massachusetts Climate Change Adaptation Report, MA EOEEA, Sept. 2011, Table 1.
* Projections for period 2079-2099.
** Historical sea-level rise based on MA Climate Change Adaptation Report, p. 15. Sea-level rise projections based on Pfeffer et al 2008 and Rahmstorf, 2007, as reported in MA Climate Change Adaptation Report, Table 2.

Due to variations in elevation and proximity to the coast, climate change impacts throughout the region are expected to vary. Climate patterns in the Metro Boston area are affected by differences in vegetation and ground cover as a result of urban development.

II.B.1. Sea Level Rise

As ambient air temperatures increase, the effects of ocean thermal expansion are anticipated to intensify. While the IPCC predicts global increases in sea level to be between 15 and 95 cm (6 – 37 inches) by 2100, this number largely reflects the impacts of thermal expansion and does not include the potential contributions from melting of the great ice sheets. We therefore do not use these IPCC estimates as the bases for defining coastal vulnerability and subsequent development of adaptation strategies. Rather, we rely on global average sea level projections that include the contributions

from the great ice sheets, which range from 20 to 40 cm (8 to 16 inches) by 2050 and 50 to 201 cm (20 to 79 inches) by 2100.[8] If subsidence continues at the same rate as estimated by the IPCC, then these ranges would increase to between 24 to 44 cm (9 to 17 inches) in 2050 and 59 and 210 cm (23 to 83 inches) by 2100. This could have severe impacts on coastal zones, in particular low lying zones that could be subject to more frequent or permanent inundation. Further, sea level rise will exacerbate erosion, threaten beaches and salt-water marshes, and cause greater damage to coastal infrastructure.

Sea level projections in the IPCC Fifth Assessment Report, which now include Greenland and Antarctica ice sheet contributions, can be compared with other and geographically-specific projections. There are now observations, modeling, and paleoclimate studies that suggest sea-level rise on the order of 80-150 cm (31 to 59 inches) or more by 2100. Moreover, recent research points to the possibility that the Northeast, including the Boston region, will experience particularly high sea-level rise, far more than the projected global or U.S. average.[9]

II.B.2. Severe Storms

In order for hurricanes to form, they require sea surface temperatures of at least 80°F. For hurricanes or tropical cyclones to gain momentum, they feed off of warm, moist air. Therefore, with an increase in sea surface temperatures, the potential for severe tropical cyclones to develop increases. With climate change there is an anticipated increase in severe storms hitting the Massachusetts coast, with an estimated 2 to 10 times more damage as a result of severe storms by the end of the century.[10] Previous storm surge heights along the Massachusetts coast have been as high as 10 feet. These heights are expected to be reached more frequently and even exceeded with the additional intensity and increased sea level. Further, as coastal erosion worsens, the impacts of storms will be felt that much more. Increased storm intensity will therefore lead to more frequent and extreme inundation without appropriate adaptation measures.

II.B.3. Precipitation, Droughts and Floods

Although summer months are expected to become dryer, the annual precipitation levels are expected to increase in Massachusetts by as much as 14 percent by the end of this century with an estimated 30 percent increase in precipitation in winter months.[11] With increased temperatures, winter precipitation will likely be mostly in the form of rain meaning a decrease in snow cover and earlier and less intense spring flows. The projected decrease in snow cover in the Boston metro area is consistent with a broader regional trend throughout the Northeast. As illustrated in II.1, the area historically covered with snow for at least 30 days in the average year is expected to shrink dramatically by late-century.[12]

[8] Intergovernmental Panel on Climate Change (2014), *Fifth Assessment Report: Climate Change 2014*, Chapter 5: Coastal Systems and Low-Lying Areas. Retrieved on May 28, 2014 from http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap5_FGDall.pdf.

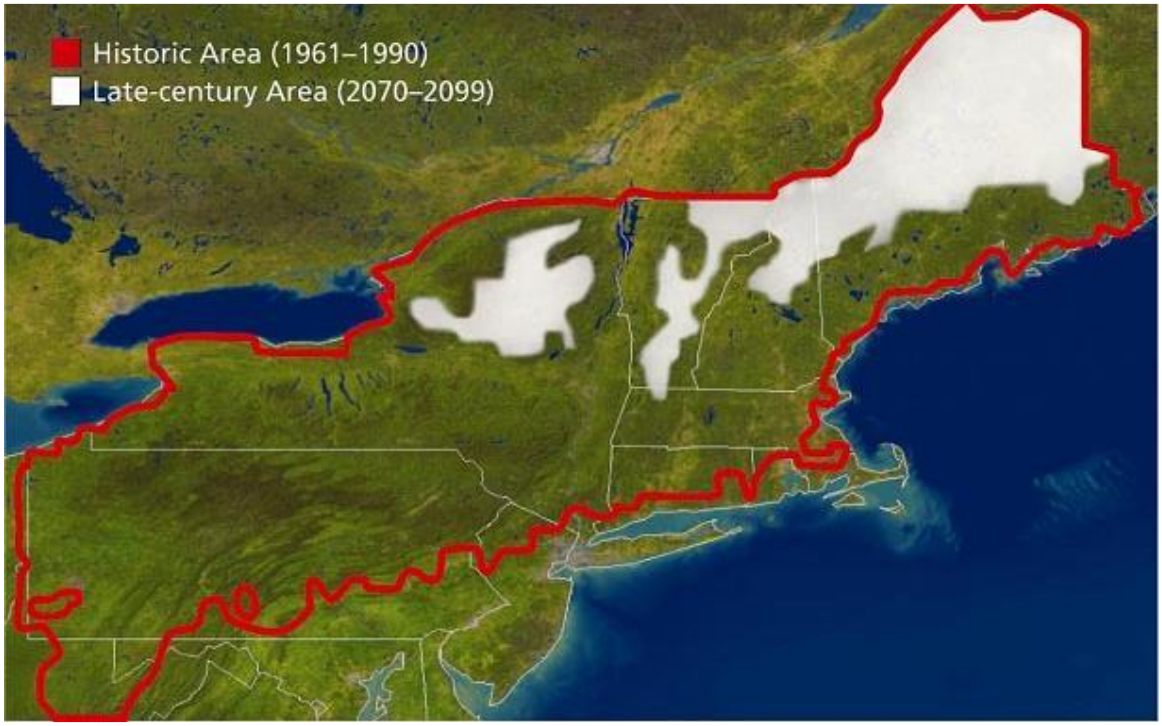
[9] Sallenger, "Hotspot of accelerated sea-level rise on the Atlantic coast of North America, Nature Climate Change, June 24, 2012; Parris, Global Sea Level Rise Scenarios for the United States National Climate Assessment, December 6, 2012; Boon, "Evidence of Sea-Level Acceleration at U.S. and Canadian Tide Stations, Atlantic Coast, North America," Journal of Coastal Research, Vol. 28, No. 6, 2012..

[10] http://www.epa.gov/otaq/climate/420r06003.pdf

[11] Massachusetts Climate Change Adaptation Report, MA Executive Office of Energy and Environmental Affairs, September, 2011.

[12] According to the Northeast Climate Impacts Assessment report of 2007 (p. 11), "If higher emissions prevail, a typical snow season may become increasingly rare in much of the Northeast toward the end of the century. The red line in the map captures the area of the northeastern United States that, historically, has had at least a dusting of snow on the ground for at least 30 days in the average year. The white area shows the projected retreat of this snow cover by late-century to higher altitudes and latitudes, suggesting a significant change in the character of a Northeast winter."

Figure II.1: Projected Changes in Winter Snow



Source, NECIA, 2007

According to the Massachusetts Climate Change Adaptation Report winter snowpack currently melts on average 84.5 days after January 1st. This average is anticipated to decrease to be between 76.5 to 79.5 days by mid-century and 71.5 to 73.5 days by 2100. Increased winter precipitation and early snow-melts would lead to more flooding events in winter and earlier peak flows in spring. Extended low-flow periods are expected in summer months, increasing the number of droughts by as much as 75 percent by 2100, with lower water levels threatening water supplies.[13]

Frequency of extreme precipitation is also expected to increase by as much as 8 percent by mid-century and up to 13 percent by 2100. This increase would lead to more frequent and damaging ice storms and increased flood levels. What is currently the 100-year flood is expected to become the once in 2 to 3 year flood by mid-century and to further increase to being once every 1 or 2 years by the end of the century.[14]

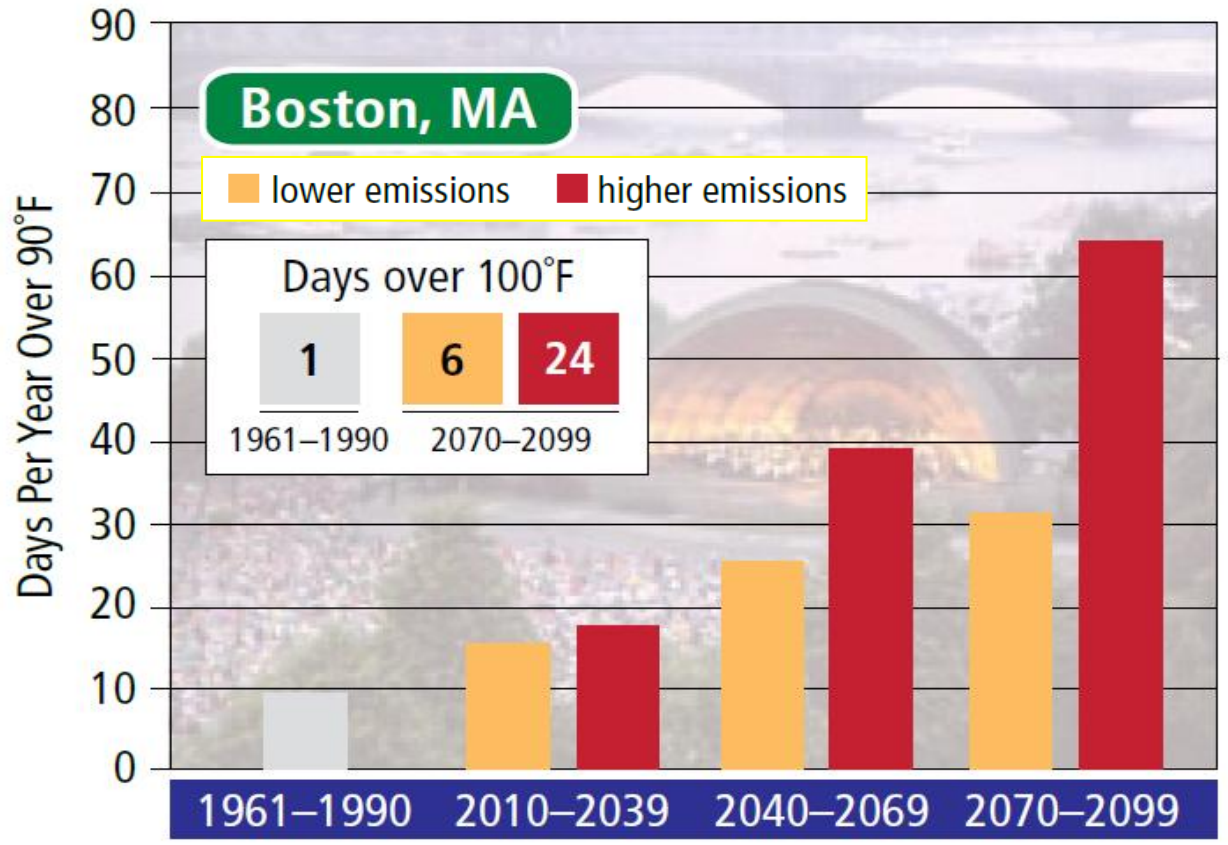
II.B.4. Temperature Change and Extreme Heat

The average temperature in Massachusetts between 1961 and 1990 has been about 8°C (46.4°F). By mid-century this is anticipated to increase by 2 to 3°C (3.6 to 5.4°F) and by 2100, average temperatures are expected to increase by 3 to 5°C (5.4 to 9.0°F). Due to urban heat island effect, the increases in temperature are expected to be more dramatic in urban areas where there is less shade and a higher fraction of dark, absorbing surfaces.

[13] Massachusetts Climate Change Adaptation Report, MA Executive Office of Energy and Environmental Affairs, September, 2011.
[14] Massachusetts Climate Change Adaptation Report

With an increase in average temperatures, comes an increase in the number of days with extreme heat. By the end of this century, the number of days in a year with temperatures above 90°F (32°C) is anticipated to be between 30 and 60 whereas previously there have been between 5 and 20 days. Moreover, as shown in Figure 2, days above 100°F (38°C) are expected to increase by between 3 and 28 days, whereas historically such extreme temperatures averaged fewer than two days per year.[15]

Figure II.2: Projected Changes in Winter Snow

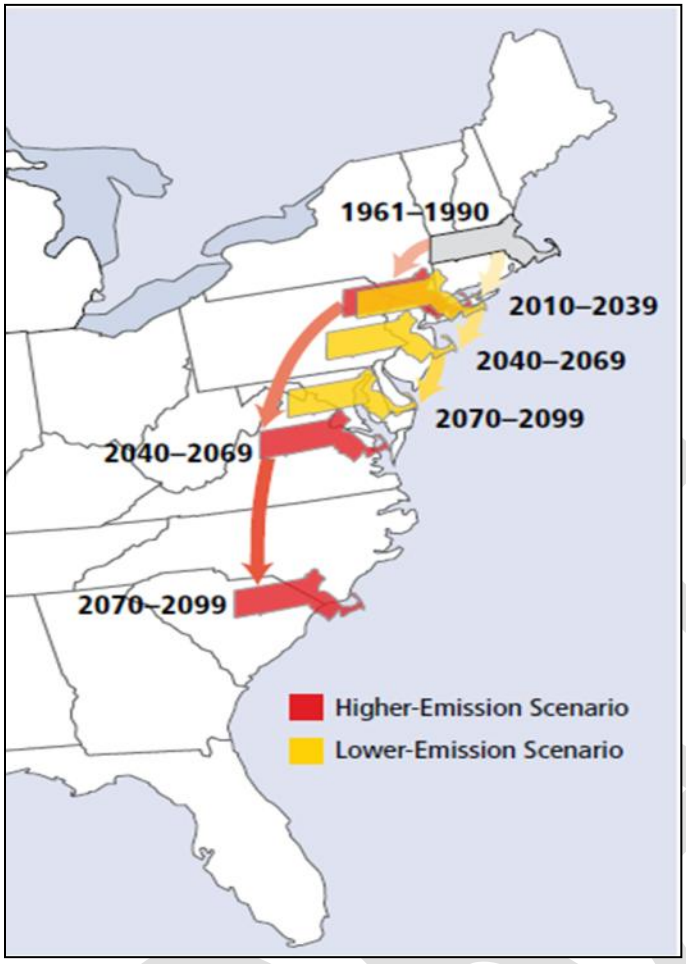


Source: NECIA, 2007

Over the course of the next century the projected temperature increases for Massachusetts will have a profound impact on how we experience daily life. For example, as depicted in the 2007 Northeast Climate Impacts Assessment report (NECIA, 2007), reproduced below in Figure 3, summer temperatures in our region will feel like New Jersey or Maryland by mid-century and Virginia or the Carolinas by late century. While this portends dramatic changes, it should be noted that the forthcoming IPCC Fifth Assessment Report will make the higher emissions scenario used in the NECIA report a conservative/low estimate.

[15] Massachusetts Climate Change Adaptation Report, MA Executive Office of Energy and Environmental Affairs, September, 2011.

Figure II.3: Temperature Change Impacts: How will it feel?



Source: Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions, NECIA, 2007.

II.C. Vulnerabilities of our Natural Resources

As discussed previously, the IPCC Climate Change Assessment of 2014 reported that natural resources will suffer the greatest impacts from climate change. This is primarily due to the existing stress placed on natural systems: aquatic, terrestrial, and associated species; by development. The vulnerabilities described in this section are those of particular importance since natural systems are not only important to the environment in which we live, but – in a healthy state – are the best protectors of human developed areas.

II.C.1. Ecosystem Values & Existing Conditions

The concept of ecosystem values is relatively new in the environmental field. Over the past several years that included an economic recession, where the primary societal concerns are focused on economic development, it has become increasingly important for environmentalists to attempt to place an economic value on ecosystem functions and "services." Ecosystem function is the term used to describe the physical, chemical, and biological attributes that maintain an ecosystem. For

example, nutrient cycling, soil development, and water budgeting, are ecosystem functions. Ecosystem "services" are the beneficial outcomes to man or nature resulting from these functions such as providing wildlife habitat, clean water and carbon sequestration. Although not an exact science and often difficult, ecologists and economists have identified methods to quantify ecosystem services in order to assign a monetary value based on actual market values. For example, pollinators could be estimated to be worth at least $20-$40 billion, which equates the value of the crops that wouldn't exist without their pollination. Another way to estimate value is to calculate the cost of replacing an ecosystem service. For example, water purification services by natural habitats have been valued to equal the cost of a new water filtration plant ($3-$8 billion).

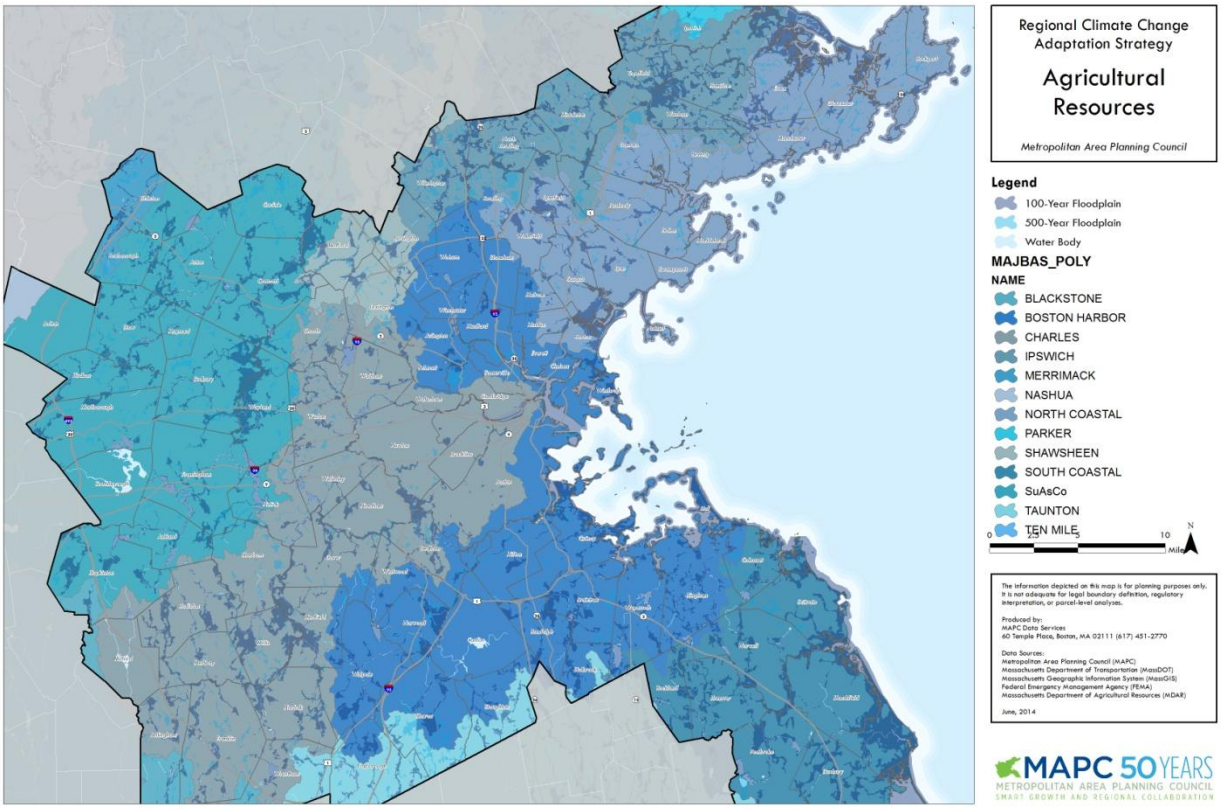
II.C.1.a) FORESTED AREAS

In terms of climate mitigation, as an adaptation feature; forested areas provide a number of important ecological services that are important to consider. One of the most important services provided by forested areas is carbon sequestration. In 2005, forests throughout Massachusetts were estimated to sequester nearly 85 million metric tons of carbon or about 13.3% of all carbon emissions in the region. There is a diverse mix of tree species in the MAPC region. Commonly found are northern trees species (sugar, maple, beech, yellow and white birch), southern species (e.g. oak, hickories and chestnut), together with wide ranging species (red maple). Within the City of Boston alone, there are over 120 different tree species, with the largest share (23%) being Norway maples.

II.C.1.b) WATERSHEDS

Of the 27 major river basins in Massachusetts, all or significant portions of seven watersheds are located in the MAPC region: Boston Harbor, Charles, Ipswich, North Coastal, Shawsheen, South Coastal, and SuAsCo. In addition, portions of one or more MAPC communities are located in several other basins, including the Merrimack, Parker, and Taunton watersheds (see Figure II.4). Mainstream rivers, such as the Charles, are characterized by wide low gradient streambeds and extensive flood plains with organically enriched soils. These soils support diverse ecosystems that span forests, shrub swamps and other habitats. Figure II.4 shows the extent of river basins within the MAPC region. Several of the larger watersheds in the region and key ecosystem attributes are described below.

Figure II.4: Watersheds – MAPC Region



Ipswich River Watershed

The Ipswich River Watershed encompasses approximately 155 square miles of land and includes all or part of 21 communities in northeastern Massachusetts, with an estimated population of 160,000 people. Beginning in the northeast corner of Burlington, the Ipswich flows through various land uses to Plum Island Sound in the Town of Ipswich. The river and its tributaries flow through and adjacent to several wetlands, which help to maintain high water quality throughout the watershed. About 74 percent of the basin is forestland, which includes various levels of residential land use, and about 10 percent is covered by lakes, ponds, and marshes.

The base flow of the Ipswich River is mainly from groundwater and wetlands. During much of late summer and early fall, when evapotranspiration rates and water withdrawals are high, streamflow in the Ipswich River Watershed is severely affected, causing the river to flow backwards and sometimes run dry.

Approximately 350,000 people, a significant portion of who reside outside the watershed, rely on the Ipswich River Watershed as their source of drinking water. USGS has determined that groundwater withdrawals are mainly responsible for summer low flows, especially in the upper watershed. Municipal water suppliers in Wilmington, North Reading, Lynn, Lynnfield, Danvers, Salem, Beverly, and Peabody all withdraw from the Ipswich basin, as do a number of private wells.

These low flows harm critical habitat for fish and other aquatic organisms, cause water temperatures to rise and lower dissolved oxygen levels. This has led to the loss of river dependent fish such as brook trout and reduced summertime recreational opportunities.

North Coastal Watershed

The North Coastal Watershed has a total drainage area of approximately 168 square miles. It encompasses all or part of five river sub-basins, including the Danvers, Essex, Saugus, Pines, and Annisquam Rivers. There are approximately 2,428 acres of lakes and ponds in the watershed. The North Coastal encompasses all or part of 26 Massachusetts municipalities, and supports a population of approximately 500,000 people. The major resources in the region include a major lobster fishery, as well as shellfishing.

In the upper portions of the watersheds, groundwater, rainfall and runoff create small streams that flow year round. These streams typically have low fish variety, low productivity and relatively high gradients but they support environmental integrity by maintaining soil quality, reducing flood impacts and maintaining summer base flow. The southern portion of the watershed is dominated by the shores of Cape Ann, which provide the most distinctive rocky coastline in Massachusetts, with an irregular coastline of rocky peninsulas, interspersed with embayments, pockets of salt marsh and estuaries.

Boston Harbor Watershed

The Boston Harbor Watershed, encompassing approximately 293 square miles of land area, including all or part of 45 municipalities, as well as most of downtown Boston, is located in and around historic Boston Harbor. The watershed includes some portions of the Mystic River Watershed to the north and the Neponset, Fore, Back, and Weir River Watersheds to the south.

Although the Boston Harbor Watershed is comparatively small in area, it contains over one million people, more than one-sixth of the state's population. The Boston Harbor Watershed is approximately 34% urban, 27% forestland, and 3% wetland (including salt marsh habitat).

As a result of long-term community involvement and major investments in wastewater and stormwater infrastructure improvements, (e.g., MWRA's Deer Island Waste Water Treatment Plant and, in conjunction with Boston and other municipalities, implementation of an extensive Combined Sewer Overflow Control Plan) the harbor has seen dramatic improvements in water quality over recent decades. Many species that had not been seen in the harbor for years are on the rebound, including harbor porpoises, seals, river herring, and other marine species. The Boston Harbor Islands were designated as a National Recreation Area on November 12, 1996.

Mystic River Watershed

The Mystic River Watershed covers 76 square miles of land area that drains into the Mystic River. The "Lower Mystic River Watershed" refers to the area below the Amelia Earhart Dam in Somerville, which is tidally influenced. Whereas the "Upper Mystic River Watershed" refers to the freshwater area above the Amelia Earhart Dam. There are 44 lakes and ponds within the Watershed, with Spot Pond being the largest at 307 acres in size. The Watershed headwaters begin in Reading, MA and form the Aberjona River, then flow into the Upper Mystic Lake in Winchester. From the Lower Mystic Lake, the Mystic River flows through Arlington, Somerville, Medford, Everett, Chelsea, Charlestown, and East Boston before emptying into Boston Harbor. The Mystic River Watershed is one of the most urban and densely populated watersheds in the Commonwealth, inclusive of three Superfund sites and various Environmental Justice communities.

Neponset River Watershed

The Neponset River Watershed includes roughly 130 square miles of land southwest of Boston. All of this land drains into the Neponset River, and ultimately into Boston Harbor. The Watershed includes parts of 14 cities and towns: Boston (Hyde Park, Mattapan, and Dorchester), Canton, Dedham, Dover, Foxborough, Medfield, Milton, Norwood, Randolph, Quincy, Sharon, Stoughton, Walpole and Westwood. Approximately 300,000 people live within the watershed boundary, Because the Neponset River ultimately flows into Boston Harbor, the Watershed is itself a part of the larger Boston Harbor Watershed, along with the Mystic River Watershed to the north of Boston, the Charles River Watershed to the west of Boston and the Weymouth-Weir River Watershed, which, like the Neponset River Watershed, originates south of Boston.

Sudbury-Assabet-Concord

The Sudbury-Assabet-Concord (SuAsCo) Watershed is located in the metro-west area, includes a large network of tributaries that ultimately flow into the Merrimack River. The watershed has a total drainage area of approximately 377 square miles. The SuAsCo encompasses all or part of 36 municipalities, most of which are within the MAPC region, and supports a population of over 365,000 people.

Twenty-nine free-flowing miles of the three major rivers in the SuAsCo Watershed were designated as Wild and Scenic in 1999. The rivers were recognized for their outstanding ecological, historical, scenic, and recreational values. The SuAsCo also encompasses two National Wildlife Refuges (NWRs) - the Great Meadows NWR, located primarily in Sudbury and one of the largest wetlands in the region, and the Assabet NWR, located primarily in Stow.

Charles River Watershed

The Charles River is 80 miles in length and has a drainage area of approximately 308 square miles and encompasses all or part of 35 municipalities, including a portion of Boston. It is generally divided into three distinct regions: the rural upper basin, the suburban lakes or middle region, and the urban lower basin.

The watershed supports a population of over 900,000 people. In the area surrounding its headwaters in Hopkinton along Route 495, the watershed contains some of the fastest growing communities in the state. The Charles basin contains over 8,100 acres of protected wetlands, referred to as Natural Valley Storage areas, which play a critical role in flood protection and provide various habitats for the numerous plant and animal species that contribute to the state's wealth of biodiversity.

The Charles River and its tributaries are home to many species of resident fish and provide important breeding habitat for anadromous fish. Currently, most migrating fish enter the river through the locks in the Charles River Dam and use a series of fish ladders to navigate dams upstream of the Lower Basin.

South Coastal Watershed

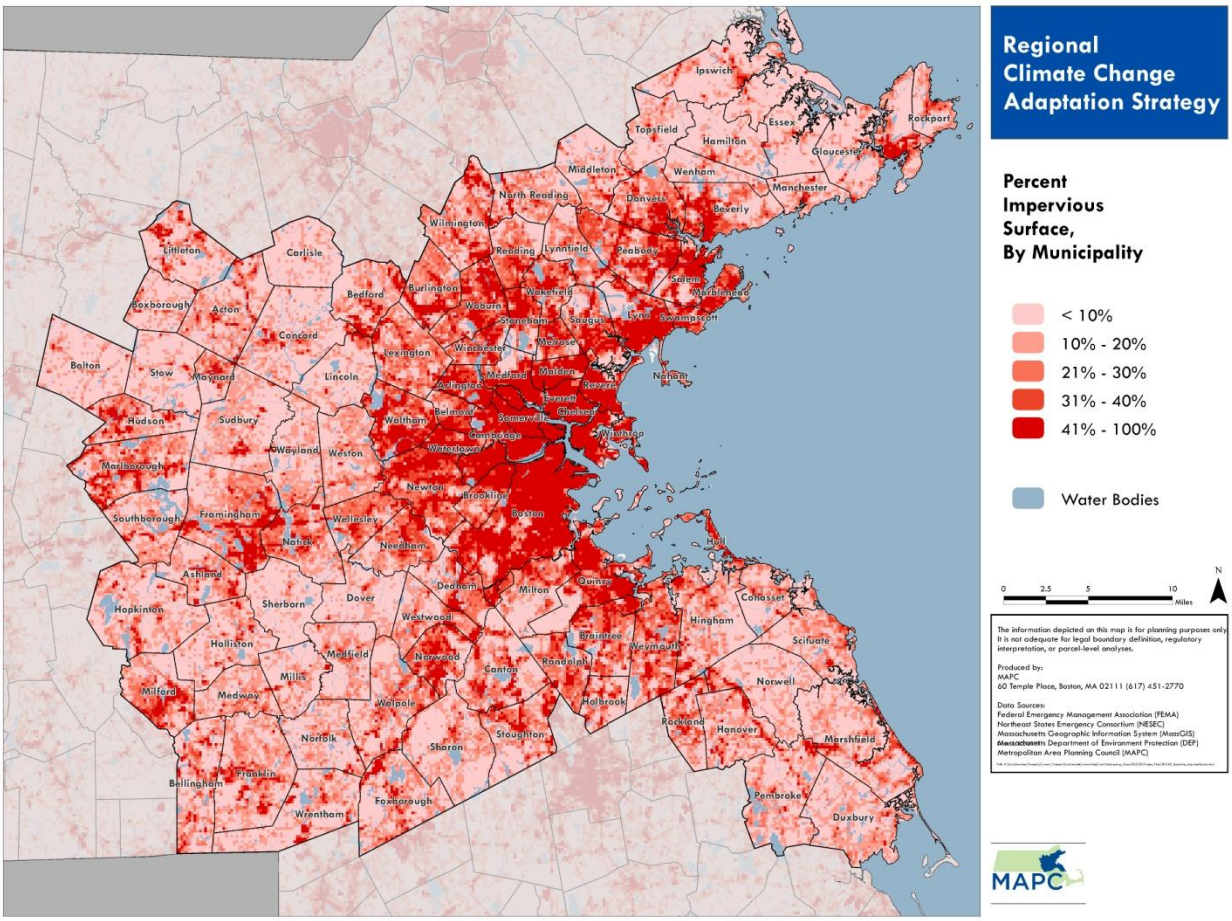
The South Coastal Watershed has a total drainage area of approximately 240 square miles that span all or part of 19 municipalities, including all or large portions of nine communities within the MAPC region. The towns of Kingston and Plymouth in the southern portion of the watershed are not within the MAPC region. The major coastal sub-watersheds include the North and South Rivers. There are numerous wetlands and many small coastal lakes and ponds scattered throughout the basin.

Portions of the South Coastal Watershed are biologically significant because they are home to rare and endangered species. For example, the Town of Duxbury (as well as Plymouth, south of the MAPC region) provides habitats to shore birds of the sandpiper family that migrate in the late summer.

II.C.2. Climate Threats

Impervious surfaces within developed areas create climate vulnerabilities to both natural resources and developed areas. As development and redevelopment occurs, typically, natural green spaces decrease and impervious surfaces increase, thereby; changing the area's hydrologic cycle. Figure II.5 illustrates the percentage of impervious surface across the region. As shown, the highest percentages of impervious surface appear within the Inner Core area of the MAPC Region; within the most urbanized municipalities.

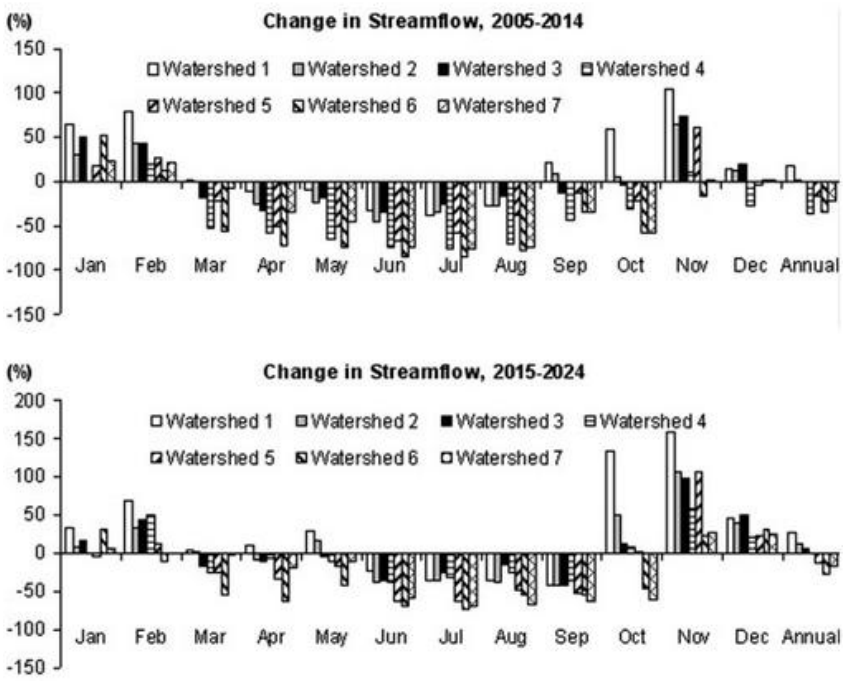
Figure II.5: Impervious Surfaces



There have been a number of studies on the impacts of climate change on the hydrological cycle. Increased impervious surfaces and subsequent flooding is expected to alter the volume and timing of streamflow of rivers, which will in turn alter both the runoff over watersheds and the distribution of river-born pollutants. Steady urbanization adds to impervious surface area thereby increasing the volume of runoff. In addition, many studies link climate change with increased streamflow variability, which adversely affects water quality.

Similar to the general studies of climate change on hydrology a 2009 study modeled the effects of both land use change and climate change for an 80 km radius around metropolitan Boston for 2005-2022 (see Figure II.6).[16] Not surprising, the study found that climate change would alter the timing of streamflow. For example, streamflow in fall and winter months would increase for most watersheds by almost 50% over the baseline but in the summer months would decrease by the same amount. This could be attributed to earlier snowmelt in the winter and spring caused by rising temperatures. However, while the monthly distribution of streamflow changed, the annual volume of streamflow stayed constant even under future climate change scenarios.

Figure II.6: Change In Streamflow (2005-2014, 2015-2035) 10



Because streamflow affects nitrogen loads, the seasonal shift in streamflow is expected to translate to a similar shift in nitrogen loading. Late fall and winter months will show higher nitrogen levels than in the summer.

In the early seventies, much of the area within Route 128 had already been heavily developed, with forested areas largely pocketed outside of town and village centers. Since then, there has been significant industrial growth moving outward from Route 128 to and even beyond Route 495. During this period, roughly 88,000 acres of land was converted from forested and open space to residential use, mostly low-density single-family subdivisions well removed from the village and town centers (see orange-shaded areas in Figure II.1). An additional 27,000 acres of land was converted to commercial and industrial use, mostly in automobile-oriented development. Today, the impact of these trends is seen in the reduction in forested areas, leading to degraded natural habitats.

Forested areas in the MAPC region are vulnerable to urban development and unsustainable forest management. A recent study estimated future land use within the region in 2060 based on the linear continuation of forest conversion to development and timber harvesting for the period from 1999 to 2005. Numerous high priority conservation areas have been identified where planning would ideally focus on land preservation and the discouragement of extensive development. Intensive urbanization will occur along the fringes of the current MAPC region. The overwhelming majority of these areas are located in communities beyond Route 128. If current trends continue through 2030, roughly 58 thousand acres of forested wildlife habitats would be lost.[17]

[16] Combined impact of climate and land use changes on streamflow and water quality in eastern Massachusetts, USA, Jun Tu, Journal of Hydrology, 30 December 2009. http://www.sciencedirect.com/science/article/pii/S0022169409006465?np=y

[17] http://metrobostondatacommon.org/site_media/calendar/Calendar2008_05May_MetroFuturePriorityConservation.pdf

Although urban development poses major impacts to forested areas, climate change will adversely affect forest structure and species composition. As described previously, the region has experienced a substantial average annual temperature increase as well as increased rainfall variability. Impacts on such a dynamic system are difficult to predict with certainty, but it is expected that most native tree species will shift northward and be replaced by more southern tree species. For example, some tree species may thrive under warmer weather conditions (oaks) while others may either decline or disappear altogether (spruce, maples). Existing forests will also be vulnerable to more frequent and intense weather events, such as droughts, which would damage forest ecosystems.

II.D. Vulnerabilities of our Coastal Zone

The Massachusetts Bays cover more than 800 miles of coastline, from the tip of Cape Cod Bay to the New Hampshire border. The coastline is typified by sandy sediments and rocky habitats that span 50 coastal communities, including 32 municipalities in the Metro Boston area, from Ipswich in the north to Duxbury in the south. The watersheds that drain into the Bay, support freshwater and saltwater marshes, tidal flats, barrier island beaches, eelgrass meadows, rocky intertidal shores and numerous small lakes and salt ponds.

The continued health of these habitats enables Massachusetts Bay to support a thriving and diverse marine ecosystem that supports whales, fish and more than 300 species of birds. Finfish caught in the Bays include Bluefin tuna, Atlantic cod, winter flounder, Atlantic flounder, and Atlantic herring, and harvested shellfish species include soft shell clams, oysters, bay scallops, American lobster, and blue mussels.

II.D.1. Existing Conditions & Values

There are numerous coastal habitat types that provide numerous ecological and economic benefits. For the purposes of this report, we have focused on two critical habitat areas: coastal wetlands and seagrass areas, which are two of the most vulnerable coastal habitats within the region, in addition to the natural shoreline.

II.D.1.a) Coastal Wetlands

Coastal wetlands, particularly salt marshes, are a key feature along the coast. Coastal wetlands 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.

Figure II.7: Salt Marshes

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

Salt marshes are one of the most productive ecosystems on the planet. They are particularly rich in nutrients that can sustain finfish, shellfish and other macro and micro invertebrates. In Massachusetts, the low marsh is characterized by a tall form of salt marsh cordgrass (Spartina alterniflora) while the high marsh is a mix of short salt marsh cordgrass, salt meadow hay, black grass (Juncus gerardii) and spikegrass (Distichlis spicata). Salt marshes and their adjacent tidal flats are among the most productive ecosystems that exist. They often act as nursery ground for various aquatic species, including winter flounder and striped bass, and provide wildlife habitats for migrating waterfowl and shorebirds.

Seagrass

Further off the coast, kelp beds and seagrass are among the area's most important marine habitats. Eelgrass (Zostera marina) is the most common species of seagrass in the area. Like salt marshes eelgrass is a highly productive habitat – it produces oxygen, which benefits animals living in seagrass beds, and improves water quality by absorbing nutrients. Studies have document 40 species of fish alone living in eelgrass, which is often used as a nursery for commercially valuable species, such as bay scallops, blue mussels and winter flounder. The "wasting disease" outbreak along the Atlantic coast in the 1930s killed around 90% of the eelgrass in the region and demonstrates the ecological importance of seagrass. What followed included massive erosion of sediments, changes in water quality, and significant losses in waterfowl and shellfish populations, both of which depend on seagrass beds for food and shelter.

II.D.2. CURRENT THREATS

Coastal development in particular has created a wide-range of existing environmental concerns including storm-water runoff, sewage related pollutions, growing ecosystem stress from human development, and now a changing climate. The intensive development pattern of the region amplifies a number of these existing risks to both natural features and man-made structures, as illustrated in Figure II.8 showing homes along the coast of Plum Island after the March 9, 2013 storm.

Figure II.8: Plum Island, March 2013

Source: Boston Globe, March 21, 2013; David L. Ryan, Globe Staff

These development pressures cause approximately 1,000 acres of coastal wetlands along the coastline to be lost every year. Severe water quality contamination persists within our urbanized coastal areas where parcels are often have elevated levels of PAHs, copper, arsenic, lead, cadmium, mercury, chromium, nickel, zinc, PCBs, and pesticides. Two primary threats from the changes that will likely have considerable impacts on coastal communities are sea level rise and stronger and more frequent storm events.

Coastal development in particular has caused a number of environmental concerns, including storm-water runoff, sewage related pollutions, growing stress from human development and climate change. Combined, these pressures cause around 1,000 acres of Bays' coastal and inland wetlands to be lost every year. The area around Boston Harbor is particularly prone to toxic contamination, with elevated levels of PAHs, copper, arsenic, lead, cadmium, mercury, chromium, nickel, zinc, PCBs, and pesticides.

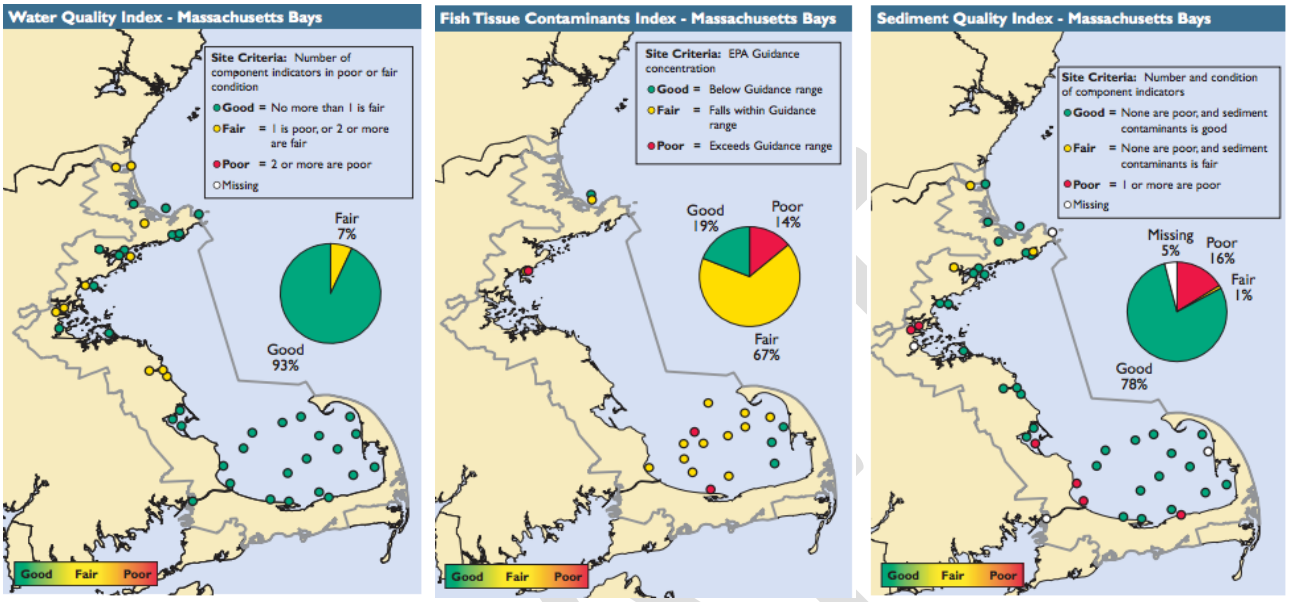
II.D.2.a) WATER QUALITY IMPAIRMENT

An important marker in determining the health of an aquatic ecosystem, particularly coastal wetlands and seagrass areas, is its water and sediment quality conditions. In 2000 and 2001, US EPA's National Coastal Assessment (NCA) surveyed 44 sites within Massachusetts Bay, and rated them as being in "fair" condition, based on their finding for water quality, sediment quality, and benthic index and fish contaminants.

Interestingly, the greatest concentrations of "fair" water quality locations within the Bay were found are around the greater Boston area, indicating the vast improvements in point source pollution abatement within the inner harbor. Sediment quality was rated "poor" for the Bay and high sediment

contamination was found at two Boston Harbor sites. In addition, one of the highest concentrations of pollutants found in fish tissue was found within the region, within the North Coastal Watershed. Figure II.8 shows ratings for separate locations within Massachusetts Bays[18].

Figure II.8: Estuarine Quality Indices



II.D.2.b) SHORELINE CHANGE

Adjacent private and public lands are vulnerable to natural changes to coastal landforms such as loss and accretion of sediment; and vice-versa. Although loss and accretion of sediment do occur naturally, shoreline structures such as seawalls and revetments can influence these natural processes, especially by accelerating or inhibiting movement of sediment. 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.

[18] http://water.epa.gov/type/oceb/nep/upload/2007_05_09_oceans_nepccr_pdf_nepccr_nepccr_ne_partd.pdf

Figure II.9: Man-Made Coastal Structures

Bulkhead /Seawalls

Groins / Jetties

Revetments

Engineered Coastal Beach

II.D.2.c) SEA LEVEL RISE

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 most MAPC municipalities, long term tide gauge data is not 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.

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.

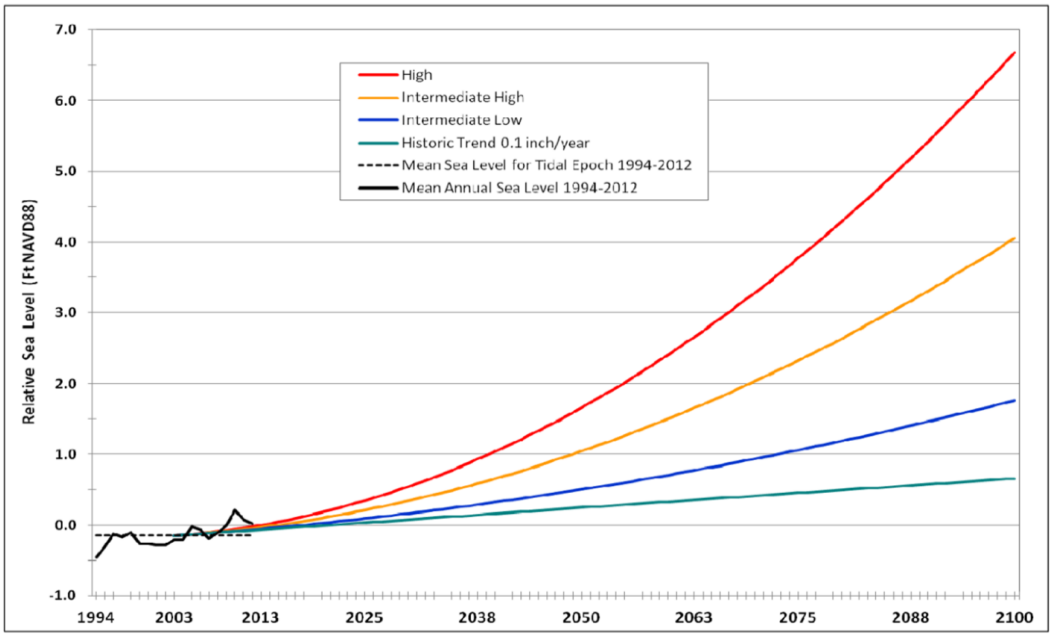
In 2013, the Massachusetts Office of Coastal Zone Management prepared sea level rise projections based on the four global mean sea level rise scenarios for 1992 to 2100 as contained in *Global Sea*

Level Rise Scenarios for the United States National Climate Assessment[19] (Figure II.10). Their projections include adjustments to the global scenarios to account for local vertical land movement (-0.84 mm/yr), using methods and equations from *Matching Mean Sea Level Rise Projections to Local Elevation Datums*[20] and the U.S. Army Corps of Engineers[21] (Figure II.11). It is estimated that the rate of change in MSL for Boston Harbor is ranges from 0.09 millimeters by 2025 (0.31 feet) to 1.83 mm by 2100 (6.02 feet).

Figure II.10: Relative Sea Level Rise Estimates for the Greater Boston Area[22]

Scenario	2025		2038		2050		2063		2075		2088		2100	
	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
Highest	0.49	0.15	1.08	0.33	1.81	0.55	2.80	0.85	3.92	1.19	5.33	1.63	6.83	2.08
Intermediate High	0.36	0.11	0.73	0.22	1.19	0.36	1.80	0.55	2.47	0.75	3.32	1.01	4.20	1.28
Intermediate Low	0.24	0.07	0.43	0.13	0.65	0.20	0.92	0.28	1.21	0.37	1.55	0.47	1.91	0.58
Lowest (Historic Trend)	0.18	0.06	0.29	0.09	0.39	0.12	0.50	0.15	0.60	0.18	0.71	0.22	0.81	0.25
Range	0.31	0.09	0.79	0.24	1.42	0.43	2.30	0.70	3.32	1.01	4.62	1.41	6.02	1.83

Figure II.11: Relative Sea Level Rise Scenarios for the Greater Boston Area (MA CZM)



[19] Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss, 2012. Global Sea Level Rise Scenarios for the United States National Climate Assessment. NOAA Technical Report OAR CPO-1.
[20] Flick, E., K. Knuuti, and S. Gill, 2012. Journal of Waterway, Port, Coastal, and Ocean Engineering. doi: 10.1061/(ASCE)WW.1943-5460.0000145.
[21] U. S. Army Corps of Engineers, 2011. Incorporating Sea-Level Change Considerations in Civil Works Programs, EC 1165-2-212.
[22] Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning, Massachusetts Office of Coastal Zone Management, December 2013.

New models are currently being developed within the Boston Harbor area that use sea level rise projections, such as that described above, and adding wave action, flow and water movement, such as the model developed by the Woods Hole Group. This model, developed as part of the Massachusetts Department of Transportation and the Federal Highway Administration, was prepared initially to assess the vulnerabilities of the Central Artery Tunnel system. The model combines the Advanced Circulation Model and the Simulating Waves nearshore Model creating a risk assessment tool that provides the probability of a given storm and its flooding conditions, based on sea level rise scenarios. As this and other models become available to paint a dynamic picture of sea level rise inundation, MAPC will utilize these tools in its coastal areas to provide coastal municipalities with robust data for planning purposes, as needed.

Coastal Wetland Habitats

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

Table II.2: Impacts to Coastal Wetland Habitats

Type	Key Pressures
Salt Marshes	Habitat alteration and destruction (from coastal development) Sea Level Rise, Pollution/Contamination
Mudflats	Navigational Dredging, Pollution/Contamination
Seagrass/Eelgrass	Pollution/Nutrient Loading
Kelp Beds	Storm events, Rising Temperatures
Sandy Shore	Storm events
Estuaries	Nutrient Loading, Pollution/Contamination

Up until the present time, salt marshes within the region have accumulated enough sediment to maintain their elevation despite gradual sea level rise. However, in recent years, some marshes have struggled to adapt to more rapid sea level rise. More productive low marsh vegetation is being overtaken by less productive high marshes. Beyond a certain threshold, rapid sea level rise will result in a total loss of marsh vegetation, leaving coastal areas more vulnerable to erosion and flooding, threatening habitats for numerous birds and fish, and allowing more pollutants to enter open coastal waters.[23]

[23] http://www.northeastclimateimpacts.org/pdf/confronting-climate-change-in-the-u-s-northeast.pdf

As part of the development of 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 areas within the MAPC Region where migration is likely to occur. (See Appendix for *Map Series G: Potential Inland Migration of Salt Marshes.*)

Seagrass habitats are exceptionally vulnerable to lower water quality from nutrient loading, sedimentation, algal growth and turbidity. Kelp beds are vulnerable to over harvesting of groundfish, sea urchins and kelp and an increase in storm events can dislodge large portions of the kelp beds from the sea floor. These beds also require cooler water temperatures, and therefore; could be harmed by warmer coastal waters.

Rising surface water temperatures may also impact fish populations that live within specific temperature ranges. High and low projections for surface water temperature indicate between a 2-4 C increase by 2080. As ocean temperatures rise, suitable cod and lobster habitats will likely shift north. Over the next 60 years, all Gulf of Maine waters will lose some of their capacity to support both adult and young cod populations.[24] While Boston's coastal waters are projected to continue to support adult cod populations, they will have only a marginal ability to support young cod, which could adversely affect the region's fish population. In contrast, warming in Massachusetts Bay may actually benefit lobster populations by extending the growing seasons, and accelerating growth and hatching. Yet warmer water may also make lobsters more vulnerable to bacteria, which can destroy their shells and has already caused serious harm to lobster populations near south Cape Cod.

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)[25] report indicates that 0.15 meters of subsidence has occurred in coastal areas of Massachusetts.

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).

The *MA Coastal Infrastructure Inventory and Assessment Project* reports described above, include not only a condition assessment for each coastal protection structure, but also a priority rating based on the presence and potential risk to inshore structures. The five-level priority rating system ranges from "None" (Priority Level I) where no inshore structures or residential dwellings are present to

[24] Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions, Northeast Climate Impacts Assessment Synthesis Team, July 2007.
[25] Climate's Long-term Impacts on Metro Boston (CLIMB) Final Report V1.1, 2004.

"Immediate/Highest Priority" (Level V) where the structure protects an emergency evacuation route or shelter, critical inshore structures, or high-density residential dwellings.

The ultimate priorities identified for each year in the report's 20 Year Maintenance and Repair Spending Plan (Appendix I) combines the results of the Condition Assessments and the Priority Ratings. This is essentially a first cut vulnerability assessment. The Spending Plan identifies a total of more than $625 million of required maintenance and repairs over the 20-year period, generally between $30 and $35 million per year. Of the 136 priority projects identified for the first five years, 83 (56%) of the structures are within the MAPC/Metro Boston region. Table X below provides an overview of how many priority projects were identified for each of the Metro Boston communities during the first five years. The detailed listing of the prioritized projects for the first five years, including the overall priority, the location and type of structure, and the estimated repair costs (from the *Inventory and Assessment* report) can be found in the Appendix.

While it is beyond the scope of this Report to provide community-by-community and structure-by-structure information, this data is available from the *Inventory and Assessment* reports on MA CZM's Stormsmart coasts website.[26] These include very detailed information for each structure in each community in terms of its history, ownership, physical characteristics, elevation, structural condition, priority rating, etc. On a standardized form Structure Assessment Reports for each protection structure are provided, supplemented with photographs as well as relevant documents such as licenses, location and site plans, engineering drawings, etc. As mentioned above, the *Inventory and Assessment* report covers only publicly owned or maintained infrastructure protection structures.

This detailed data provides all MA coastal municipalities (including those in the MAPC region) with critical information for taking the next steps in assessing structure-specific vulnerability to climate change for the highest priority structures. The *Inventory and Assessment* report recommendations refer to the next step as full condition surveys and design work, which would include physical inspection of the entire structure, borings and soil sampling, plus developing alternative hard and soft design solutions and associated cost estimates for each.

[26] See http://www.mass.gov/czm/stormsmart/mitigation/infrastructure_reports.htm. Note that the detailed community *Inventory and Assessment* reports are organized into MA CZM's five coastal regions and MAPC communities comprise all of the Boston Harbor region and most of both the North Shore and South Shore Regions. The 12 MAPC communities on the North Shore are covered in four sub-regional reports; the 9 Boston Harbor communities are documented in three sub-regional reports, one of which is for Boston alone; and each of the 6 MAPC South Shore communities is covered in a separate report.

Table II.3: Coastal Structure Vulnerabilities

Municipality	Total Number of Structures	No. in Poor or Critical Condition	Structures In Metro Boston Prioritized in Years 1 -5				
			Year 1	Year 2	Year 3	Year 4	Year 5
Ipswich	1	0					
Essex	0	0					
Gloucester	33	3	2				2
Rockport	22	5	1	1		1	
Manchester	21	4					
Beverly	20	2	2			1	
Salem	42	7				1	
Marblehead	37	4	1			1	
Swampscott	9	2					
Lynn	11	4					1
Saugus	3	0					
Revere	15	0				3	
Nahant	25	7			2		
Winthrop	33	4				2	4
Chelsea	4	0					
Everett	0	0					
Boston	103	13	2	6	2	1	5
Milton	0	0					
Quincy	39	3				3	
Braintree	10	1			1		
Weymouth	25	4	1	1			
Hingham	34	4	1		2		1
Hull	89	10	2	2	3	1	11
Cohasset	16	1			1		
Scituate	71	6		1		3	
Marshfield	32	6		4			
Duxbury	13	1					4
Totals	**708**	**91**	**12**	**15**	**11**	**17**	**28**

Source: Adapted from Massachusetts Coastal Infrastructure Inventory and Assessment Project, 2009.

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 Plum Island and 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 in 2007 and 2013.

II.D.2.d) STORM EVENTS

Storms present a current hazard to development along the coastline from coastal flooding and storm surges butting up to barriers such as buildings, and coastal structures. These storms are typically a result of tropical hurricanes or ex-tropical northern storms (nor'easters), with the nor'easters posing the more frequent hazard for the region, as its southern coastline is protected by the Cape Cod landmass. 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 region's 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.

- 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.

- 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.

These storms provide a picture of the how coastal municipalities are currently vulnerable. It should be noted that although Repetitive Loss Claims through the National Flood Insurance Program (NFIP) capture impacts of the storm on inland and coastal private properties, they do not include costs associated with 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.

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.

As noted in the Climate's Long-term Impacts on Metro Boston (CLIMB) report, if the rate of sea level rise continues the trend from the past century, a typical 10 year storm would have the intensity of a

100 year storm and a present 100 year storm could equal the power of a 500 year storm.[27] 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).[28] 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.

II.E. Vulnerabilities of Developed Areas & Infrastructure

Developed areas and key infrastructure facilities provide the services that allow the region's residents and businesses to function. Here we consider the vulnerability of these areas and associated key infrastructure, including several major subsectors:

- Buildings (commercial, residential, industrial, institutional and government)
- Energy (electric, gas, petroleum, and renewables)
- Transportation (land, sea, air)
- Water (supply, wastewater, stormwater)

II.E.1. Baseline Conditions

Much of the key infrastructure in the Boston region is located along the coast and near major rivers, owing to the historic transportation advantages as well as the aesthetic amenities offered by such sites. Moreover, virtually all the existing "infrastructure resources were sited and designed based on historic weather, sea level, and flooding patterns."

II.E.1.a) Buildings

As one of the earliest regions developed in the U.S., Metro Boston experienced rapid growth in population and throughout the 19th and first half of the 20th centuries. It is home to many historic buildings and structures, both in downtown Boston and throughout the region. The vast majority of buildings were constructed based on building design standards that reflect historic climate patterns.

The MetroFuture Plan describes the region as having four community types, based largely on density of buildings/land use development and transportation services: Inner Core, regional Urban Centers, Maturing Suburbs, and Developing Suburbs. The Inner Core comprises 16 cities and towns inside Route 128, including Boston, Cambridge, Somerville, Chelsea, Brookline and Newton, with approximately 1.3 million residents. It is characterized by high density neighborhoods, multifamily housing and significant immigrant populations. regional Urban Centers are located mostly outside Route 128 (e.g., Framingham, Peabody, Salem, and Woburn) and have dense development patterns, though unlike the Inner Core, generally contain some developable land. Their housing and demographic characteristics are similar to Inner Core communities.

[27] 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.
[28] Weiner C (1993) Frequency of tidal flooding at Boston Harbor, U.S. Army Corps of Engineers. New England Division, Concord MA.

About 50 towns along the Route 128 corridor with a total population of about one million residents are considered Maturing Suburbs (e.g., Milton, Braintree, Reading, Saugus, Lexington, and Wellesley). These communities contain moderate-density neighborhoods, mostly single-family residences, a dwindling supply of developable land, and are generally less diverse than the Inner Core or regional Urban Centers. Developing Suburbs along Route 495 and the North and South Shores (e.g., Wrentham, Hopkinton, Boxborough, and Ipswich) are less densely developed, though some have strong town centers, are dominated by single-family housing, and have considerable developable land.

The region's developed areas include the full range of residential, commercial, institutional, government and industrial buildings. Some of the oldest and most dense concentration of buildings is found along the coast as well as near major rivers for ease of transportation and aesthetics.

II.E.1.b) ENERGY SUPPLY

To meet its energy needs the region relies on a variety of energy sources and related infrastructure. Major energy-related infrastructure in the region are associated with importing, storing and/or distributing natural gas and distillate fuel oil, as well as generating, transmitting and distributing electricity.

The region hosts three liquefied natural gas import terminals, one on land in Everett and two offshore of Gloucester, with other natural gas delivered by pipeline. Gas is delivered to customers through underground transmission pipes and an extensive network of local distribution pipes. It also imports petroleum products through five major terminals along Boston Harbor as well as smaller terminals in other coastal communities. In addition, one of the nation's two Northeast Home Heating Oil Reserves storage sites, intended to cushion the effects of disruptions in the supply of home heating oil, is located in Revere.

The electric power infrastructure comprises power generating plants, substations, and an extensive network of high-voltage transmission lines and local distribution wires. The Metropolitan area consumes approximately 22 million megawatt-hours (MWh) of power annually from a variety of both renewable and nonrenewable sources.[29] Much of this power is generated within state, but a significant fraction is imported from neighboring states.

In 2011, 68 percent of Massachusetts' electricity generation was from natural gas, about 15% from nuclear, 11 percent from coal, and just over 6 percent from renewable resources, primarily biomass and hydroelectricity. The three largest electric generating plants in the region, all located on coastal sites, are: the Mystic Generating Station in Charlestown (1,968 MW), the Salem Harbor plant in Salem (744 MW), and the Fore River Generating Station in North Weymouth (688 MW).[30] An inventory of power generation facilities in the MAPC region, fuel use, and 2012 generation is provided in the Appendix.

Because ISO-New England, the designated Regional Transmission Organization for New England manages the dispatch of electricity on a regional New England-wide basis, and the precise mix of facilities sending power to the regional grid is constantly changing, it is not possible to describe the degree to which the Boston metropolitan area's electricity requirements are met by specific generating facilities.

[29] MA Climate Change Adaptation Report, MA EOEEA, September 2011 based on data from ISO New England.
[30] U.S. Energy Information Administration, Form EIA-860, "Annual Electric Generator Report."

Significant increases in energy demand are expected in the region by 2100, with growth in peak demand related to greater summer cooling needs caused by more frequent periods of extreme heat.[31]

Massachusetts' growing commitment to renewable energy has begun to reduce the region's reliance on large central station fossil fuel plants and diversify the energy supply mix. Due to a range of state initiatives, including the Green Communities Act and the Renewable Portfolio Standards, installed solar capacity has increased in Massachusetts from less than 10 MW in 2009 to 699 MW as of December 2014, with the Boston metro region hosting a large number of solar installations on commercial, government, institutional, and residential properties. Similarly, installed wind capacity has increased from less than 10 MW in 2009 to 107 MW as of December 2014. As described below under Current Response Strategies, significant growth of renewables in the region's energy supply mix is expected to continue in the coming years.

II.E.1.c) TRANSPORTATION

The MAPC Region contains a wide network of transportation infrastructure including roads, railways, airports, and marine terminals, serving both passengers and freight. Major transportation infrastructure in the region includes the following listed in Table II.4.

Table II.4: Transportation Infrastructure

Type	Description
Airports	Boston-Logan International Airport: New England's largest airport with over 13.5 passenger boardings in 2010[32] Hanscom Field located in Bedford, MA along the Route 128/95 and Route 495/3 corridors
Roads/Highways/ Tunnels	Interstate highways: I-93 (including Central Artery), I-95, I-90 (Massachusetts Turnpike) Coastal Roads: 3A and 1A Tunnels: Callahan, Sumner, Ted Williams
Rail	MBTA: Subway, Silver Line, Commuter Rail AMTRAK: coastal routes to Portland, ME and New York via Providence
Marine Terminals/ Ports	Cruiseport Boston: serves >300 thousand passengers annually Conley Terminal: handles 1.5 million metric tons of cargo per year[33] Port of Boston Terminals: supports 34,000 jobs

II.E.1.d) WATER SUPPLY

Water related infrastructure includes the water sources, pump stations, storage tanks or reservoirs, treatment facilities, as well as water mains and distribution pipes. Of the 101 communities in the MAPC region, 53 cities and towns receive water and/or sewer services from the Massachusetts Water Resources Authority (MWRA) the regional wholesaler of water and sewer services to communities in the eastern and central part of the state (see Figure II.12). Forty-four MAPC communities receive full or partial water service, while 43 receive sewer service, accounting for the vast majority of population and water/wastewater flows in the region. (Note there is overlap as 34

[31] Amato et al., 2005. Regional Energy Demand Responses to Climate Change: Methodology and Application to the Commonwealth of Massachusetts. Climate Change, Vol. 71, #1, pp. 175-201.

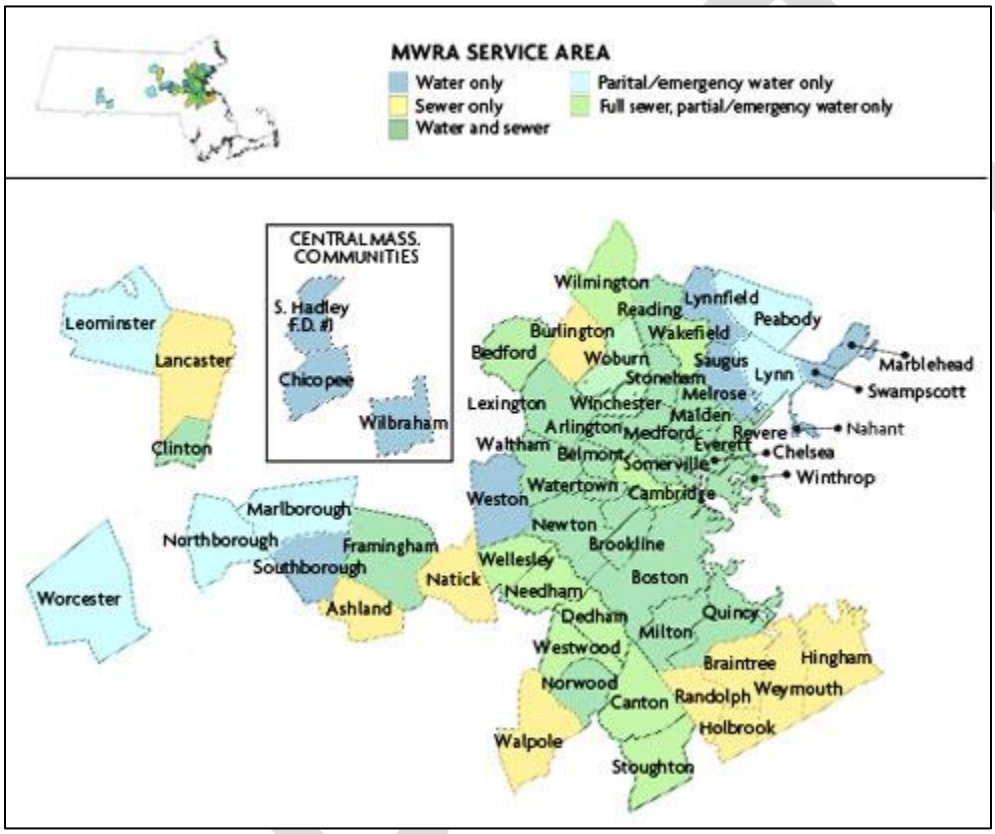
[32] http://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/media/cy10_primary_enplanements.pdf

[33] www.massport.com

MAPC communities receive both water and sewer services; see Appendix Y.) MWRA water is treated at a treatment plant at Walnut Hill in Marlborough, sent through the MetroWest Water Supply Tunnel, stored in covered tanks, and from there is drawn into distribution mains and many smaller community pipes throughout its service territory.

The remaining MAPC communities rely on local surface or groundwater sources. The adequacy and reliability of such sources varies depending on conditions in their respective watersheds. Communities in certain basins have experienced chronic water supply shortages (e.g., the Ipswich Basin). MA DEP reported that in 2012 at least 40 MAPC communities had Municipal Non-Essential Outdoor Water Use Restrictions (36 of which were mandatory restrictions), which is a strong sign of water supply stress in many of the region's non-MWRA communities (see the Appendix).

Figure II.1: MWRA Service



II.E.2. Vulnerabilities of Developed Areas & Infrastructure

Climate change impacts of most concern to developed areas and key infrastructure include sea-level rise as well as increased intensity and frequency of extreme storm events. These will cause coastal inundation and storm surges, and inland flooding from increased precipitation. In addition, increases in extreme heat will also have an impact on the region's energy infrastructure system.

With increases in storm intensity and sea level rise, low-lying coastal locations that are already vulnerable under today's conditions will be exposed to greater risks of more severe flooding and will

experience more flood-related damage. Increases in erosion will further expose coastal regions to more potential damage, and recreational beaches and natural sediment flows will be disrupted as ocean levels rise. Further, property values will likely decrease in areas where vulnerability to flooding increases or neighborhood amenities such as beaches are impacted.

Recent modeling of potential sea-level rise and coastal inundation over coming decades reveals the enormity of the potential damage to development and key infrastructure. By mid-century substantial changes in coastal flooding are projected, with increases in maximum elevation of major coastal floods as well as much greater frequency of such events. In fact, today's 100-year flood events are projected to occur every two to three years in Boston under the higher- and lower-emissions scenarios, respectively. By 2100 the projected impacts are even more dire, with most locations experiencing flood elevations roughly 2.5 feet above the current 100-year flood elevation under the higher-emissions scenario and 2 feet under the lower-emissions scenario. Moreover, such major floods are projected to occur on the order of every year or two in Boston under both scenarios.

Projected sea-level rise will result in major flooding of all the major infrastructure sub-sectors: buildings, roadways, tunnels (including MBTA), water and wastewater treatment facilities, electric generating facilities and telecommunications facilities. Some of the most important infrastructure, including Logan Airport and the Deer Island Wastewater Treatment Facility are located in coastal areas projected to be impacted by sea-level rise.

As flood risks increase, the availability and cost of insurance will reflect this change. And as it becomes infeasible to insure new development, building of new infrastructure within coastal communities may decline or be significantly modified to meet more rigorous building codes. Ultimately, the extent to which the region's vulnerability results in damage to development will be a function of (1) the rate of sea-level rise and increased storm intensity, and (2) the timeliness of adaptation.

II.E.2.a) VULNERABLE BUILDINGS

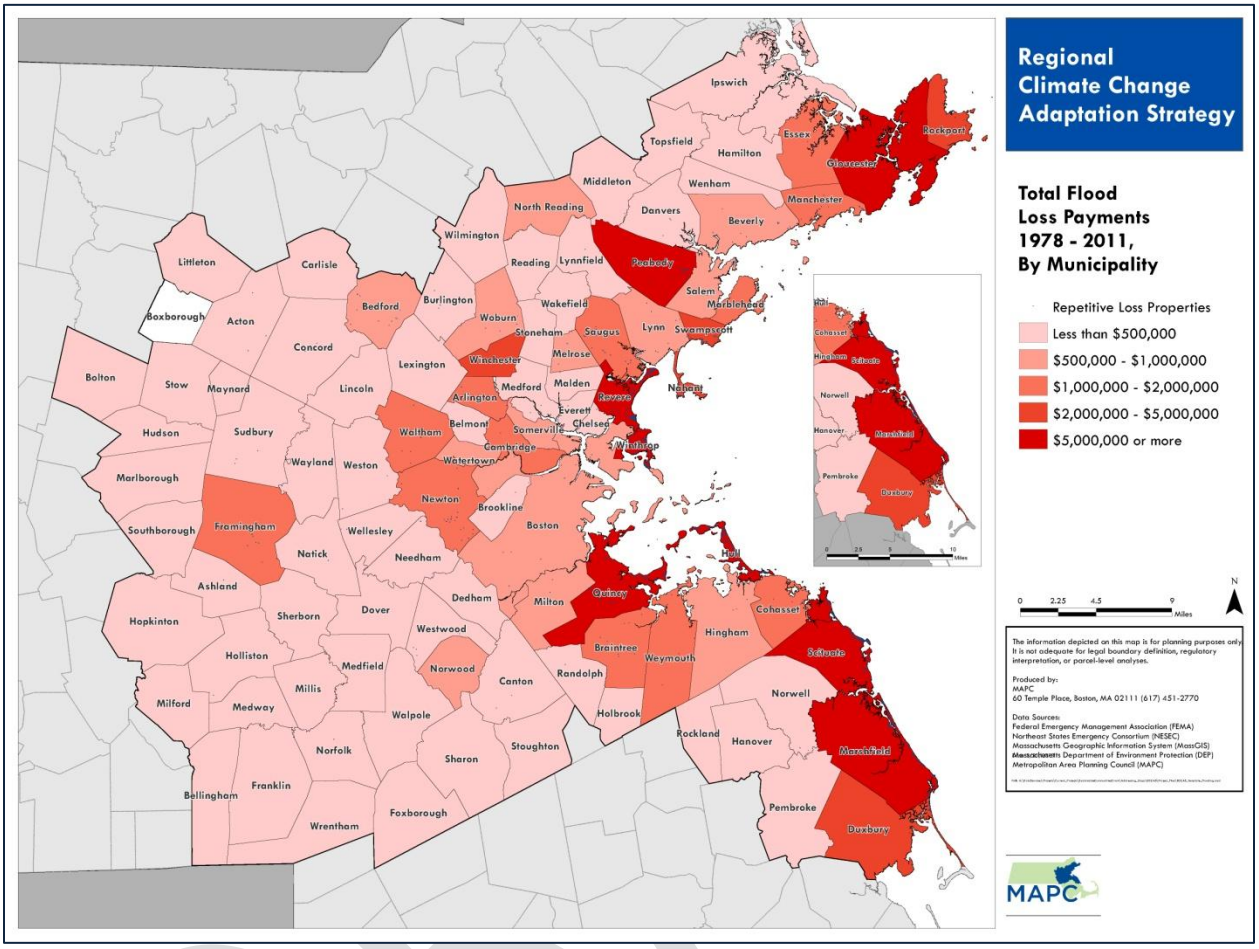
Buildings of all types, both in coastal and inland areas, are subject to the impacts of climate change. With sea-level rise buildings along the coast are particularly vulnerable to flooding, corrosion due to salt water intrusion, and other damage. Unfortunately, this is precisely where much of the region's most valuable residential, commercial, and institutional property is located.

Building structures and/or performance throughout the region may be vulnerable to a number of climate-related changes. More frequent and intense storms are extending floodplains such that flood-proofing will be necessary in previously unprotected areas and may need to be enhanced in others. This may lead to increased mold in certain buildings, which can in turn cause building-related respiratory and other illnesses. In addition, higher summer temperatures will result in greater building cooling demands and thermal stress on building materials may increase.

Figure II.13 below illustrates the communities within the MAPC region that have experienced flooding since 1978. Locations that have seen upwards of $5 million in damage include Gloucester, Revere, Quincy, Winthrop, Peabody, Scituate, and Marshfield.[34] We anticipate these locations, as well as other low-lying coastal communities such as portions of Boston, Cohasset, Duxbury, Weymouth, Rockport, and Swampscott, will become more vulnerable over this century. In addition, locations such as Cambridge, Everett, Saugus, Chelsea, and Arlington, which have already seen damage due to hurricane storm surges, will likely see an increase in damage as storms become more intense.

[34] MAPC, 2013. Map titled "Regional Climate Change Adaptation Strategy, Total Flood Loss Payments 1978-2011, by Municipality."

Figure II.13: Flood Loss Payments



II.E.2.b) VULNERABLE ENERGY SUPPLIES

The major climate change impacts of concern for the energy sub-sector are the same as for infrastructure generally: flooding caused by sea-level rise and increased storm intensity and frequency, extreme weather events, and increased temperature.

Particularly vulnerable are large energy generation, terminal, storage and transmission facilities located along the coast, where the combination of sea-level rise and more extreme weather events may damage equipment as well as underground wires and pipes. Such damage can lead to loss of service or a disruption in supplies, in some instances threaten public health and safety, and ultimately require large investments to repair, rebuild, or relocate critical energy infrastructure facilities. Moreover, potential releases caused by damage to petroleum or LNG terminals or transmission pipelines pose a serious environmental and public health threat.

The vulnerability of the electric supply system warrants particular attention given the critical role is plays in the daily life of the region's residents and businesses. Several of the largest electric generating plants are along the coast making them vulnerable to flooding as a result of sea level rise and storm surges. Rising temperatures and heat waves will lead to increased air conditioning demands, diminished power plant cooling capacities, and impaired performance of generation and transmission assets. There is further concern that the cooling plants of current electric generating

facilities will be unable to operate as effectively if river or ocean temperatures become warmer. In addition, distribution lines for power will be vulnerable to extreme events such as high winds or ice storms and increased exposure to seawater could lead to greater erosion of existing facilities.

In the near-term, day-to-day operations and practices will need to be adjusted in order to better manage these climate change risks through, for example, improved energy demand forecasts, monitoring of natural water supply/availability, and new power station heat rate and cooling water supply planning assumptions. In the long-term, given the capital-intensive and long-lived nature of energy infrastructure, a framework for a systematic response to the growing risk that climate change poses to sustainable energy supply and delivery is essential in order to avoid locking in systemic vulnerability of vital infrastructure for decades to come.

Recent impacts from major storms help to illustrate the vulnerabilities of the electric transmission system and provide a sense of the potential damage from more intense and more frequent weather events. Most recently in late October 2012 Hurricane Sandy disrupted electricity service to thousands of customers throughout the Boston region and beyond.

As with all built infrastructure, facility-specific vulnerability assessments will be necessary to identify the likelihood of particular risks faced by individual energy facilities, and to inform adaptation strategies.

II.E.2.c) Vulnerable Transportation

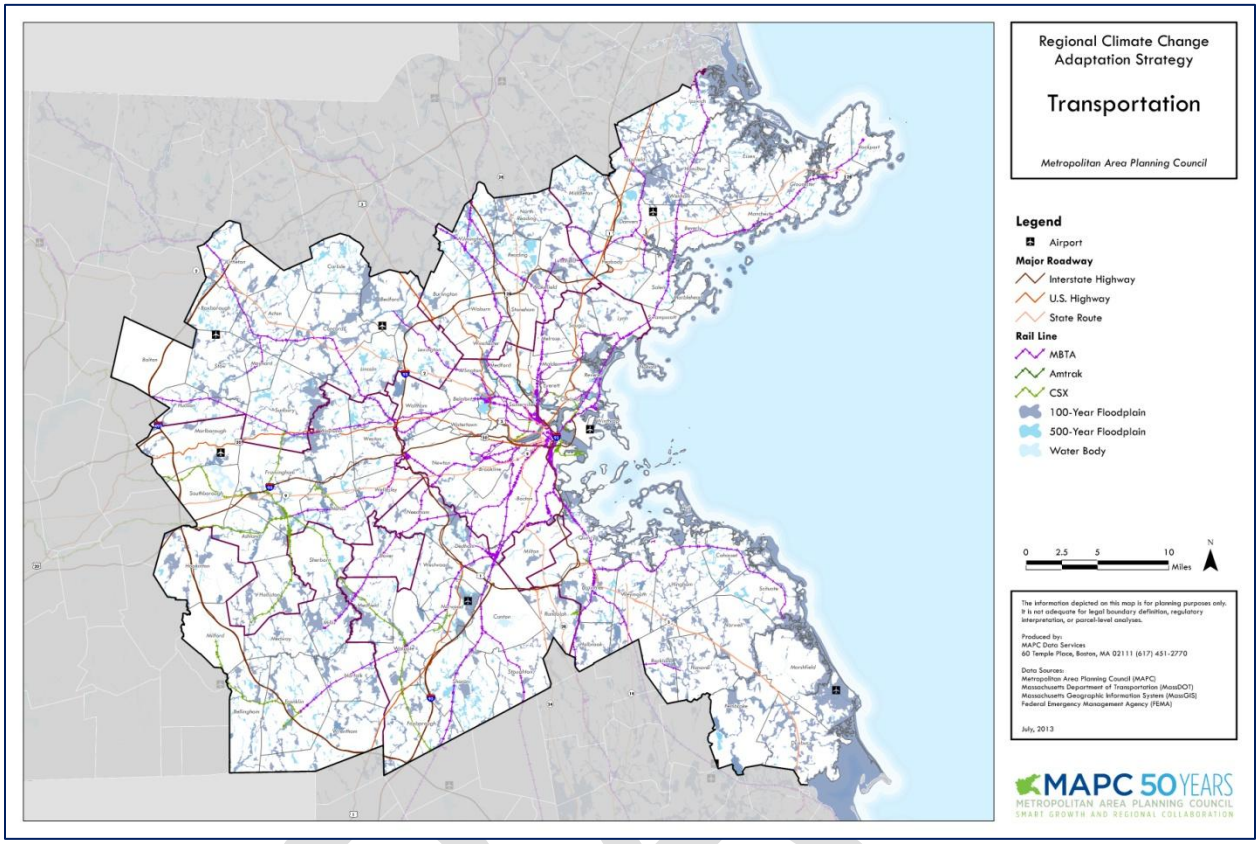
State and regional agencies are at an early stage in assessing transportation infrastructure vulnerability and the development of response strategies is just starting. Very recently there are signs that state and regional agencies are beginning to think about systematically assessing transportation system infrastructure as it relates to climate change vulnerability. One relevant recommendation in the Massachusetts Climate Change Adaptation Report is that the state map and survey floodplains accurately so as to identify vulnerable infrastructure and the frequency of possible incidents. In May 2012 as part of its sustainability initiative the Massachusetts Department of Transportation (MassDOT) released its GreenDOT Implementation Plan. Actions identified in the Plan include assessing MassDOT facilities for climate change vulnerability, which is the first step in identifying potential adaptation strategies.

The primary risks to the Boston region's transportation infrastructure are from sea-level rise and extreme weather events, which threaten virtually all types of infrastructure including roadways, bridges, tunnels, subways, commuter and freight rail, ferries, bus facilities, airports, and ports.[35] Sea-level rise and storm surge put Logan Airport as well as coastal roads, tunnels, rail and transit lines at risk of inundation, potentially disrupting both passenger and freight transportation.

Threatened coastal transportation infrastructure includes intercity rails running from Boston to Portland, ME, and Boston to New York via Providence; as well as certain segments of the Massachusetts Bay Transit Authority (MBTA) commuter rail routes (e.g. Rockport and Greenbush lines). Significant portions of the MBTA subway system are also highly vulnerable to flooding, especially stations and tunnels along the waterfront and in the Back Bay. As described earlier (see Figure II.14), these areas are projected to experience severe and frequent flooding and inundation from sea-level rise and storm activity.

[35] Boston Region Metropolitan Planning Organization, September 2012. Carbon Dioxide, Climate Change, and the Boston Region MPO: 2012 Update.

Figure II.14: Transportation Vulnerabilities



Given the MBTA's central role in the region's transportation system, increased vulnerability to its infrastructure warrants particular attention. The MBTA system is vast; it has a total of 124 rapid transit and light rail stations, 131 commuter rail stations (not all within the MAPC region), approximately 20 miles of tunnels (14 miles for the subway system) and 473 bridges within its various systems. With MBTA average weekday ridership in 2011 of almost 1.3 million passengers, flood-induced disruption to key tunnels or stations in the downtown, waterfront, and/or Back Bay areas would cause significant disruption to both residents and commuters. The recent closure of the entire MBTA system on October 29, 2012 due to fear of flooding from Hurricane Sandy was an unprecedented event, but may portend things to come if adaptation measures are not taken. And with the City's transportation system shuttered, businesses throughout the city had no choice but to close. While not easy to estimate, the economic losses associated with significant disruption to the transit system (or other major transportation infrastructure) can be very significant.

MBTA officials were recently quoted in the Boston Globe as saying that prior to Hurricane Sandy "there has only been one severe flood in a subway tunnel, in October 1996 when a three-day storm caused the Muddy River to overflow. At least 14 million gallons of water gushed into the Green Line portal between Fenway and Kenmore with such force that it moved tons of rock 500 feet into the tunnel." Now during severe storms the MBTA reportedly "stations a person with a measuring stick at the Muddy River and, when the river gets too high, shuts down service between the two stations and replaces it with busing."[36]

[36] Boston Globe, November 2, 2012. Boston could be vulnerable to more severe storms, Beth Daley and Eric Moskowitz.

MBTA officials indicate that they have identified the stations most at risk of flooding, but have apparently not yet conducted a systematic vulnerability assessment as it relates to potential climate change impacts. In The Boston Harbor Association's recent report, *Preparing for the Rising Tide*, discussed above, one of the case study facilities for which a vulnerability assessment was completed is the (newly renovated) Aquarium MBTA Station on the Blue Line. It found that while the entrance to the subway station is above ground, except for a small entrance foyer the station is underground and below sea level, and is therefore vulnerable to flooding during a 100-year storm surge with sea-level rise of MHHW+2.7 (which is less than either of the sea-level rise scenarios highlighted in the *Rising Tide* report). The report concludes that: "Were significant seawater to enter the station and flood the subway line, the Blue Line from East Boston through Revere would be cut off from the rest of the MBTA subway system."[37]

Another major vulnerability is air transportation. With Logan Airport serving as the aviation hub of the entire New England region, its coastal location is threatened in terms of sea level rise, storm surge, and flooding. Massport, which owns and operates Logan and other facilities, has identified a number of vulnerabilities at the airport including: potential damage to terminals and navigation aids, pressure on cargo storage if cargo cannot leave the site. In addition, "high temperatures and dense air conditions could increase runway length requirements to accommodate typically diminished aircraft performance in such weather situations."[38] This concern may also apply to secondary airports in the region, including Hanscom Field in Bedford.

Key roadways vulnerable to sea-level rise and flooding include the Central Artery as well as the Callahan, Sumner and Ted Williams tunnels under Boston Harbor. The vast majority of freight moves through the region by truck and there is not adequate alternative capacity (i.e. rail) if key roadways were to be severely damaged. Low-lying secondary coastal roads throughout the region, many of which already experience periodic storm-related flooding, will also become increasingly vulnerable to more frequent and more severe flooding. Extreme fluctuations in temperature, then the freeze-thaw process could instead lead to an increase in pavement buckling and potholes and therefore an increase in repair costs. Further, road damage as a result of extreme summer heat may be exacerbated as infrastructure deteriorates more quickly with more heat extremes, and thermal expansion of metal structures adds additional stress to road and bridge infrastructure. To inform local adaptation strategies, each coastal municipality in the region will need to assess the specific roadways most at risk based on a combination of historical experience and recent regional projections of increased sea-level rise, storm intensity and storm surge.

II.E.2.d) VULNERABLE WATER SUPPLIES

Threats to drinking water supplies include increased droughts and minimal recharge to groundwater causing diminishing water availability, and extreme precipitation causing river basins to flood exposing water supplies to toxins. In addition, coastal communities that rely on freshwater aquifers may be threatened by saltwater intrusion. On the wastewater side, the most significant threats include sea-level rise and increased storm intensity, which can cause inundation and flooding to wastewater and stormwater infrastructure. The increase in storm intensity and the amount of precipitation from individual events increases the potential for sanitary sewer system overflows.

The MWRA has been assessing the potential impacts of climate change on its systems since the late 1980s. The Authority utilizes its Master Plan update process as an opportunity for senior management and the Board of Directors to grapple with climate change considerations. Climate

[37] *Preparing for the Rising Tide*, Dr. Ellen Douglas, Dr. Paul Kirshen, Vivien Li, Chris Watson, and Julie Wormser, The Boston Harbor Association, February 2013, p. 35.
[38] Massachusetts Climate Change Adaptation Report, MA Executive Office of Energy and Environmental Affairs, September 2011, p. 58.

change considerations are also part of the Authority's vulnerability analysis for extreme events (such as hurricane preparedness exercises), which identifies possible infrastructure improvements to enhance resiliency. MWRA's preliminary vulnerability assessment found that the adequacy of its water supply system is not threatened, and only a small number of water distribution shafts were vulnerable. However, the Authority's headquarters in Charlestown were at risk of flooding due to projected sea-level rise and increased storm intensity. Moreover, a number of wastewater facilities, including several coastal pump stations were found to be vulnerable to coastal inundation and flooding. MWRA has utilized a range of scenarios regarding the combination of potential storm surge and sea-level rise to refine its vulnerability assessment of specific at-risk facilities.

II.F. Health and Human Welfare

Changes in global climate patterns over the past century have increasingly compromised human health and exacerbated health problems.[39] As described above, among the most important changes that will impact human health and welfare directly and indirectly are more frequent and severe heat waves, extreme weather events, and sea-level rise. Potential consequences of these changes include more frequent and severe flooding, increased vector-borne diseases, and damage to infrastructure.

II.F.1. Baseline Conditions

The Climate and Health Program of the U.S. Centers for Disease Control and Prevention (CDC) identifies a number of potential health effects of climate change, including:

- Heat-Related Morbidity and Mortality
- Asthma, Respiratory Allergies, and Airway Diseases
- Vector-borne Diseases
- Cardiovascular Disease and Stroke
- Weather-Related Morbidity and Mortality
- Foodborne Diseases and Nutrition
- Waterborne Diseases
- Mental Health and Stress-Related Disorders

Several of the most prevalent potential health impacts are described further in the Vulnerabilities section, below. It is beyond the scope of the current project to provide detailed health status profiles for each of these potential health impacts and each municipality in the region. Rather, the discussion below presents an overview of the health status of the region as whole, as well as for two distinct subregions with very different socioeconomic and demographic characteristics, and therefore different health profiles.

[39] Pachauri, Rajendra K., et al. "Climate Change 2014: Synthesis Report. Summary for Policymakers." (2014):15. Accessed June 2015 from http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf.

This baseline health status overview presents a few key health indicators that are among those most likely to be impacted by climate change, including asthma/respiratory disease morbidity and mortality and cardiovascular disease morbidity and mortality.

It is well established in the climate and public health field that socioeconomic factors play a key role in determining health risks associated with climate change. For example, children and people 65 years of age and older are more susceptible to the impacts of higher temperatures and heat stress, as are low-income populations and those who live alone or are socially isolated.

The baseline conditions reflect information from the Massachusetts Department of Public Health (DPH), which maintains a wide array of data on health status, health outcomes, program utilization, and demographics for the Commonwealth's population. Under the Executive Office of Health and Human Services (EOHHS), in which DPH is located, all 351 cities and towns in the Commonwealth are assigned to one of six regions (West, Central, Northeast, MetroWest, Southeast, and Boston) and 27 subregions called Community Health Network Areas (CHNAs).

DPH provides the health related data through a powerful on-line tool called the Massachusetts Community Health Information Profile (MassCHIP) system, in which data sets can be analyzed based on geography (including at the municipal, CHNA, and state level or a customized user-defined region), year, age, race and ethnicity, gender, or income.

As summarized in Appendix X, the 101 communities in the Metro Boston region are found in five regions (all but West) and 14 different CHNAs. Baseline conditions are presented in Table X below for the entire MAPC region and, for illustrative purposes, two subregions:

1. Northwest Suburban Health Alliance (CHNA 15), which serves a relatively affluent suburban population in 12 MAPC communities (Acton, Bedford, Boxborough, Burlington, Carlisle, Concord, Lexington, Lincoln, Littleton, Wilmington, Winchester and Woburn); and

2. Boston Alliance for Community Health (CHNA 19), serving a more ethnically diverse and lower-income urban population in four communities (Boston, Chelsea, Revere, Winthrop).

The existing public health and health care infrastructure are critical to effectively managing the potential health impacts of climate change.

The Massachusetts Hospital Association (MHA) directory lists 68 hospitals in the MAPC Region (see Appendix X), 38 of which are considered acute care facilities, 9 long-term care hospitals, 7 inpatient psychiatric facilities, and 4 inpatient rehabilitation facilities.[40] Not surprisingly, there is a large concentration within the City of Boston, with 22 of the 68 hospitals and 14 of the 38 acute care facilities.

II.F.2. Public Health Vulnerabilities

II.F.2.a) Heat-Related Morbidity and Mortality

Climate change is expected to cause both increased averaged temperatures in the region as well as more frequent and severe heat events. Highly urbanized centers with less tree canopy, such as many

[40] Massachusetts Hospitals: Directory, Massachusetts Hospital Association, http://www.mhalink.org/AM/Template.cfm?Section=Hospital_Directory&Template=/CustomSource/HospitalDirectory/HospitalDirectory.cfm, accessed June 2013. Note that the MHA provides two different lists of acute care hospitals, one of which lists 81 facilities (38 in the MAPC region) and the other 74 facilities (33 in MAPC region).

neighborhoods in the MAPC's urban core, will likely suffer from the highest temperature increases due to what is called the "heat island effect." The CDC describes heat exposure as having a range of health effects, from mild heat rashes to deadly heat stroke. The degree of human risk to heat-related illness is related to a number of factors including age and existing health conditions, as well as socioeconomic status, which may determine access to air conditioning. Heat exposure can exacerbate chronic health conditions such as cardiovascular and respiratory disease, with potentially severe consequences. Higher temperatures also may increase ground-level ozone concentrations, which can cause direct lung injury and increase the severity of asthma and chronic obstructive pulmonary disease. Heat waves and can also increase the demand for electricity and the combustion of fossil fuels, thereby releasing additional particulate pollution and indirectly increasing respiratory disease.

Longer term, increased temperatures make droughts more frequent and severe and cause other ecosystem changes. Though not common in the Metro Boston region, droughts can result in reduced water quality and shortages of clean water. Among possible ecosystem changes in which increased temperature plays a role are the migration of disease vectors such as Lyme disease.

At the same time, with more mild winters expected,[41] there will likely be a decrease in illness and mortality from exposure to extreme cold. Finally, climate change is expected to increase weather variability in the region, the impacts of which on health are not yet clear.

More frequent and intense extreme weather events will also result in a number of direct and indirect health effects, including increased injuries from flooding, interruption to the normal provision of health care services, and possible population displacement from damage to homes, businesses, or major infrastructure.

Sea-level rise exacerbates the health risks of extreme weather events in coastal areas. It may also result in saltwater intrusion into freshwater drinking supplies or increase salt content in coastal soils, thereby impacting potential agricultural productivity.

II.F.2.b) Asthma, Allergies and Respiratory Diseases

Climate change is expected to negatively impact air quality in several ways, thereby causing or exacerbating asthma, allergies and other respiratory conditions. For example, increased temperature and higher concentrations of CO_2 cause earlier blooming of flowers (shrubs and trees), which in turn affects the timing and distribution of pollen and other allergens. Other airborne allergens that are affected by precipitation patterns such as mold spores are also a concern.

In addition, ozone formation increases with higher temperatures and increased sunlight and can be affected by changes in humidity and other factors. Fine particulate pollution (PM2.5) may also be impacted by temperature and humidity and is associated with exacerbating cardiovascular disease symptoms such as heart attacks and deep vein blood clots. According to the CDC, exposure to increased ground-level ozone, PM2.5, and allergens triggered by climate change is linked to decreased respiratory health including aggravation of asthma and chronic obstructive pulmonary disease (resulting in more hospitalizations for these diseases), as well as premature mortality. Those with preexisting respiratory conditions are at the greatest risk and those with increased vulnerability to disease include children, pregnant women, elderly, and low-income people.

[41] Frumhoff, P. C., J. J. McCarthy, J. M. Melillo, S. C. Moser, and D. J. Wuebbles, 2006. "Climate Change in the U.S. Northeast: A report of the Northeast Climate Impacts Assessment". Cambridge, MA: Union of Concerned Scientists, accessed June 2015 from http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/confronting-climate-change-in-the-u-s-northeast.pdf.

II.F.2.c) VECTOR-BORNE DISEASES

The ecology of vector-borne diseases is quite complex, but weather and climate are known to be among the factors that affect disease transmission and human disease incidence. Certain vector-borne diseases may become less prevalent in certain regions as local habitats become less hospitable to host or vector populations and disease transmission, while climate-induced ecosystem changes may make it easier for other vector-borne diseases to thrive and spread. An example cited by the CDC and others is Lyme disease, whose range is expected to expand northward as the habitat of the deer tick, which transmits Lyme disease, expands in this direction. Other vector-borne diseases that may increase in Metro Boston as ticks and mosquitoes adapt to changing climactic conditions include Eastern Equine Encephalitis and West Nile Virus (WNV).

According to the MA DPH, 33 cases of human infection with WNV in 2012, the most ever recorded, including cases in Middlesex (13), Norfolk (3), and Suffolk (6) Counties, all within the MAPC region.[42]

According to the CDC, the significant impacts experienced by coastal and marine ecosystems (e.g., increased temperatures and storm intensity, sea level rise, changes in salinity) will likely lead to changes in biodiversity, as well as to the altered patterns of growth, survival, persistence, distribution and transmission of disease-causing organisms, vectors, and reservoirs. However, the CDC also cautions that because of the complexity of disease, combined with the uncertainty around local impacts of climate change, it is difficult to project the changes in disease incidence and transmission.

II.F.3. VULNERABLE POPULATIONS

Some populations are more vulnerable to climate change impacts and the associated health impacts. The *Massachusetts Climate Change Adaptation Report* defines vulnerable populations as "those who are more susceptible to the effects of climate change, and for whom adaptive change will be more difficult, whether by virtue of economic status, social capacity and resources, health, age, or geography." In particular, elderly, children, disabled, individuals with chronic health issues, and linguistically isolated individuals without strong support systems may face significant challenges in responding to climate change threats. In many cases, vulnerability is amplified by being situated in geographic locations and/or development conditions that are more susceptible to higher impact risks. To equitably address the challenges, it will be important to assess, anticipate, and respond to the needs of the region's most vulnerable residents.

In developing the Regional Climate Change Adaptation Strategy, MAPC reached out to organizations that serve vulnerable populations to understand better the specific needs of the groups they represent, as well as to become acquainted with the types of state, regional and local partners with which municipalities can work. Comprehensive lists of state, regional and local resources on vulnerable populations in the MAPC region can be found in the Appendix.

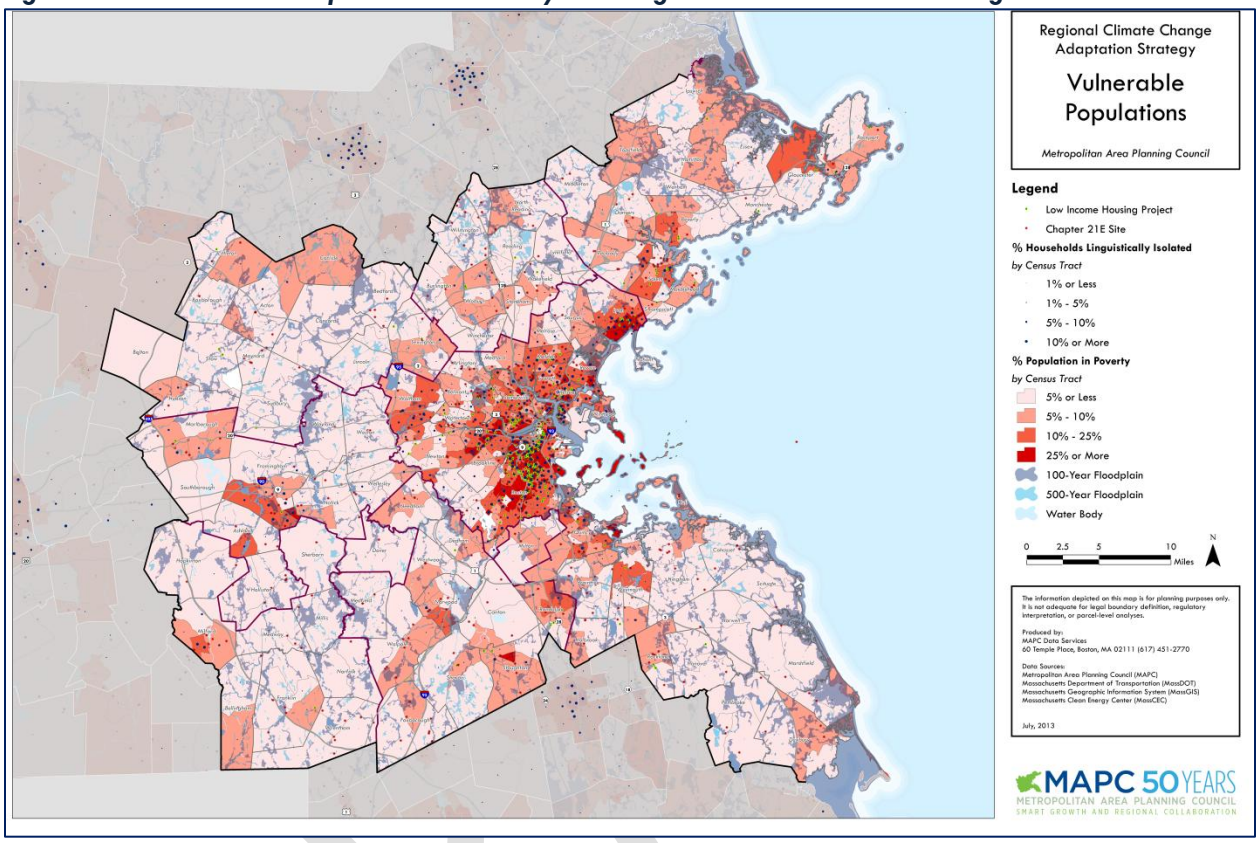
II.F.3.a) EXISTING CONDITIONS

As described below, the distribution of vulnerable populations varies considerably across the region by municipality and MAPC subregion. Four key socioeconomic factors contributing to vulnerability – age, income, linguistic isolation, and disability – are discussed in the sections below. Figure II.15

[42] Arbovirus Surveillance Summary, 2012, Massachusetts Department of Public Health, http://www.mass.gov/eohhs/docs/dph/cdc/arbovirus/2012-summary.pdf, accessed June 2013.

shows the distribution of low income and linguistically isolated populations, two of the key groups considered highly vulnerable, within the MAPC region.

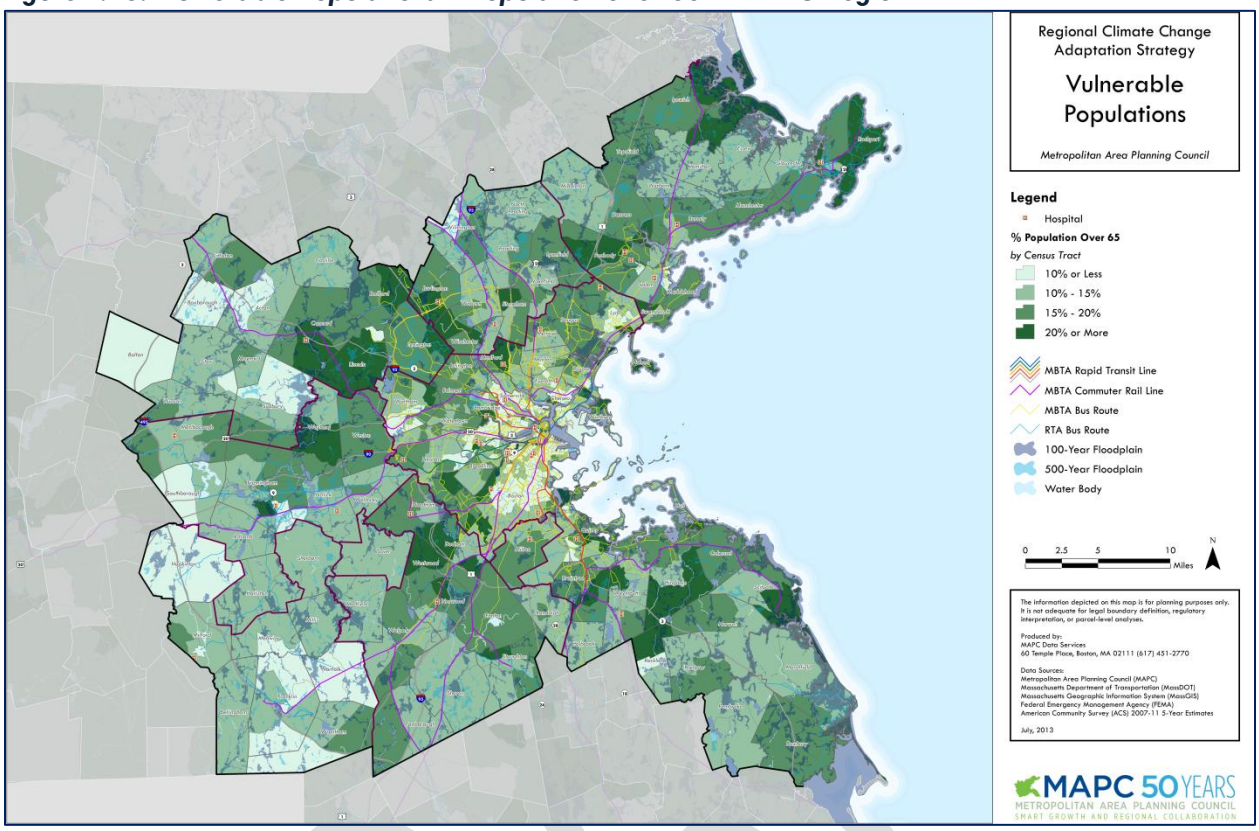
Figure II.15: Vulnerable Populations - Poverty and Linguistic Isolation – MAPC Region



Elderly

As of 2010 approximately 423,000 or 13.4% of Metro Boston's total population of 3.16 million residents were over 65 years of age (Figure II.16). In four communities (Rockport, Nahant, Peabody and Concord) elderly comprised more than 20% of the total population, while in eight communities (including Cambridge, Somerville, and Chelsea) less than 10% of the residents were elders. The City of Boston had 10.1% of its population over 65 years, reflecting its relative youth. (See the Appendix for a community-by-community listing of the elderly population.) In terms of MAPC subregions, the North Shore Task Force subregion has the highest percentage of elderly at 16.9%, while the SouthWest Advisory Planning Committee has the lowest at 10.8%, followed by the Inner Core at 11.9%.

Figure II.16: Vulnerable Populations – Population over 65 – MAPC Region



According to MAPC demographic projections, the proportion of seniors will increase from 10% to 22% between 2000 and 2030, while the total population will increase by only 9%. Over this time period, in 37 of the 101 communities in Greater Boston the over-65 group will constitute more than one-quarter of the population.

Senior citizens are generally more at risk from climate phenomena such as heat waves and flooding. Other potential issues experienced by some elderly that contribute to higher risk are reduced mobility, social isolation, poverty and less access to technology. For example, facing the likelihood of more frequent, more intense and longer heat waves, while a challenge for everyone, is a particular challenge for the elderly as they are often physically more at risk for heat-related illness or death. For some, it is hard to adjust to heat with measures such as air conditioning their homes. Due to a historically milder climate, New England homes have traditionally not been constructed with central air conditioning or built in air conditioning units. Depending on their age and condition, it can be hard for many elderly to buy and install heavy window-based air conditioners. In addition, those that do not have air conditioning in their homes may have a difficult time getting to a public air-conditioned building.

Residents Living in Poverty

Incomes are distributed less equitably in Metro Boston than in 85% of the metro areas in the US. There is a racial element to poverty in the region with nearly 25% of Latinos, nearly 20% of Blacks/African Americans, and over 15% of Asians in our region live in poverty compared to 6% of Whites.

On the other end of the spectrum, some 22 communities within the region have less than 3% of their population living in poverty. The sub-regional differences in poverty rates are dramatic. About 15.3% of residents in the Inner Core are estimated to live in poverty, representing over 235,000 or 75% of the total 311,000 residents living in poverty in Metro Boston. At the other end of the income spectrum, the MAGIC and North Suburban subregions have an estimated 3.8% of residents in poverty (a combined 14,000 people).

Poor and minority populations will on the whole have less capacity and fewer resources to prepare for, respond to, and recover from climate-related hazards and effects. As global climate change pressures affect and increase energy, food, and water prices, low-income individuals will be impacted more as they spend a greater portion of their incomes on these necessary household goods than higher-income individuals. With fewer resources, low-income individuals are also likely to have weaker safety structures in place, such as health or property insurance, and in the case of a climate event, will likely face greater challenges in recovering from related damages or health issues. High percentages of minority populations are disproportionately poor, and as such these populations will more significantly impacted than non-minority, white populations. Low-income neighborhoods are also often in geographically more vulnerable areas – located by industrially-zoned areas, or in low-lying areas, and often with limited green space or tree canopy – and these neighborhoods are often both at greater risk of flooding and pollution.[43]

Organizations working for social justice have a large understanding of climate change vulnerabilities within the communities they serve and so are ideal partners on adaptation planning. Historically, they have had unequal voice in planning and decision-making that affects their communities, and as such it is essential to build trust and partner with advocate organizations. Their expertise needs to be acknowledged at the outset to have an equitable and effective partnership.

Linguistic Isolation

As mentioned above, social isolation is a risk factor that increases a household's vulnerability to climate change impacts. Language is one potential factor that can create social isolation. The MAPC region has experienced a growth in its foreign-born population, which has increased since 2000 by three percentage points. The 2011 American Community Survey shows that about 17% of the population of the Metro Boston region is foreign-born.

Looking at the countries of origin for the region's foreign-born population gives us an indication of the incredible demographic change that the region is undergoing. Over a third of the region's immigrants were born in Latin America, nearly one third were born in Asia, followed by one fifth in Europe. Nearly 10% were born in Africa, and smaller percentages were born elsewhere in North America and in Oceania (i.e., Australia, New Zealand, and Pacific Islands).

This increase in foreign-born populations was not distributed evenly throughout the region. It was higher than average in 15% of the MAPC municipalities, mainly Boston's Inner Core and the Regional Urban Centers. These municipalities include Everett and Malden, each of which experienced at least an 8 percentage point increase.

As a result of this and other historical trends, one quarter of all households in the MAPC region speak a language other than English in the home. Of these households, 25% (or about 6.5% of total households) are considered "linguistically isolated," meaning no one in the household 14 years and

[43] Lynn, K. et al. "Social Vulnerability and Climate Change: Synthesis of Literature." USDA Forest Service, (2011), Accessed June 2015 from http://www.fs.fed.us/pnw/pubs/pnw_gtr838.pdf.

older speaks English very well.[44] Table II.5 shows that in seven communities in Metro Boston, more than 10% of households are linguistically isolated.

Table II.5: Households Linguistically Isolated by Community

Municipality	Subregion	Households	Households Linguistically Isolated	% Households Linguistically Isolated
Chelsea	ICC	12,035	3,362	27.9
Everett	ICC	15,681	2,905	18.5
Malden	ICC	23,422	3,612	15.4
Revere	ICC	19,425	2,835	14.6
Lynn	ICC	34,018	4,527	13.3
Boston	ICC	247,621	28,821	11.6
Framingham	METROWEST	26,167	3,026	11.6

The Inner Core subregion has a high concentration of linguistically isolated households, with six of these seven communities (all but Framingham, which has a large Portuguese-speaking population from Brazil). In Chelsea, Everett and Malden more than 40% of households speak a foreign language at home, and there are a growing number of non-English speaking households in certain suburban communities such as Lexington, Acton, and Randolph.[45] Almost one third of households speaking Spanish or an Asian language are linguistically isolated, while about one fifth of households speaking Indo-European languages are similarly challenged.

While 6.5% of households in the Metro Boston region are linguistically isolated, there is considerable sub-regional variation. At the high end, 9.7% of Inner Core households are linguistically isolated, followed by the MetroWest subregion with 5.7%, largely due to Framingham. All other subregions have less than 3% of households that are linguistically isolated, with the South Shore subregion having the lowest fraction at 1.1%.

Persons with Disability

The Americans with Disabilities Act (ADA) defines an "individual with a disability" as “a person who has a physical or mental impairment that substantially limits one or more major life activities, has a record of such an impairment, or is regarded as having such an impairment.” It goes on to specify that impairments include those that “limit major life activities such as seeing, hearing, speaking, walking, breathing, performing manual tasks, learning, caring for oneself, and working.” This is a very broad and diverse group and one where detailed geographic data is generally not available. Because of the diversity of this population, the outreach performed for this report was not comprehensive in connecting with organizations serving every type of disability.

The plan’s recommendations thus leverage outreach done at the state level by the Massachusetts Office on Disability (MOD). After Katrina, the MOD formed a Task Force on Emergency Preparedness and People Requiring Additional Assistance which hosted meetings to bring together people with disabilities and local emergency preparedness professionals to explore how to ensure that people

[44] “Foreign Language Households and Linguistic Isolation,” 2012 Calendar and Annual Report, MAPC. Data is based on the American Community Survey 2005-2009, MA Department of Elementary and Secondary Education.

[45] The MAPC map “Foreign Language Households and Linguistic Isolation,” in the 2012 Calendar and Annual Report shows that in certain census tracts (e.g., in Boston, Chelsea, Everett, Revere, Lynn and Framingham) more than 50% of households where a language other than English is spoken are linguistically isolated.

with disabilities have the assistance they need in times of emergency. Since 2007, "MOD has conducted over 125 personal preparedness meetings throughout the state and interacted with almost 5,600 people."

Additionally, some of the information gained from the interviews performed for the regional adaptation plan, follows. Overall, disabled individuals have very specific concerns about the effects of climate change. While many center on their vulnerability in emergency situations, there are others to be faced. An example is the ability of those with mobility impairments to get to air conditioned spaces in the event their own homes do not have air conditioning and heat waves grow longer and more frequent.

Still, a large number of concerns about the effects of climate change in the lives of disabled persons that have been heretofore identified occur in emergency situations. One of the foremost concerns that surfaced was the role of Personal Care Attendants (PCAs) in an emergency situation. Many people with disabilities work with PCAs and would need their assistance in an emergency. Training for PCAs in what to do during emergencies is one measure that could help improve the lot of disabled people in the era of climate change. Another measure would be coordinating PCA coverage for disabled people in an emergency. Personal Care Attendants might not be available due to their own family obligations and a system that addresses coverage issues could be of great value to disaster planning.

Another issue that came light was the need for redundant power for certain disabled people, such as those that are on ventilators and so are at risk during power outages. The accessibility of emergency shelters is also a concern. Shelters vary a great deal and not all of them are accessible to the various types of disabled people that may need to take refuge in them. Another concern is that emergency alert information needs to be accessible to all people. Ensuring the supply of prescription medications during a prolonged emergency is also an issue.

As many disabled people would need special assistance in the event of an evacuation, some feel the necessity of some sort of resource to help emergency personnel and others find those most in need quickly. To that end, the Boston Commission on People with Disabilities is working on creating a Functional Needs Registry of people with disabilities to help coordinate assistance during emergencies.

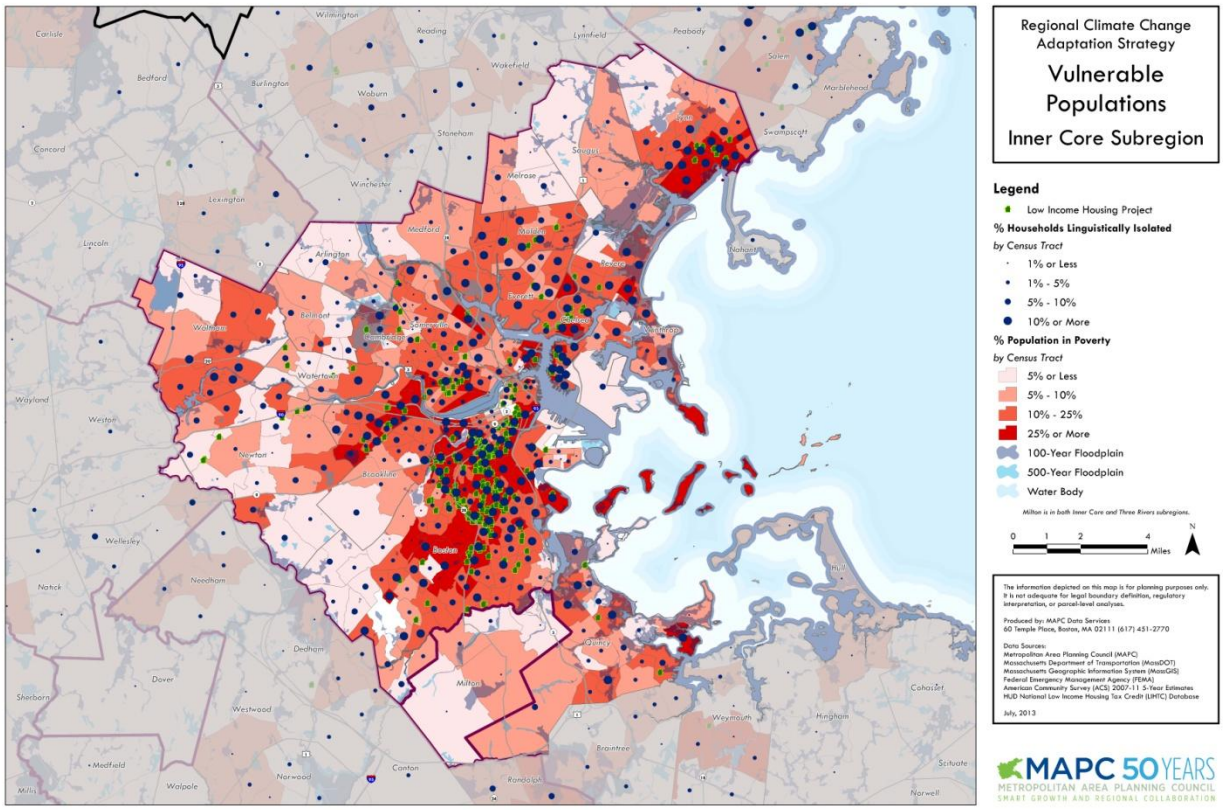
II.F.3.b) Vulnerabilities of Disadvantaged Populations

Income is an important determinant of a household's ability to prepare for, manage, and respond to climate change risks. Disadvantaged populations have fewer resources to adapt to new realities, for example, buying and running air conditioners as summers grow hotter and hotter. They are also less able to keep up with increased energy costs, as well as increased costs of many products that depend on energy, including food.

Many low income housing residents are located within in urban areas that have unique challenges to facing climate change such as the urban heat island effect with far greater impervious surfaces and adjacent and busy roadways resulting in higher levels of air pollution. Lung-related diseases such as asthma disproportionally affect children of lower income populations, which are hospitalized for such diseases at over five times the rate of Caucasian children. Inner Core communities and regional Urban Centers, for example, have less open space in their neighborhoods (per capita) than do suburban communities. The disparity of urban tree canopy cover across the City of Boston's neighborhoods is another example of social inequality. The lower income neighborhoods of East Boston, for instance, have the lowest percentage of urban tree canopy of all the City's

neighborhoods. As shown in Figure II.16, these types of vulnerable waterfront or low-lying neighborhoods have a high concentration of minority and linguistically isolated people along with an obvious lack of green spaces and green infrastructure than other neighborhoods.

Figure II.16: Vulnerable Populations - Poverty and Linguistic Isolation –Inner Core Subregion



Lower income populations are vulnerable to climate change not just in their homes, but also in their workplaces. In extreme weather conditions such as heat waves, cold snaps or floods, many lower income employees may be forced to work in dangerous conditions due to the insistence of their employer, or by their own financial need. Examples include jobs done outside like landscaping, or in non-climate controlled interiors such as a hot kitchen. Weather extremes can also significantly reduce income if work days are curtailed due to dangerous working conditions or the inability to get to work due to transportation shut-downs.

II.G. Vulnerabilities to Local Economies

The impacts of climate change will affect not only development, natural resources, and public health, but also the economy and government functions throughout the Metro Boston area and beyond. A number of economic sectors will be impacted; those based on natural resources such as fishing and agriculture; services such as recreation, tourism, and health care; as well as various manufacturing industries. A number of government services will also be affected, including agriculture, tourism, health and education services, and transportation. In turn, these impacts on local government will strain municipal budgets and require close collaboration with, and support from, the state and federal government.

II.G.1. Baseline Conditions – Local Economy

According to the Massachusetts Executive Office of Housing and Economic Development, the health care, professional and technical services, and education sectors are the three largest employers in the Boston Metro region (which comprises most but not all MAPC communities), with retail and leisure and hospitality (tourism) not far behind.

This is confirmed by a somewhat more detailed overview of the regional economy is provided by MAPC's most recent update of its Comprehensive Economic Development Strategy.[46] The Strategy identifies a number of recognized clusters and sectors in this region based on the Massachusetts Technology Collaborative's 2011 Index of the Massachusetts Innovation Economy and MAPC's independent experience:

1. Massachusetts Innovation Economy Index Clusters
    - Bio-Pharma and Medical Devices
    - Business Services
    - Computer and Communications Systems Hardware
    - Defense Manufacturing and Instrumentation
    - Diversified Industrial Manufacturing
    - Financial Services
    - Healthcare Delivery
    - Postsecondary Education
    - Scientific, Technical, and Management Services
    - Software and Communication Services
2. MAPC Regional Recognized Clusters
    - Marine Science and Technology
    - Design
    - CleanTech

According to the 2011 Innovation Economy Index, the clusters in that group account for over 38% of employment in the state, including most of the high wage jobs. With the inclusion of indirect jobs, these industry clusters support more than half of statewide employment. Given the concentration of many of these clusters in this region, it is safe to assume that they provide an even higher fraction of jobs in Metro Boston.

[46] MAPC's 2012 to 2013 Annual Update, Comprehensive Economic Development Strategy

While comprehensive sector-based employment data is not readily available for the MAPC region as a whole, the employment profile for the cities of Boston and Cambridge presents an indicative picture and provides additional detail concerning the largest sectors and individual employers.

According to the Boston Redevelopment Authority's list of largest (private) employers in the City of Boston,[47] the three largest sectors in 2011 were Health Care and Social Assistance, Finance and Insurance, and Educational Services (Higher Education). The Health Care and Social Assistance industry employed over 125,000 people in Boston, accounting for 21% of the city's total private employment. Fifteen hospitals and seven other health care and social assistance organizations employed over 500 workers. The largest employers in this sector were Massachusetts General Hospital (14,752) and Brigham and Women's Hospital (11,229).

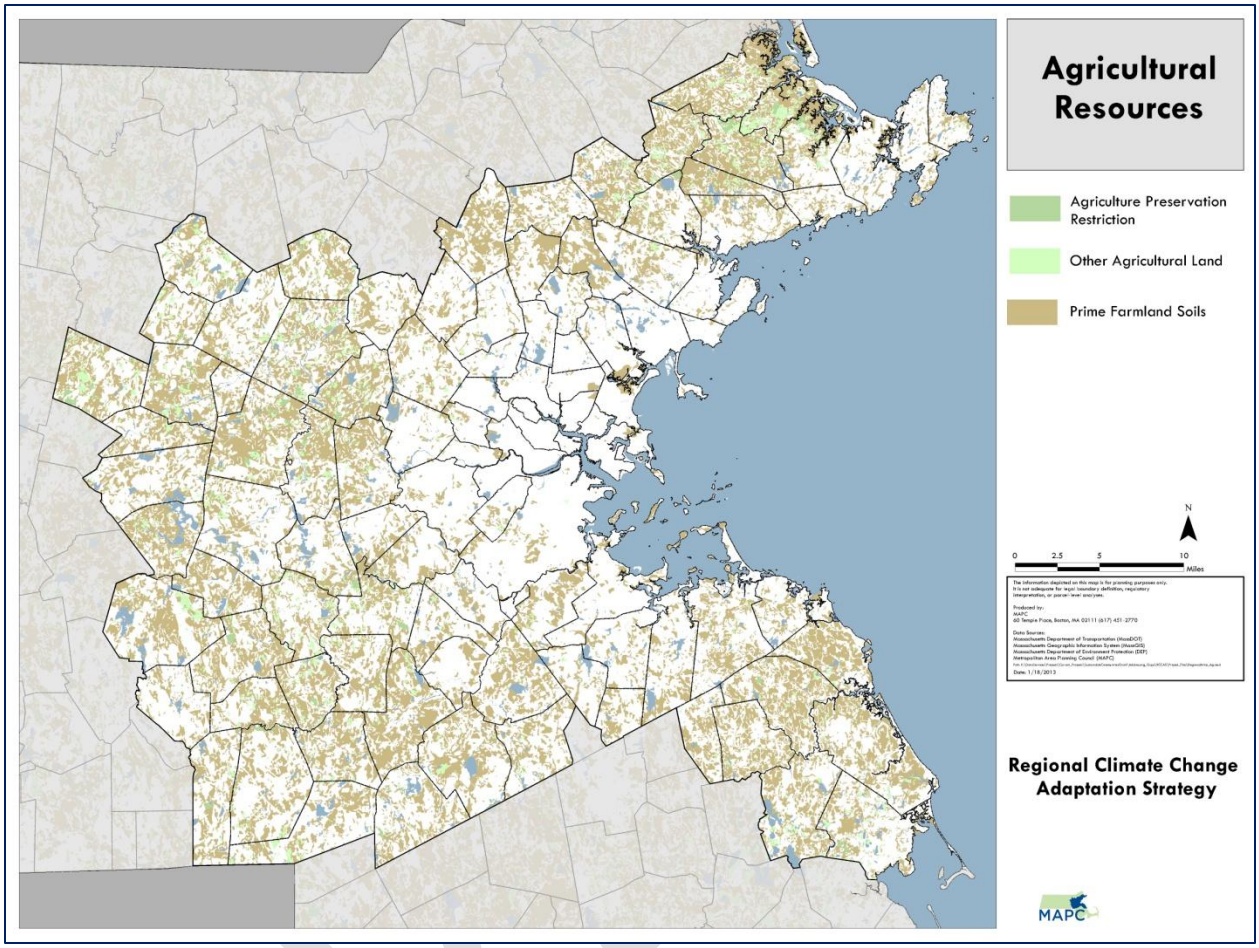
The Finance and Insurance sector employed over 79,500 people in Boston in 2011, or 13% of the city's private employment. Twenty-nine companies (6 commercial banks, 7 insurance agencies, and investment companies) employed over 500 workers. The largest employers in Finance and Insurance were State Street Bank and Trust Co. (7,800) and Fidelity (5,500).

The Higher Education sector employed almost 54,000 workers in Boston in 2011, accounting for 9% of the city's private employment. Ten universities employed at least 500 workers, with the largest being Boston University (9,783) and Harvard University Graduate Schools (5,132).[48]

The Cambridge employment profile is somewhat different, with Higher Education the largest private sector employer in 2013, followed by biotechnology and health care. By far the largest employers are Harvard University (11,298) and the Massachusetts Institute of Technology (8,960). In Biotechnology, Novartis (2,472) and Sanofi/Genzyme (2,000) are the largest employers.

Agricultural and Fishing sectors, including crop, livestock and fishing operations make up a modest part of the Massachusetts economy, but these sectors are especially vulnerable to climate change impacts and important to consider regarding adaptation and mitigation strategies. MAPC regional economic data is not currently available, however in 2014, statewide the Agricultural sector generated $525 million in crop and livestock sales and employed 3500 people[49]. The Shell- and Finfishing sector had $950 million in fish and shellfish sales, and 100 employees[50]. In 2006, the commercial fishing industry alone supported 83,000 jobs in the State, a significant portion of which was in the MAPC region, as shown in Figure 1.17. This includes a range of products from cod to scallops, tuna to oysters. The industry is also a draw for tourists, particularly in Gloucester given its rich history and active working waterfront.

[47] The Largest Employers in the City of Boston, Boston Redevelopment Authority, November 2013.
[48] Note that the Harvard figure includes only the Business, Medical, Dental, and Public Health Schools as these are located in Boston. All other Harvard University employees are located in Cambridge.
[49] ReferenceUSA (2014). Agricultural sector query: NAICS 111150; 111199; 111334; 111336; 111339; 111920; 111998; 112111; 112210; 112420. Retrieved April 28, 2014 from http://www.referenceusa.com.
[50] ReferenceUSA (2014), Finfish and Shellfish sector query; NAICS 114111 and 114112. Retrieved April 28, 2014 from http://www.referenceusa.com.



II.G.2. VULNERABILITIES TO THE LOCAL ECONOMY

The nature of the impacts on a particular sector is dependent on its characteristics, and the vulnerabilities of a specific business or institutions depend on its geographic location. For example, sea level rise and flooding can affect business and tourism and recreation dependent on waterfront infrastructure, real estate, as well transportation systems on which virtually sectors rely. Rising temperatures may alter the growing season and productivity of certain agricultural crops, and may lengthen the tourism season. The expected impacts changes from sea-level rise, more intense and frequent storm events, extreme heat, and altered precipitation patterns were discussed earlier in this report in Section 2, Climate Change Impacts. As noted, the change in relative sea levels in Massachusetts is expected to be among the most rapid in the U.S., with 3 feet of potential sea-level rise by 2050, which will amplify the impacts of coastal storm events and storm surges.

More frequent and intense extreme weather events can disrupt virtually all sectors and will likely have a profound impact on insurance sector in terms of risks and losses as well as the availability and cost of property insurance. Extreme events will also increase the demands on emergency services and the health care sector.

The economic consequences of climate change are both short- and long-term. A recent report on the risks of coastal flooding faced by metropolitan areas worldwide ranked Boston eighth, with expected

annual economic losses of $237 million. As tropical storm Irene and super storm Sandy have recently demonstrated, a single extreme weather event can cost a region tens of billions of dollars in damaged property and infrastructure (both insured and uninsured), service disruptions, and lost productivity.

The future prospect of rising sea levels and storm surges, intensifying hurricanes, and increasing property values combine to dramatically increase the future economic risks of climate change. A recent study of the economic risks in Massachusetts estimated the expected annual losses from hurricanes and tropical storms through the year 2060. As Table 1.6 shows, losses are expected to rise dramatically, more than doubling in each decade, due to the combined effects of global warming on hurricane intensities and sea level, along with the increase in property value at risk.

Table 1.6: Expected Annual Losses from Hurricanes and Tropical Storms ($billions)

Year	2010	2020	2030	2040	2050	2060
Expected Annual Loss	1.75	5.3	14.8	39.1	99.6	247.0

Source: The Rising Risks of Climate Change in Massachusetts, Robert Repetto, May 2012

As the likelihood of all climate-related disasters, not just hurricanes, grows over coming decades, the state and regional economy, as well as the economic well-being of residents and businesses, will become increasingly precarious. This rapid rise in losses will have important implications for residents and businesses, including the insurance sector as the availability and cost of insurance will be affected. In fact, the effects are already being felt. Property and casualty insurers are withholding policies from properties in certain coastal and near-coastal locations, and/or raising insurance premiums. Increasingly property owners are turning to the state government for insurance, which has also been modifying coverage terms and rates.

Massachusetts farms, and especially coastal operations, are highly susceptible to the temperature changes, changes in precipitation patterns and flooding. High temperatures may shift plant hardiness zones, increase reliance on limited water supplies, impact health and productivity of livestock, cause crop heat stress, and introduce invasive species, pests and plant diseases. Variable precipitation patterns could lead to crop failure or damage and soil erosion. Coastal farming operations may be vulnerable to flooding and encroachment of salt water.[51]

Fisheries off the Massachusetts coast are also threatened by climate change. As water temperatures warm, algal blooms, disease, and parasites become more common, damaging the health of fish and shellfish populations. Certain species, such as cod, may need to move north to colder waters to survive. In addition, sea-level rise will threaten coastal estuaries and marshes, undermining the habitats of numerous fish and shellfish species including clams, scallops, flounder, and others. Feeding habitats could also be altered, resulting in migrations of fish to cooler waters outside the region. Further, the growing shellfish aquaculture industry, like that in Duxbury, relies on shallow tidal areas, which could be reduced or destroyed as sea levels rise. Given their contribution to local economies, steps should be taken to best mitigate potential impacts.

[51] Climate Change Adaptation in New England Agriculture, Manomet Center for Conservation Sciences http://www.manomet.org/sites/default/files/publications_and_tools/Agriculture_fact_sheet%205-13.pdf

III. CLIMATE CHANGE GOALS AND OBJECTIVES

Having identified current and future risks to Metro-Boston municipalities, MAPC then worked closely with the Regional Climate Advisory Committee to establish a series of objectives, which will provide a framework for accomplishing the primary climate change goal that was previously established during the development of the MetroFuture Regional Plan:

> *Goal 11: The region to be prepared for, and resilient to, natural disasters and climate change.*

It should be noted that in addition to this goal, which is mostly directed towards resiliency and adaptation, the Regional Plan also includes numerous goals for climate change mitigation. A number of goals that are most directly linked to climate change mitigation include, but are not limited to:

- Goal 1: Population and job growth will be concentrated in municipalities already well served by infrastructure, with slower growth in less developed areas where infrastructure is more limited.
- Goal 34: The region will be a national leader in the green technology and clean energy sectors.
- Goal 56: The region will be a national leader in reducing greenhouse gas emissions.
- Goal 57: The region will use progressively less energy for electricity, heating, cooling, and transportation.
- Goal 58: The region will produce less solid waste, and more of that waste will be recycled or composted.

The objectives created with the help of the Advisory Committee are listed in the table below.

Table III.1: Climate Change Adaptation Objectives

Sector	Subtopic	Objectives
Developed Areas	*Development, Green Infrastructure, Tree Canopy*	1) All new development and redevelopment in the region will be designed to adapt to climate impacts (heat, precipitation, etc.)
	Development	2) Redevelopment within the region will be located outside of the highest hazard areas most vulnerable to climate change (flood hazard zones, velocity/storm surge zones, etc.)
Natural Resources & Habitat	*Protection*	3) Natural functions of ecosystems, shorelines and critical habitat areas will be restored to reduce impacts from climate change
	Management	4) Conserve and manage habitats to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate
	Restoration	5) Restore ecosystem processes to increase capacity to adapt in a changing climate.
Coastal Zone	*Protection, Storm Assessment*	6) Coastal areas will become resilient to climate change impacts
Key Infrastructure	*Energy, Water/Waste Water/Storm Water, Transportation, Green Infrastructure*	7) Existing transportation, water/wastewater, and energy infrastructure will become resilient to climate change impacts
	Roads & Crossings	8) All existing tide and flood control structures within the region will be identified and assessed for their flood control capacity.
Local Government and Economy	*Asset Management, Capacity*	9) The region will undergo local and regional asset management preparation to inventory assets, damages and monitor local assistance by partners
Human Health & Welfare	*Vector Diseases, Vulnerable Populations*	10) The general public will be protected from extreme climate change health impacts, with particular focus on communication with and protection of vulnerable populations (disadvantages populations due to socioeconomic status, housing challenges, disabilities, and those with pre-existing illnesses)

The strategies and action steps included in the following section are aimed towards fulfilling the goals and objectives described above.

IV. Regional Climate Adaptation Strategy

This new Regional Climate Change Adaptation Strategy has been developed to implement the Regional Plan's climate change goal: *the region to be prepared for, and resilient to, natural disasters and climate change*, and associated objectives, as discussed in Section 2 of this report. In keeping with the format of the MetroFuture Implementation Strategies document, this Strategy follows the following hierarchy:

Strategy (Regional Climate Change Adaptation)

A. Sub-Strategy

A.1) Recommendation

A.1) a. Implementation Step

In terms of its range regarding adaptation measures, the Strategy subscribes to 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.

Implementation Steps offered reflect a No Adverse Impact (NAI) approach to adapt to existing and future risks of the natural environment and developed areas under new climate conditions. These are measures or "action items" that should be considered under any conditions, as they include the best practices for environmental protection, ensuring public health and safety, and economically feasible and sustainable growth in appropriate locations. Furthermore, they are actions that would not cause harm or impact to our communities as they would be implemented in manner that does not increase risks, for example; by not causing additional damage or increased costs to private or public property owners.

This Strategy as a whole will serve as a guide – a "road map" – for MAPC, its state and local partner agencies, nonprofit or community organizations, municipal officials, and regional residents as to how our communities can best become resilient to climate change. The sub-strategies include an explanation of the issue and recommendations that each of the aforementioned partners should consider, as they are designed to be undertaken NOT just by MAPC, but all stakeholders. In following a primary principle of the MetroFuture Plan; implementation of strategies will be fulfilled by "a network of 'regional stewards' operating in both the public and private sectors, to bring recommendations forward."

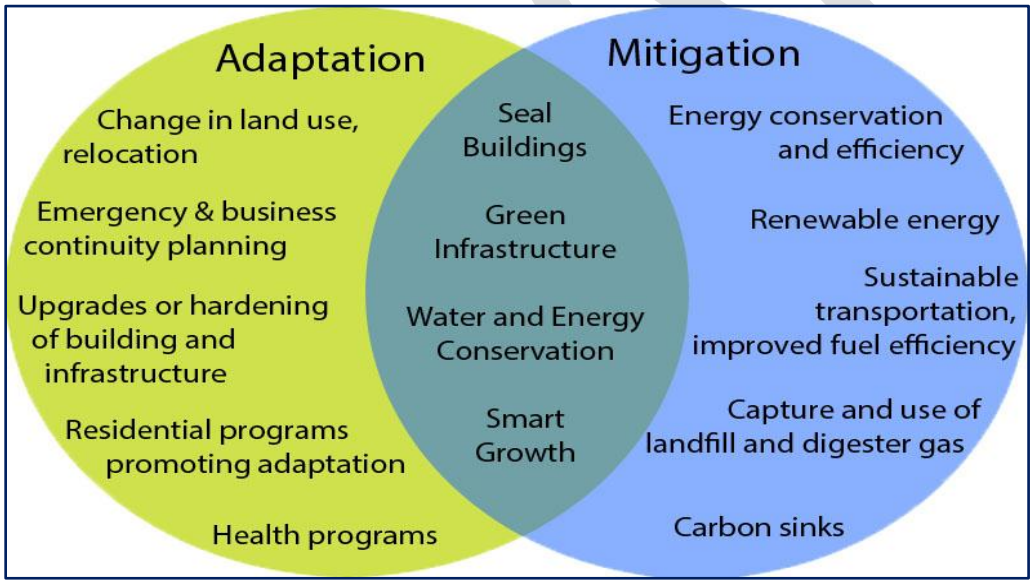
The following sections provide the Sub-strategy title, associated Recommendations, and in some cases, specific Implementation Steps where there has been consensus regarding approach. MAPC views this strategy white paper to become a "living document" in which MAPC, the Advisory Committee, and other partners continue to build upon what's been provided this far, and then decide upon specific approaches and then add to the implementation steps.

IV.A. Implement Mitigation as Adaptation

We believe that the first step to adapting to climate change is to continue to reduce GHG emissions, which, in turn, will reduce impacts and the level of adaptation required. In addition, there are some mitigation measures that overlap with adaptation in that their end result is both reduced GHG and resiliency, such as water conservation, energy conservation, and green infrastructure (Figure 3.1). Therefore, the first series of implementation steps included within this strategy are those related to mitigation of greenhouse gases (GHG).

The MAPC Clean Energy Program has worked collaboratively with MAPC's Environmental Division to provide technical assistance and guidance to regional municipalities on most of these mitigation measures offered: energy efficiency on municipal properties, energy efficient utilities for residents, and implementing alternative energy sources. However, there are new sub-strategies recommended that will further this work, aimed at implementing measures that have co-benefits (i.e. GHG emission reduction, new sources of energy creating economic growth, as well as environmental protection). In addition, MAPC's Transportation Division has been working hard on reducing the number of vehicles on the road, as well as trips per day by vehicle owners, in an effort to reduce GHG and other air pollutants. We will explore these smart growth-based measures that have an indirect adaptation component to them, as they drive changes in land uses that will help communities adapt to climate changes (e.g., less vehicles within in a densely populated floodplain area via lane reduction and/or traffic calming would provide a new opportunity for greenspace that could act as a buffer to, and attenuation of, floodwaters).

Figure IV.1. Mitigation and Adaptation: Overlapping Measures



It is important to note that in order for the Regional Climate Change Adaptation Strategy to be successful, these overlapping mitigation and adaptation sub-strategies must be implemented within each of the five adaptation sectors described throughout this report:

1. Natural Resources and Habitat
2. Coastal Zone

3. Developed Areas and Key Infrastructure

4. Human Health and Welfare

5. Local Economy and Government

IV.A.1. IMPLEMENT GREEN INFRASTRUCTURE

There have been numerous definitions of the term "Green infrastructure" used throughout the U.S. from a term defining alternative stormwater management techniques to an all-encompassing inclusion of water resource management and natural landscape protection. In Massachusetts, the definition of GI follows the inclusionary approach, as defined within the draft Senate Bill (2021: *An Act improving drinking water and wastewater infrastructure*) as:

> *"An approach to infrastructure and natural resource management that includes sustainable water infrastructure, preserving and protecting natural or "green" systems, decentralized solutions, or other innovative approaches and technologies that provide multiple benefits. Techniques include but are not limited to: decentralized wastewater systems; water reuse; low impact development techniques such as rain gardens, porous pavement, green roofs, water efficient landscaping, infiltration planters, trees and tree boxes and rainwater harvesting systems; preservation and restoration of natural landscape buffers such as forests, floodplains, and wetlands; restoration of natural stream channels; and land use policies that maintain or restore the natural hydrologic cycle and minimize imperviousness in a watershed."*

Simply put, green infrastructure is a term used to describe non-traditional infrastructure methods for water management and the use of green spaces as protective "infrastructure." While it's true that in some cases it will be important to implement both conventional ("grey") and ("green") infrastructure to protect economic assets, green infrastructure provides multi-functional benefits. The comparison between these techniques is described in Table 3.1.

Table IV.1. Green versus Gray Infrastructure

Conventional (Gray) Infrastructure	Green Infrastructure
Singe function – carry waste and water; built for cars only; electricity from fossil fuels	Multi-functional - store and treat stormwater; aesthetically pleasing; provide wildlife habitat; electricity from wind, solar; multi-modality, etc.
Manufactured materials	Manufactured and natural materials
Transports stormwater away from site	Manages stormwater on site
Concentrates stormwater and pollutants	Naturally treats and disperses stormwater and pollutants
Roads built for cars only	Roads that accommodate bicycles and pedestrians, and often, have natural elements too.
Electricity from fossil fuels	Electricity from multiple renewable energy sources
Cookie-cutter approach, no room for creativity or complementariness	Work well in tandem with and are complimentary to other types of infrastructure

Source: Janak, Germond et al. 2008

There are tremendous efficiencies of scale in implementing green infrastructure for climate change resiliency and stormwater management. Protecting green spaces and natural lands, particularly within floodplain and coastal flood hazard areas, provides multiple benefits for a community such as flood storage and retention and wave energy capture. In addition, green infrastructure brings a host of additional benefits such as cleaner air and water, wildlife habitat, and open spaces for people.

Green infrastructure is a term also used to describe innovative wastewater and stormwater management that mimics natural hydrology. This provides a great benefit in protecting developed areas from floodwaters and storm surges, as well as assisting MAPC communities in complying with impending new requirements for the National Pollutant Discharge Elimination System (NPDES) for Municipal Sanitary Storm Sewer Systems (MS4), which will require the use of low impact development and green infrastructure strategies. The following sections provide specific action measures recommended for use of varying types of Green Infrastructure.

General strategies regarding the implementation of GI for climate resiliency are described below. Specific, topic-related, strategies are described in the following sections.

Measure A.1) a: MAPC and its partners will work with municipalities to ensure that GI tools are implemented at development/redevelopment sites. Specifically, MAPC will:

- Continue to work with municipalities to ensure that existing codes do not preclude or create barriers to the implementation of GI.
- Work with DEP and partners to incorporate GI tools for stormwater management into the MA Stormwater Handbook.

Step A.1) b: MAPC and partners will develop educational templates for municipal use in educating property owners in the benefits and economic value of GI. Materials will be based upon information developed by the Natural Resources Defense Council (e.g. The Green Edge Report) and the Trust for Public Land studies that provide economic (often monetary) values of GI use.

Step A.1) c: MAPC will work with EEA to establish funding for retrofitting existing water management infrastructure to include GI practices. Funding should be targeted towards municipal governments and nonprofit organizations, which are best positioned to implement these retrofit projects.

Step A.1) d: MAPC will work with municipalities to help them establish stormwater funding mechanisms (i.e. via the application of the MAPC Stormwater Financing/Utility Kit), as well as tax credits, stormwater fee credits, and rebates to incentivize GI implementation on private properties.

Examples:

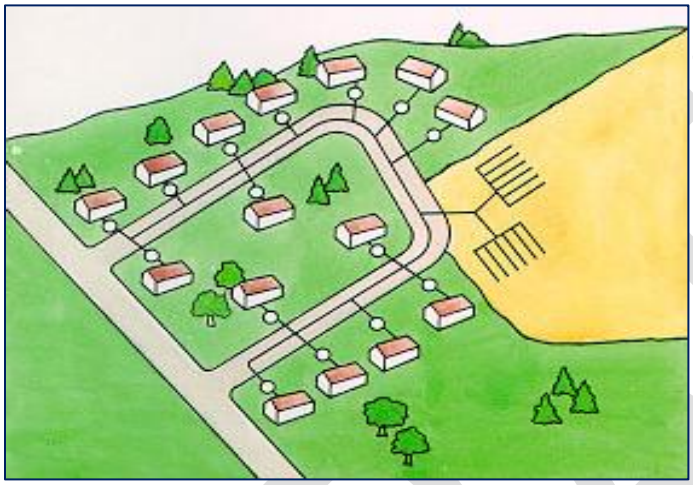
- City of Newton, MA: Established a stormwater fee based upon average impervious surface area of varying land uses. Funds are used to implement GI and alternative stormwater projects aimed at improving impaired waterbodies and creating climate resilient neighborhoods.
- New York City: Legislation established to renew and expand upon a property tax credit for green roofs, allowing property owners to earn a one-year credit up to $200,000 for the inclusion of a green roof on at least 50 percent of a structure.
- City of Philadelphia, PA:
    - Businesses are eligible for a credit of 25 percent, at a maximum of $100,000, of green roof installation costs (e.g. a midrise apartment building in Philadelphia with an 8,400-square-foot green roof could receive a one-time tax credit of over $50,000.)
    - Provides up to an 80 percent reduction in stormwater utility fees for property owners who install green infrastructure.[52]

[52] Natural Resources Defense Council. *The Green Edge: How Commercial Property Investment in Green Infrastructure Creates Value*. December 2013.

IV.A.1.a) DECENTRALIZED WASTEWATER SYSTEMS

Decentralized wastewater treatment systems, also known as cluster or communal systems, or package plants consist of a variety of approaches for collection, treatment, and dispersal/reuse of wastewater for individual dwellings, industrial or institutional facilities, clusters of homes or businesses, and a specific area of a community (e.g.. downtown village) with mixed uses. Decentralized wastewater systems allow for flexibility in management, as different parts of the system may be combined into "treatment trains," or a series of processes to meet treatment goals, overcome site conditions, and protect natural resources. A site design that includes a subdivision-based decentralized wastewater system is shown in Figure 3.2 below.

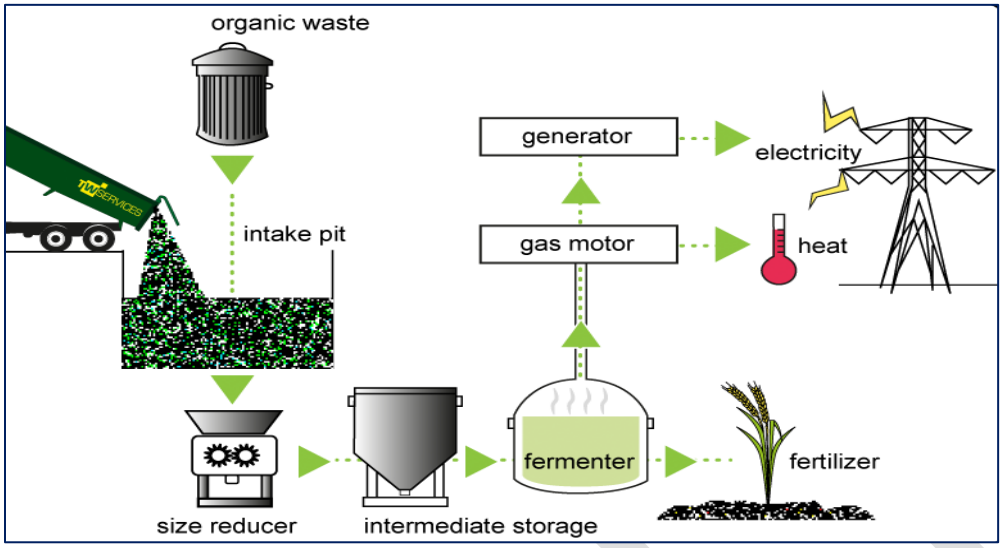
Figure IV.2. Decentralized Wastewater for a Cluster of Homes.



Source: U.S. EPA

A specific concept utilizing decentralized wastewater systems is "Smart Sewering," established by the Charles River Watershed Association. This approach includes selecting an area of a community that is most appropriate for development to occur and establishing wastewater infrastructure within this area to limit growth and development to this area only. With this approach, municipalities can promote targeted development without suffering additional climate impacts from sprawl explosion associated with community-wide or regional sewage infrastructure. A small local wastewater system can focus growth in the sewered area and protect the quantity and quality of local streamflow. Protecting streamflow capabilities is a critical element in reducing flood conditions, as well as loss of recharge to the watershed. There is also a great potential for energy generation at the wastewater treatment plant if anaerobic digestion is used to treat the wastewater, as shown in Figure 3.3.

Figure 3.3: Anaerobic Digestion Process.



Source: TW Services.

Step A.1) e: MAPC will work with MA DEP to work with and support the efforts of local communities to develop innovative technology, planning, and management structures under a community decentralized wastewater treatment district framework.

Step A.1) f: MAPC will work with CRWA, and MA DEP, to further the Smart Sewering concept in appropriate areas within the MAPC Region.

IV.A.1.b) Innovative Stormwater Management

Green Infrastructure includes the implementation of a series of innovative stormwater management practices that aim to mimic the natural hydrology of an area. These practices, in turn, will help to reduce GHG emissions and, of course, reduce flooding from increased precipitation. Instead of piping stormwater out of the watershed where it can no longer provide flood protection or recharge to groundwater/streamflow, GI eliminates this hard engineering allowing rain to fall onto pervious and/or "soft" stormwater management facilities where it can recharge the water and control volume.

The benefits of stormwater recharge, within appropriate locations (e.g. not in areas with documented pollution hotspots from industrial activity) are numerous. Recharging stormwater within the watershed – preferably subbasin – in which it was generated, protects streamflow and aquatic habitat, replenishes groundwater and drinking water sources, reduces flooding, and in most cases reduces costs associated with engineered systems. In terms of climate resiliency, recharging stormwater eliminates the treatment of rainwater as a waste product, creating the need for engineering to pipe water away from its source. By managing stormwater in small-scale, distributed facilities, flooding effects to downstream properties from flash storm events are greatly reduced.

Most of the current infrastructure in place within urbanized areas consists of a "grey" management system that is aging and very costly to repair. The Water Infrastructure Finance Commission's 2012 study reported that it would cost approximately $18 billion in Massachusetts to repair aging stormwater infrastructure (plus a combined $22.4 billion for drinking and waste water). Therefore, it's imperative that municipalities within the MAPC Region (and beyond) begin to mandate and/or

incentivize the use of innovative stormwater management systems, including onsite recharge, as there is a great need for system-wide repairs, as well as climate change adaptation measures.

The primary innovative GI systems that reduce water volumes and flood potential include those listed below. Additional information and design specifications can be found within MAPC's LID Toolkit.

1. **Permeable Pavement**: Permeable paving allows rainwater to percolate through the paving and into the ground before it runs off. This approach reduces stormwater runoff volumes and minimizes the pollutants introduced into stormwater runoff from parking areas. All permeable paving systems consist of a durable, load bearing, pervious surface overlying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, parking stalls, and overflow parking areas.

2. **"Green" or "Blue" Roofs**: Both Green and Blue Roofs have dual purposes when it comes to climate resiliency; reducing rainfall volumes, and providing heat absorption. Green roofs reduce the volume of rainwater runoff by capturing rainfall and infiltrating it into vegetation, thereby reducing flooding potential in areas adjacent to its use. In addition, the vegetation also serves as a method for absorbing heat and maintaining appropriate temperatures inside the building. Blue roofs are a relatively new concept in Massachusetts, in which

3. **Bioretention**: Bioretention is a term for the use of technique that uses soil, plants and microbes to treat stormwater before it is infiltrated or discharged. Bioretention "cells" are shallow depressions filled with sandy soil, topped with a thick layer of mulch, and planted with dense vegetation. Stormwater runoff flows into the cell and slowly percolates through the soil (which acts as a filter) and into the groundwater; some of the water is also taken up by the plants.

4. **Raingardens**: Raingardens are a type of Bioretention Cell that is on a smaller scale. The primary differences are that raingardens are frequently used on residential lots; they generally include simple overland outlets/overflows; and rather than requiring specialized bioretention media, simpler soil amendments for the planting bed are all that's needed.

5. **Vegetated Swales**: Vegetated swales are used to convey stormwater runoff. These open, shallow channels slow runoff, filter it, and promote infiltration into the ground; as a result, runoff volumes are smaller, peak discharge rates are lower, and runoff is cleaner. This approach contrasts with conventional stormwater strategies that rely on gutters and pipes that increase the velocity of runoff and do nothing for water quality. Vegetated swales can replace curb and gutter systems as well as storm sewers that convey runoff. However, they are not just ditches under another name—they must be carefully designed and maintained to function properly. The vegetation in swales, usually thick grass, helps to trap pollutants (suspended solids and trace metals), and reduce the velocity of stormwater runoff; stormwater also percolates through the natural substrate.

6. **Grass Filter Strips**: Grass filter strips are low-angle vegetated slopes designed to treat sheet flow runoff from adjacent impervious areas. Filter strips function by slowing runoff velocities, filtering out sediment and other pollutants, and providing some infiltration into underlying soils. They provide good "pretreatment" of stormwater that will then be routed to another technique such as a bioretention area for water quality treatment. Filter strips differ slightly from buffer strips, which are natural vegetated areas alongside streams and lakes that are

left undisturbed for habitat and flood protection. Alternatively, filter strips are altered areas designed primarily for effective and inexpensive stormwater management.

7. **Rainfall Capture and Harvesting**: This concept is a method to essentially remove the need for stormwater management locally. It starts by capturing rainfall before it runs-off an impervious surface ending with the reuse of this water. We've provided a further explanation of rainwater harvesting in the section below as some of the methods associated with this practice are slow to take hold in Massachusetts.

IV.A.1.c) RAINWATER HARVESTING

Rainwater Harvesting is a specific water capture and reuse term for the collection of rainwater, prior to its runoff onto impervious surfaces, for use in irrigation, landscaping, and other innovative applications. With projected seasonal droughts due to climate change, rainwater reuse will become more and more of a necessity. According to MA DEP, merely 1/4 inch of rainfall on a typical roof will fill an entire residential rain barrel- a full rain barrel will water a 200 square foot garden. Rain water is free from minerals and chemicals such as chlorine, fluoride, and calcium that are often present in municipal water, therefore; rain water is considered ideal for landscaping. Rainwater Harvesting can be achieved in varying scales from a backyard rainbarrel at a residence to a large commercial cistern system (shown in Figures 3.4 and 3.5 below).

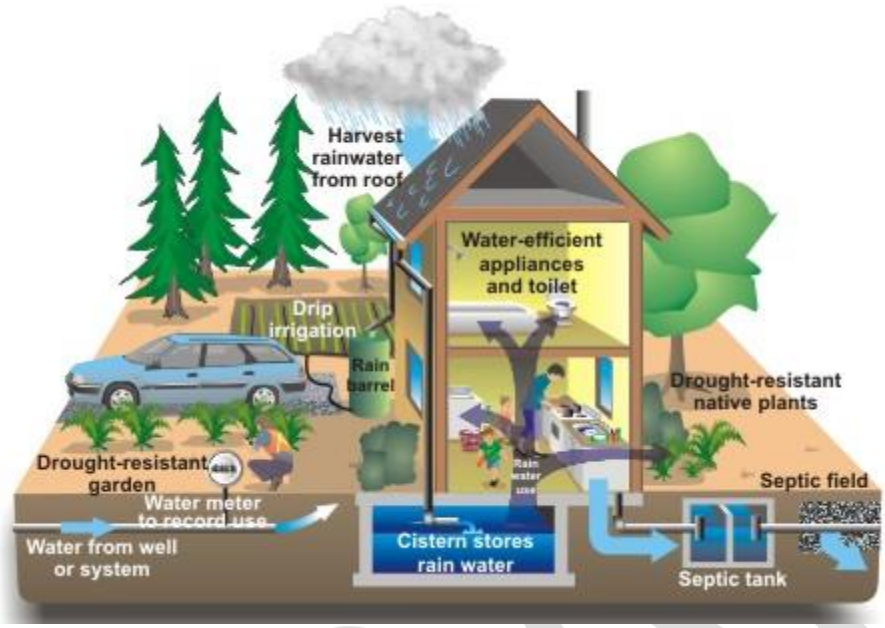
Figure 3.4. Rain Barrel Figure 3.5. 15,000 Gallon Cistern at Boston Univ.

Source: American Rain Barrel Co.

Capturing rainwater and using it onsite are important, and affordable, climate resilient actions that can be achieved by all property owners and residents within a municipality. Figure 3.6 below illustrates there varying approaches to rainwater harvesting. As shown, rain that falls first upon the roof's surface is the most easy to collect within a roofing gutter system, which is then funneled into a rain barrel. This is the most basic of collection systems. As shown, this rainwater can be used to irrigate outdoor plants and gardens either through the simple use of the water via an attached hose or even a slightly more sophisticated drip irrigation system in which a gravity-fed hose with irrigation holes to allow rainwater to escape into a bed of vegetation. A more elaborate and innovative method of rainwater harvesting is through its collection and storage within a cistern, which is then disinfected and filtered before its piped into water efficient appliances/fixtures throughout a building (e.g. low-flow toilets, washing machines). While rooftop runoff may contain pollutants (metals or hydrocarbons from roofing materials, nutrients from atmospheric deposition, bacteria from bird

droppings), these pollutants are generally found in significantly lower concentrations, and the runoff is generally free of the toxic contaminants that may be picked up after the runoff mobilizes off-site.[53] Although this water is substantially cleaner than stormwater runoff, it should not be used as a potable water source due to the possibility of these trace pollutants.

Figure 3.6: Rainwater Harvesting.



Source: Team WaterSmart.

Step A.1) g: MAPC and its partners will work with municipalities to implement the recommendations offered in its Once is not Enough: A Guide to Water Reuse in Massachusetts.

Step A.1) h: MAPC and its partners will work with MA DEP and municipalities to ensure that water reuse is a feasible, desired option for property owners. Specific measures include:

- Expand the regulatory allowance of water reuse in other applications such as residential and agricultural.
- Updating the state plumbing code to ensure the allowance of rainfall reuse.
- Assist municipalities in establishing coordinated local stormwater/wastewater planning and management.
- Assist municipalities in developing public education programming regarding the multiple benefits of rainwater harvesting (e.g. cost savings, stormwater (and potentially fee) reduction, climate resiliency, water efficiency, etc.).

Example:

Portland's Rainwater Harvesting One and Two Family Dwelling Specialty Code: Rainwater reuse is permitted for these facilities, but due to the unique design of each system, commercial reuse systems are considered on a case by case basis.

[53] U.S. Environmental Protection Agency, Managing Wet Weather With Green Infrastructure, Municipal Handbook, Rainwater Harvesting Policies EPA-833-F-08-010, December 2008. (http://www.epa.gov/npdes/pubs/gi_munichandbook_harvesting.pdf.)

Step A.1) i: MAPC and its partners will work with municipalities to include GI tools as standards within municipal regulations/rules (e.g. site plan, stormwater management, wetlands protection). At a minimum, GI tools to address the following stormwater management principles should be used as the basis for decision-making:

- Maximize retention of native forest cover and vegetation and restore disturbed vegetation to intercept, evaporate, and transpire precipitation.
- Preserve permeable, native soil, and enhance disturbed soils to store and infiltrate storm flows.
- Retain and incorporate topographic site features that slow, store, and infiltrate stormwater.
- Retain and incorporate natural drainage features and patterns.
- Utilize a multidisciplinary approach that includes planners, engineers, landscape architects, and architects at the initial phases of the project.
- Locate buildings away from critical soils that provide effective infiltration.
- Reduce hard surfaces and impervious surface areas, and increase retention of native vegetation.

IV.A.2. A.2) Institute Water Conservation Practices

Water conservation would go a long way to reduce the impacts of climate change, specifically increased summer drought and heat. Currently, during times of low precipitation in Massachusetts (typically, mid-summer and fall), there already are significant environmental impacts in some watersheds due to lack of recharge to replenish groundwater systems. Conservation practices across the Commonwealth have greatly reduced the demand on the Quabbin Reservoir (the primary drinking water source for approximately 50 municipalities within the region). However, there are over 50 communities that withdraw their own drinking water from surface and groundwater sources and approximately 40 communities that send their wastewater to the Deer Island Wastewater Treatment facility; entering Massachusetts Bay rather than replenishing their host watershed system. Furthermore, high rates of development/redevelopment throughout the region has resulted in more intense water usage and increased impervious surfaces, thereby creating extreme low-flow conditions and impairments in our waterbodies. For example, flow levels on the Ipswich River have been at critically low levels from midsummer through mid December year after year, primarily due to groundwater withdrawals from town-wide development (i.e. irrigation, consumption, and washing).

Conservation measures have been identified by the state's Sustainable Water Management Initiative (SWMI) as critical mitigation measures for water withdrawals. SWMI was a three-year, multi-stakeholder process to update the implementation of the Water Management Act (WMA). The WMA is the primary statute governing large water withdrawals within the Commonwealth. In the fall of 2012 the Executive Office of Energy and Environmental Affairs (EEA) issued the final SWMI Framework, which spells out the goals and key concepts developed during the SWMI process. The SWMI Framework lays out a set of eight standard conditions that all WMA permittees in the Commonwealth will be required to comply with. Of these, conditions 4-7 have a direct bearing on water conservation, which will become increasingly more important for communities to become climate resilient.

Step A.2) a: In light of SWMI, as well as the understanding that water conservation also creates climate resiliency in a community, MAPC and its partners will assist municipalities in implementing the following steps:

- Watering restrictions within municipalities that have municipal water supplies or private wells to include:

    - Restrictions that limit irrigation to two days per week outside the hours of 9 am to 5 pm;
    - Easily understood and communicated restriction mandates or tiers such as “no sprinklers” and “total ban.”
- Educational templates such as flyers, press releases, notifications to be added to water bills, and website postings, which describe the critical importance of conservation for climate resiliency. These templates can be easily altered by municipal officials to reflect their city/town bans.

Step A.2) b: According to MRWA's 2010 board report, 16 communities use inclining block rate structures and 24 use ascending block with a base minimum (out of 61 MWRA communities). The Water Infrastructure Alliance should work with water utilities to understand the importance of, and adopt:

- Increasing block rate structures,
- Seasonal rate structures that charge higher unit costs during peak demand periods, and
- Higher water rates for outdoor meters to send an appropriate conservation signal to consumers.

IV.A.3. A.3) Implement Energy Efficiency and Renewable Energy Measures

Everything requires energy to respire, move, grow and reproduce. Most energy on Earth is originally derived from the Sun, the only input into an otherwise closed and self-sustaining system.

Current energy sources generally come from non-renewable energy sources such as the following (in order of the most used to the least):

1. Petroleum
2. Natural gas
3. Coal
4. Nuclear electric power

The first three categories are also known as “fossil fuels,” because they were created as a result of biomass being compressed and “fossilized” under the Earth’s surface over the course of millions of years. Fossil fuels have an extremely high energy content and have historically served as the driving force behind industrialization, population growth, and economic development. However, there are a number of problems associated with the conversion technologies used to turn the stored chemical energy in fossil fuels into active thermal energy (e.g., combustion), including the generation of GHGs.

The most recognizable renewable energy technologies, such as solar panels or wind turbines, work by harvesting naturally available forms of energy and converting them into electric energy. These are the types of energy sources that, when implemented, would serve as both mitigation of, and adaptation to, climate changes. Renewable energy use mitigates climate change by reducing GHG emissions, while also creating far more sustainable and resilient communities that no longer must utilize land areas for conversion purposes. Furthermore, these land areas are typically adjacent to the coastline due to historic and current shipping requirements, making these facilities far more susceptible to more intense coastal climate change conditions.

MAPC's Clean Energy Division has developed a Clean Energy Toolkit to provide guidance to municipalities for the implementation of programs and projects that achieve greenhouse gas reductions and reduced reliance on fossil fuels. The Toolkit contains over 40 strategies, best practices, and model documents that encompass capacity building, funding, project planning, and implementation on the local and regional level. These strategies include, for instance, how to create a local energy action plan, hire a shared energy manager, receive Green Communities designation, procure clean energy services, and contract for solar energy management services.
In addition to empowering municipalities with the information and support they need to implement innovative clean energy strategies across the municipal, commercial, and residential sectors, MAPC has developed the following implementation steps to maximize climate resiliency in the region:

Step A.3) a: MAPC's Clean Energy Division will collaborate with partners, such as the MA Department of Energy Resources (DOER) and the MA Department of Public Utilities (DPU), to support the improvement of the region's electric grid in order to minimize transmission losses, manage peak demand, and support widespread distributed generation.

Step A.3) b: MAPC's Government Affairs team will advocate for policies that promote GHG reduction mechanisms, such as the expansion of the Renewable and Alternative Portfolio Standards, incentives for clean energy technologies, energy data accessibility, and improved building and energy rating standards.

Step A.3) c: MAPC's Clean Energy Division will continue to assist municipalities in the development of energy and GHG emissions baselines and short- and long-term clean energy planning.

Step A.3) d: MAPC's Clean Energy Division will continue to support development of local and regional renewable energy generation for shared or on-site consumption.

Step A.3) e: MAPC's Clean Energy Division will continue to support energy use reductions within developed areas. This includes sustainable building practices for new construction, the promotion of energy audits and retrofits for existing buildings, and exploration of behavior-based programs across all sectors.

Step A.3) f: MAPC's Clean Energy and Environment Divisions will assist municipalities in building capacity to execute clean energy and climate initiatives through creation of dedicated local and regional staff positions and sustainable funding mechanisms, such as green revolving funds.

Step A.3) g: MAPC's Clean Energy Division will seek to leverage the State's Community Clean Energy Resiliency Initiative, a $40 million grant program announced in 2014 to strengthen cities and towns' ability to provide clean power to vulnerable sites in times of grid instability. Through this and an expanded resilient clean energy workstream, MAPC will seek to enhance municipal clean energy resiliency through actions such as:

- Promoting microgrids, district energy, and battery storage,
- Facilitating widespread adoption of residential solar PV, and
- Supporting the uptake of renewable thermal technologies.

IV.B. B. Protect and Preserve Natural Resources

The preservation of green space and proactive water resource management are the most important components of climate adaptation and mitigation. Protecting natural resource functions such as flood absorption and storage, absorption of heat, and carbon sequestration is critical to ensuring community resiliency. Planning for linked open spaces that provide co-benefits (ecological, recreational, and water storage),restoring wetlands, protecting and increasing tree canopy, and preserving natural land are critical actions for local climate change adaptation. Specific action measures and examples/resources are explained below.

It should be noted that there are a number of strategies described in the prior section (Mitigation as Adaptation) such as Green Infrastructure, Water Conservation, Energy Alternatives, and others that can be implemented in concert with strategies that are specific to protecting and preserving natural Resources, as described below.

IV.B.1. B.1) Regulation and Zoning

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

In addition to establishing superlative individual laws and regulations to protect natural resources, which play a critical role in ensuring coastal resiliency, it is important for local, regional and state government entities in Massachusetts to consider the fragmentation of its resource protection laws. Similar to the Commonwealth's water resource protection rules and responsibilities, which are scattered under the jurisdiction and prevue of a number of government entities, natural resource protection occurs at many levels of government with varying laws and regulations. Table 3.2 below compares the primary Massachusetts laws pertaining to natural resource protection with a more synchronized format in Maine.

Table 3.2 Laws Pertaining to Natural Resource Protection

Topic/Resource	Massachusetts Laws	Maine
Climate Change	MGL c. 21N Global Warming Solutions Act	MRS c. 13 Protection and Improvement of Waters
Coastal Development	MGL c. 91 Public Waterfront Act MGL c. 21A, s. 4A Coastal Zone Mgmt.	MRS c. 13
Surface and Groundwater (Drinking Water Sources)	MGL c. 13; MGL c. 21A; MGL c. 30A; MGL c. 40; MGL c. 111; MGL c. 112; MGL c. 140; MGL c. 162; MGL c. 165;	MRS c. 13
Waterways	MGL c. 91 MGL c. 21 s. 26-35	MRS c. 13
Wetlands	MGL c. 131 s. 40 Wetlands Protection Act	MRS c. 13

Topic/Resource	Massachusetts Laws	Maine
	MGL c. 258, Acts of 1996 Rivers Protection Act	
Habitat & Wildlife	MGL c. 21A s. 27 Areas of Critical Environmental Concern MGL c. 131 s. 23 Endangered Species Natural Heritage Program MGL c. 132 s. 40 to 46 Tree Harvesting	MRS c. 200
Marine Fisheries	MGL c. 130	MRS c. 13, 401
Watershed Protection	MGL c. 21, 21A, 30A Water Resources Commission MGL c. 92A ½ Quabbin and Wachusett Watershed Protection	MRS c. 13

IV.B.1.a) Freshwater Wetland and Floodplain Regulations

Protecting wetlands and floodplain areas are extremely effective climate adaptation strategies. Wetlands function as sponges, as buffers against storms, and as sources of fresh water and food. Another important function of wetlands is its natural ability to sequester carbon. Depending upon the wetland's make-up, they can hold up to up to five times the carbon stored in tropical forests. Floodprone or floodplain areas are natural conduits for floodwaters.

It's important to make distinctions between floodplain, floodprone, and regulated flood hazard terminology, as described in the Strategy definitions:

- Floodplain, also sometimes called the "floodway," is the area next to a river that experiences flooding when water comes out of the banks of the main channel. Floodplain is the term FEMA used to include: "any land area susceptible to being inundated by flood waters from any source."
- Floodprone Area is an area bordering a stream that will be covered by water at a height of twice the maximum bankfull depth.
- Special Flood Hazard Area (SFHA) are areas designated by FEMA as "having special flood, mudflow, or flood-related erosion hazards, and shown on a Flood Hazard Boundary Map or a Flood Insurance Rate Map (Zone A, AO, A1-A30, AE, A99, AH, AR, AR/A, AR/AE, AR/AH, AR/AO, AR/A1-A30, V1-V30, VE, or V)." NOTE: in determining Community Rating System premium discounts AR and A99 zones are treated as non-SFHAs.)

For the purposes of this Strategy, we typically refer to the Floodplain (sometimes the floodprone) areas rather than SFHAs, as we advocate for protection of all areas exposed to flooding; not just the areas regulated under FEMA. This is because FEMA floodplain mapping typically does not take climate change impacts into account within inland riverene systems. Recent updates to FIRM maps included a change in methodology regarding the determination of base flood elevation, yet projections regarding the anticipated rise in base flood elevation due to increased storm intensity and duration have not been included.

The Massachusetts Wetlands Protection Act (WPA) and its accompanying regulations is the typical basis for protection of wetland resources that many MAPC municipalities choose to rely on. However, the WPA does not protect the values and functions of aquatic resources (listed below), which could provide flood protection and habitat for critical species. Some municipalities have created their own,

and often more protective, Wetlands Bylaws. However, from our latest inventory it appears that there are still a number of municipalities within the region that have not adopted a Wetlands Bylaw or the language in the bylaw can limit the approval of more innovative protective measures.

Due to the constraints raised above, MAPC proposes the following actions:

Step B.1) a: MAPC will work with municipalities to adopt flexible regulations, planning policies, and land use laws to increase, and mandate, protective buffers to the following resources:

- Land Outside the FEMA 100-year Floodplain
- Isolated Vegetated Wetlands
- Vernal Pools
- Intermittent Streams
- Landward Migration of Wetlands

Step B.1) b: MAPC, with assistance from its state partners (MEMA, DCR, MA GIS) will assist communities in mapping and regulating an area outside the FIRM, as it is critical to ensuring flood protection.

Example: 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.

IV.B.1.b) Stormwater Management Regulations

As evidenced by the descriptions above, a vast number of Green Infrastructure (GI) techniques are designed to manage and treat stormwater at the site of its origin in order to maintain the hydrologic cycle. Unfortunately, there are numerous municipalities across the region that do not have their own stormwater management bylaw/ordinance or regulations. These municipalities rely on the Massachusetts Stormwater Handbook to manage stormwater on public and private properties. Although the Stormwater Standards included in the Handbook encourage Low Impact Development and Green Infrastructure techniques, they are not mandated and are not cited as required in areas of high climate change risk. Municipalities that do have their own stormwater bylaw/ordinance and regulations often are not progressive enough to either incentivize the use of GI or require a long-term funding source such as a drainage fee and/or utility structure (described in more detail under strategy: Developed Areas). Funds generated can be used to implement or retrofit existing stormwater facilities with new innovative GI.

Step B.1) c: MAPC will continue to help municipalities establish or revise land use controls and stomwater regulations to promote innovative practices (i.e. GI and better site planning), and promote the importance of updating Capital Improvements Plans to emphasizing funding of G.I.

Step B.1) d: MAPC will continue to help municipalities establish a reliable long-term funding source for stormwater management (i.e. drainage fee and/or utility) where funds generated are used to implement GI techniques.

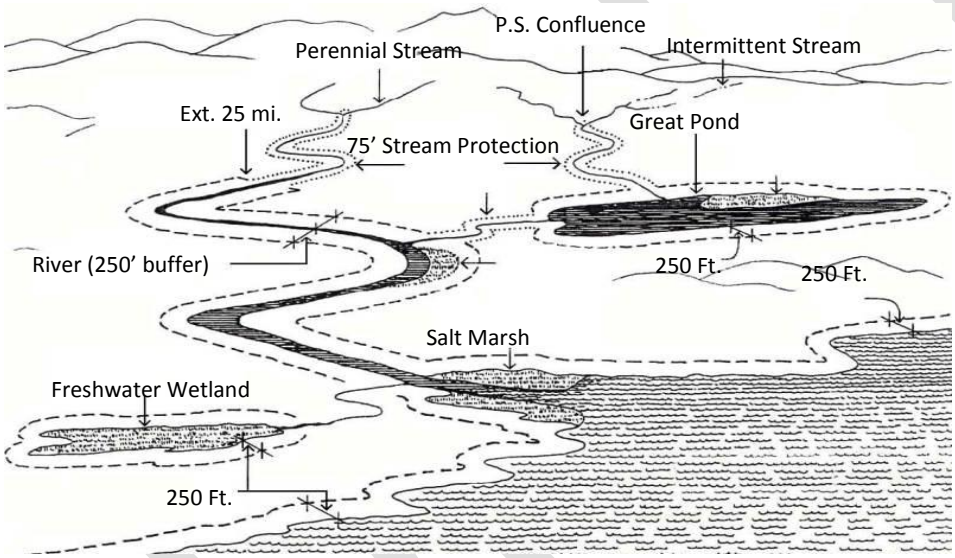
Step B.1) e: MAPC will work with DEP and other partners to make additional revisions to the MA Stormwater Handbook regarding recharge. The recharge standard included in the USACE/DEP Water Quality Certification permit: “Loss of annual recharge to ground water shall be eliminated or

minimized through the use of infiltration measures including environmentally sensitive site design, low impact development techniques" should be used as a model.

IV.B.1.c) Shoreline Protection Laws

A number of our New England neighboring states have embraced the concept of shoreline protection along both inland and coastal waterways. Shoreline protection laws and regulations, generally, include the fortification of good water quality, elimination of erosion, and wildlife and vegetation protection. In terms of development areas, shoreline protection laws regulate how landowners develop and use their shoreland property. Shoreline protection laws can be employed at the state and local level. However it should be noted that protective laws established at the state level help to assure a level regulatory playing field, and to maintain consistency in the law across municipal boundaries. Regardless of whether a state or local law is imposed, they all require municipalities to identify shoreland areas and establish specific districts or zones within those areas.

Figure 3.7. Aquatic Resources Included in Shoreline Protection Law (adapted from ME Shoreline Zoning Handbook)



***Step B.1) f*:** MAPC will work with state partners to develop a template shoreline protection bylaw using Maine and other New England State law as guidance.

Example: Maine Shoreline Zoning Handbook for Shoreland Owners.

IV.B.2. B.2) Ecological and Habitat Restoration

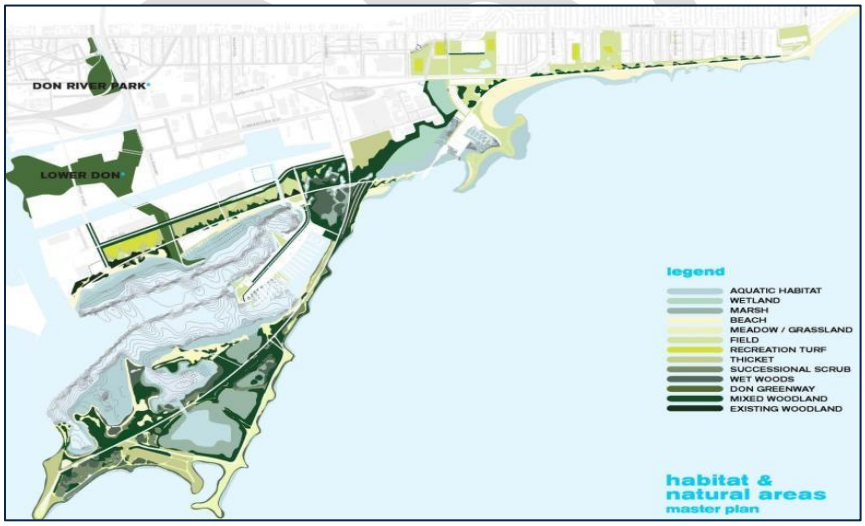
Restoring existing wetlands and riparian corridors should become a municipal planning and investment priority. Habitat restoration projects provide a range of valuable ecosystem services, including the generation and preservation of soils, cycling and movement of nutrients, partial stabilization of climate, mitigation of droughts and floods, and purification of air and water. The ecosystem services concept is designed to illustrate the benefits of habitat restoration projects to local economy. According to Professor Steven Handel from the Department of Ecology, Evolution, and

Natural Resources at Rutgers University: "the sell is pretty easy, you don't have to sell public finance officials on this.[54]"

Professor Handel has worked on a number of innovative habitat restoration projects including the substantial Fresh Kills Park in New York City. The Fresh Kills Park project included the restoration of habitat on top of a 2,000-acre landfill on Staten Island. The project utilized reclaimed soil from building excavation projects in Manhattan, which had been buried deep in Manhattan for centuries, and therefore; in fine condition for the project. Yard waste, collected from New Jersey residents, was used as composting to re-grow plant life. As with many urban projects, there was little funding available for the restoration aspect of the project, so the team planted fruit bushes (beach plum, blueberry, blackberry and wildrose); attracting birds to spread the seeds, and clusters of plants to proliferate native species. Ants were also brought in as the "landscape contractors" of the park grounds to help spread plant diversity.[55]" According to Handel this project illustrates the importance of project designers working closely with ecologists to prevent "environmental disasters" such as when landfills are turned into dull grasslands. Innovative restoration projects, such as the Fresh Kills project, are essential to creating or restoring habitat that are critical to ensuring climate-resiliency of a community and habitat species.

Another important function of ecological restoration for climate resiliency is the concept of "adaptive infrastructure," which includes the connection of habitat areas across scales and geography. Nina-Marie Lister, Visiting Associate Professor, Harvard University Graduate School of Design is a promoter of this concept in which she describes as the idea of providing a landscape "network strategy." The idea is that landscape is infrastructure and features edges, nodes, and bridges. Designers can use these landscape components to plan for "complex ecological interaction" to ensure that communities and wildlife become resilient to climate changes. The Lake Ontario Park master plan has been cited as a primary example of a master planning project, in this case along the waterfront, which includes ecological restoration as a primary focus including a flexible and resilient landscape framework, as shown in Figure 3.8.

Figure 3.8. Lake Ontario Park Master Plan: Habitat and Natural Areas Plan



[54] J. Green. *Recreating Wildlife Habitat in Cities.* "The Dirt: Uniting the Built and Natural Environments" American Society of Landscape Architects online Blog. 05/20/2010.
[55] J. Green. *Recreating Wildlife Habitat in Cities.*

The Massachusetts Division of Ecological Restoration (DER) has developed several studies identifying aquatic habitat resources and potential restoration opportunities and funding mechanisms. In addition, they have developed the Massachusetts Stream Crossing Handbook, which is a critical technical guidance document that informs and educates local decision makers and conservationists about the importance of properly designed stream crossings. The Stream Crossing Standards, as described in the Handbook are required as part of Army Corps of Engineers Programmatic General Permit, and should be used when designing new crossings on perennial streams.

Step B.2) a: MAPC will work with EEA and other partners to promote the importance of ecosystem values and the importance of ecosystem restoration for climate resiliency. MAPC will continue to participate as members on various committees and coalitions, such as the Boston Harbor Habitat Coalition, to facilitate and encourage restoration projects within the region.

Step B.2) b: MAPC and partners will work with municipal officials to ensure that ecological restoration is includes in community or topic-specific master planning processes. MAPC will also work with DER to provide technical assistance regarding the prioritization and implementation of restoration projects.

Step B.2) c: MAPC will work with DER to facilitate aquatic habitat restoration projects within the region, specifically those that:

- Redesign and/or remove impediments to flow, sediment supply, and habitat migration potential such as dams and undersized culverts;
- Remove obstructions and protect lands upgradient of wetlands to facilitate inland migration of wetland resources; and
- Re-vegetate/stabilize riparian corridors with native plants.

IV.B.3. B.3) Land Conservation

Traditional land conservation and stewardship measures can be utilized for the purposes of providing resiliency to climate changes. Conserving land in areas that are vulnerable to various climate changes such as flooding, heat and wind impacts, among others, can be accomplished by removing or limiting development potential through acquisition, conservation or "rolling" easements, and the Purchase and Transfer of Development Rights, as described below.

IV.B.3.a) Land Use Restrictions

A Conservation Restriction (CR) or Easement - restriction on the use of one's property – can protect land against future development and maintain the land's natural functions for climate resiliency. A CR 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. There are numerous Land Trusts throughout the region that dedicate their time and efforts towards promoting this land use measure, as well as to managing CR enforcement. A well-known partner; The Nature Conservancy has used conservation easements for years to preserve natural lands from development.

"Rolling Easements" essentially are a set of approaches that are structured to allow the inward migration of wetlands (including rivers and stream buffers) as floodplains change due to increased precipitation and storm intensity. Rolling Easements are a relatively new concept that has been

generally employed thus far in coastal areas, as described in the Coastal Zone Section below. This type of Easement takes into consideration the natural inland migration of these resources and focuses on retaining public access by: prohibiting the use of structures that obstruct this movement. These types of easements also typically are bound by a clear set of regulations regarding the upper boundary of a wetlands buffer zone. For example, a rolling easement could ensure the preservation of inland wetland resources in a high-risk floodplain by preventing the landowner from adding fill to elevate the grade of his/her yard, or at least ensure a return to the original grade at some point in the future.

Further details regarding Rolling Easements are included in the Coastal Zone section.

IV.B.3.b) 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 shown in Figure 3.9 below and 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.

It is important to note that the use of disincentives in "sending districts", as well as incentives in "receiving districts" is important to creating a successful TDR program, making it more attractive to landowners. Examples of development disincentives in sending districts are increasing lot size requirements in the base zoning, increased permitting requirements due to the sensitive nature of these areas. These strategies are designed to decrease the development potential of a resource area. Development incentives in receiving districts typically include density bonuses awarded as a part of a TDR transaction.

Although the TDR concept has been a bit slow to take hold in the region, there are a few examples in Massachusetts of its use. The Town of Falmouth employed the TDR concept in an attempt to protect its drinking water supply. It passed a TDR bylaw that established its Water Resource Protection and Coastal Pond Overlay Districts as its sending areas (called "donor districts") and designated parcels zones as Business, Residential, Agricultural, or Light Industrial as receiving districts, as long as they are not located within a Water Resource Protection District or a coastal pond recharge area. The Falmouth Planning Board approves TDR transfers in conjunction with subdivision and special permit applications. The density bonus allowed on receiving areas varies depending on the zoning of the donor site. For

example, a receiving area zoned residential could receive 1.4 credits from a donor site zoned residential, but 1.3 credits from a donor site zoned agricultural.

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.

Using Falmouth as an example, the community could have chosen its high-hazard floodplain or coastal floodplain areas as designated sending districts to protect areas from floodwater (or sea) inundation. This particular example is discussed in greater detail in the Coastal Zone Section below.

IV.B.3.c) Land Acquisition

In addition to the methods described above, municipal acquisition of natural open space areas, potentially through Community Preservation Act funding, 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.

Step B.3) a: MAPC and partners will work with both municipal officials and Land Trusts to ensure that natural resource areas and greenspaces are prioritized for land use restrictions that have the potential to create resilient communities and habitats.

Step B.3) b: MAPC and partners will promote the new concept of Rolling Easements and its potential as a palatable land use strategy for climate resiliency.

Step B.3) c: MAPC and partners will continue to promote the implementation of TDR programs and regulations for its unique function as a climate resiliency strategy. MAPC and EEA partners will explore the feasibility of a statewide TDR bank.

Step B.3) d: MAPC, EEA with the help of land use partners, will explore the feasibility of a statewide TDR bank.

IV.C. C. Protect the Coastal Zone

Coastal cities and towns in the Metropolitan 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 regarding impacts from the ocean's power both in normal and in storm conditions. Adding to these challenges is the rising sea and more intense and frequent storms as a result of hanging climate conditions.

There are a number of critical resources regarding climate resiliency in coastal areas that this Strategy will not replicate. A few key resources that are directly relevant to coastal communities within the MAPC Region include, but are certainly not limited to:

- The U.S. 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 National Oceanic Atmospheric Administration (NOAA) Digital Coast website offers a series of easy to use mapping and analysis tools, as well as webinar training, and resources that state and local officials need to understand and protect coastal systems.

- The StormSmart Coasts program, developed by the Massachusetts Office of Coastal Zone Management, is a vital online-based resource designed to help coastal communities address the challenges arising from storms, floods, sea level rise from climate change, and provides an extensive menu of tools for successful coastal floodplain management.

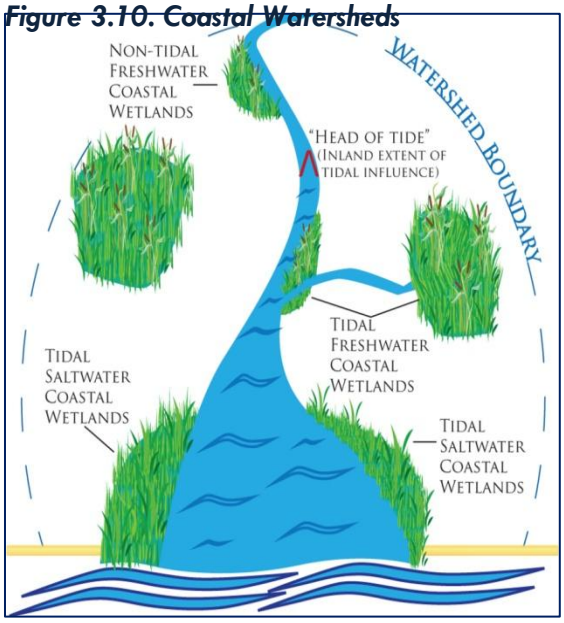
- The Preparing for the Rising Tide report by The Boston Harbor Association provides excellent information specific to the impacts on seal level rise on urbanized waterfront areas. The Report also provides visual case studies regarding climate resilient strategies that have been, and could be, implemented in waterfront neighborhoods, regardless of urbanized development patterns.

Due to the availability of these important resources by advisor organizations on this Strategy, this section of the Report will not provide lengthy information regarding tools for coastal climate resiliency. However, the substrategies discussed below will explain the context of implementation and cite these and other resources available for entities to take action. It is important to note that due to the impacts seen from Hurricane Irene, Superstorm Sandy and other coastal storms that have passed through the New England area, coastal resiliency has now become the highlighted element in the field of climate adaptation. Although it is critical that our coastlines are protected due to the threat of these severe damages, inland impacts from climate change are equally important as noted previously. In addition, MAPC recognizes the intricate interrelationships between coastal estuarine systems and regional wetlands and inland aquatic resources. This section of the Strategy will highlight such relationships as necessary.

IV.C.1. C.1) Revise/Create Regulations and Zoning to Protect Coastal Resources

Regulation of our coastline and marine waters in Massachusetts is complex, as all levels of regulation are intertwined with public access, marine industry, natural resource protection, human uses and recreation, navigation, and fisheries, to name a few. For example, the Massachusetts Public Trust Doctrine focuses on Public Access to our waterways areas, yet a series of port protection regulations are also in place to protect similar areas for marine industry. This makes for a tricky untangling of conflicting rules when it comes to the revision and inclusion of climate resiliency strategies within these laws and regulations. Having said that, there are a number of measures local governments can take to protect their shorelines and marine resources, which will be the focus of our substrategies.

Figure 3.10. Coastal Watersheds



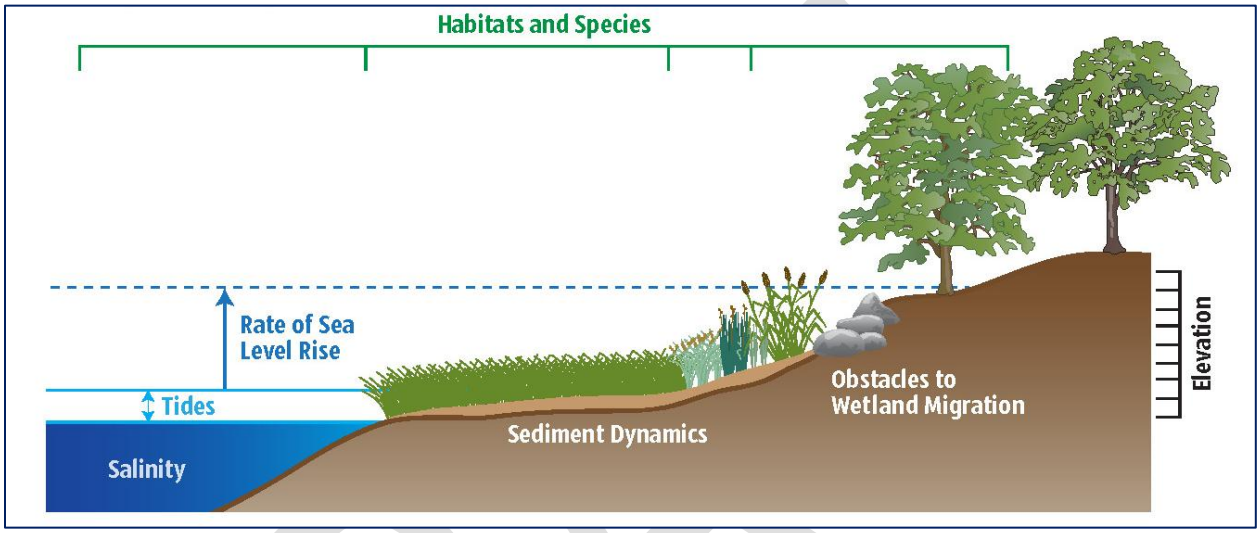
IV.C.1.a) Coastal Wetland Regulations

It is important to note that coastal wetlands include saltwater and freshwater wetlands located within coastal watersheds as illustrated in Figure 3.10. Therefore, recommended actions relating to

freshwater wetlands previously described are important for coastal managers to consider.

Coastal wetland migration is an important concept to describe as it is a critical factor for government officials, property owners, and developers to understand. Coastal Wetlands migrate due to increased sea level, salinity and sediment changes, and elevation changes, as shown in Figure 3.11 below. As wetland buffer areas are lost and encroachment by development continues to occur, migration of wetlands is restricted or prohibited thereby; limiting their ability to protect the coastline from erosion and flooding.

Figure 3.11. Coastal Wetland Migration



Source: U.S. EPA and The Nature Conservancy, from "Marshes on the Move."

The development of, or revision of an existing, Wetlands Bylaw that accounts for sea-level rise within its included resource delineation method is extremely useful to ensure that these valuable resources are protected. Regulations should also allow for wetland expansion and migration, as necessary to accommodate higher tides and coastal floodwaters.

In terms of specific coastal wetland resources to be examined for additional protection within Wetlands Bylaws; there are a number of buffer zones and flow areas to be considered. As discussed previously, the Massachusetts Wetlands Protection Act (WPA) does not protect the values and functions of some coastal resources such as Land Subject to Coastal Storm Flowage and Coastal Wetlands Buffers.

For example, the Massachusetts Coastal Hazards Commission 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.

MAPC will work with municipalities to adopt flexible regulations, planning policies, and land use laws to increase protective buffers to the following resources:

***Step C.1) a*:** MAPC will work MA DEP and MA CZM to consider revisions to the WPA regulations to include:

- Sea level rise and landward migration of the wetland resource area
- Standards for Land Subject to Coastal Storm Flowage (LSCSF).

***Step C.1) b*:** MAPC will work with municipalities to create or revise their own local wetlands bylaw/ordinances and regulations that include more stringent requirements than the WPA, particularly provisions regarding climate change.

***Step C.1) c*:** MAPC will work with state partners to develop a template shoreline protection bylaw for use in coastal communities (described under sub-strategy B).

Examples:

1. The City of Boston's Conservation Commission has recently proposed to update their local wetlands ordinance that includes language that explicitly directs that the effects of sea level rise (SLR) be taken into account during review of project impacts. Proposed changes include:
    - Land Subject to Coastal Storm Flowage (LSCSF) should be better defined and mapped.
    - A regulated buffer zone to LSCSF, initially based on elevations, should be created to account for current and future SLR. The map of this buffer zone should be periodically reviewed and revised, as necessary as new information and SLR projections become available.
    - Performance standards should be developed for projects located within LSCSF and its buffer zone so that proponents can demonstrate that a project will contribute to the protection of the interests of the ordinance; including but not limited to: flood control, storm damage prevention, and prevention of pollution, throughout its lifecycle. Standards should take into account potential flooding and expected changes to the intensity and frequency of future storm events.

2. 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.

3. 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.

4. 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).

IV.C.1.b) Coastal Floodplain Mapping and Zoning

Protecting coastal floodplain areas is one of the most important and effective ways of adapting to climate change and protecting economic assets.

It should be noted that FEMA coastal floodplain mapping typically does not currently take tidal inundation into account within coastal flood hazard areas. Recent updates to FIRM maps included a change in methodology regarding the determination of base flood elevation, yet projections regarding the anticipated rise in seal level have not yet been included.

***Step C.1) d*:** MAPC will utilize accepted model bylaws to provide technical assistance to municipalities to protect coastal floodplains.

Examples: The following regulatory approaches attempt to eliminate future impacts by prohibiting construction within the highest coastal flood hazard area:

1. 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.
2. 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.

***Step C.1) e*:** MAPC will work with CZM to create zoning templates, based on relevant state and national examples, for protection of coastal floodplains.

Examples:

1. The 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.

2. The Rhode Island Coastal Resource Management Council took Nantucket's example a further step by including an additional 50-ft minimum setback requirement from coastal shoreline features.

3. 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:

Table 3.3. Kauai Shoreline Setbacks

Setback Related to Lot Depth:							
Average Lot Depth (Feet)	< 100 or less	101 – 121	121 -140	141 – 160	161 -180	181 - 200	>200
Min. Setback (Feet)	40	50	60	70	80	90	100
Setback Related to Building Footprint:							
Building Footprint	Less than or equal to 5000 sq ft			Greater than 5000 sq ft			
Setback (feet)	40' plus 70 times the annual coastal erosion rate			40' feet plus 100 times the annual coastal erosion rate			

IV.C.1.c) ROLLING EASEMENTS

As described previously, "Rolling Easements" are a set of approaches that are structured to allow the inward migration of wetlands - in this case coastal wetland resources - as floodplains change due to sea level rise and precipitation. This type of Easement takes into consideration the natural inland migration of these coastal resources and focuses on prohibiting long-term structures that obstruct this movement. In terms of the use of rolling easements within a developed area; they are generally found to be more politically acceptable than immediate retreat policies since they allow for existing structures to remain in place until the rising tide, floodwaters, or extended floodplain boundaries reach the property. Rolling easements are typically bound by a clear set of regulations regarding the upper boundary of said inundation area. 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. Due to the complexity of this land use restriction, it is recommended that readers review the Rolling Easements primer developed by the EPA's Climate Ready Estuaries program.

Step C.1) f: MAPC will work with its state partners to promote the implementation of rolling easements at the local level within coastal floodplain areas. If possible, MAPC will also work with CZM to create a rolling regulatory easement template.

IV.C.2. C.2) COMPLETE COASTAL WETLAND AND SHORELINE RESTORATION PROJECTS

As described in previous sections, coastal wetlands are one of nature's best defenses against rising seas, wave action, and storm surges. In addition, they naturally adapt to climate conditions my migrating inland. Therefore, it is absolutely critical for coastal communities to prioritize funding and resources implement coastal wetland restoration and protection projects/programs.

In the Greater Boston Harbor area, there are a number of resources identifying coastal wetland resources, and potential restoration opportunities and funding mechanisms. Specifically, the Boston Harbor Habitat Atlas provides a consolidated source of information regarding potential restoration potential within the shoreline and waters from Saugus to Hingham, which was developed by numerous state partners from the Boston Harbor Habitat Coalition.

In addition to salt marsh restoration, 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. MA CZM StormSmart Coasts program also describes a number of ways to protect and restore shoreline areas using nonstructural measures.

An issue directly related to restoring coastal ecosystems is the importance of monitoring these systems to be able to understand – in advance - and swiftly respond to shifts in marine resource conditions.

***Step C.2) a*:** MAPC will work with DER to facilitate and encourage coastal wetland restoration projects within the region, specifically those that:

- Redesign and/or remove impediments to tidal flow, sediment supply, and habitat migration potential such as coastal dams and tide gages, and other tidal restrictions.
- Remove obstructions and protect lands upgradient of coastal wetlands to facilitate inland migration of coastal wetland resources.

Step C.2) b: MAPC will work with MA CZM to facilitate and encourage shoreline restoration projects within the region, specifically those that:

- Renourish beaches and dunes to prevent sea level rise from inundating low-lying coastal property, eroding beaches, or worsen flooding, utilizing MA DEP's Beach Nourishment guidance and MA CZM's Barrier Beach Management in Massachusetts.
- Re-vegetate/stabilize shorelines with native plants.

***Step C.2) c*:** MAPC will work with CZM, DER, UMass, and other partners to help facilitate and establish local monitoring and assessments of coastal resources.

IV.C.3. C.3) Consider Retreat / Land Acquisition Measures

Acquiring land that is vulnerable to sea level rise is an important way to reduce the risk of future disasters.

FEMA manages a federal/state 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. 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. 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.

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.

Step C.3) a: MAPC will work with MEMA, DCR, MA CZM, and MA GIS to map high risk coastal areas and prepare draft policies for local development restrictions.

Step C.3) b: MAPC and its relevant sister Regional Planning Agencies (RPAs) will work with municipalities to develop a template conservancy district zoning template that can be used in all coastal communities.

Step C.3) c: MAPC will support CZM and other state partners in the campaign for statewide policy change such as an Executive Order directing development and significant redevelopment (State Funded Projects) away from Coastal Hazard Areas, similar to Executive Orders 149 and 181.

Example: The Town of Chatham has set a primary example with the establishment of an innovative 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.

IV.D. D. Development and Infrastructure

Implementing adaptation measures not only protects the environment; it also helps a community plan for potential impacts, encourages sustainable development, and provides social and aesthetic benefits to the community. This sub-strategies included in this section are offered to protect developed areas such as implementing regulatory changes, providing development guidelines, and evaluating coastal protection structures (e.g., bulkheads, jetties). Of course, the long-term, more preventative strategy is to preserve natural resources and landscapes to ensure that high flood waters do not adversely affect infrastructure or development. The former option was previously described as priority measures. More immediate adaptation measures to be implemented at development/redevelopment sites are described below. It is important to note that the strategies suggested may require changes to development and redevelopment that will affect the grade and access to facilities, therefore; compliance with the American Disabilities Act must be considered in the design phase.

IV.D.1. D.1) Implement Protective Regulations and Zoning

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. Recent tragic impacts from intense coastal storms have shown that the lack of advance preparedness and continuation of development within high-risk areas can cause costly damage and great harm to a community. Therefore, the majority of the regulatory measures recommended are aimed at providing a community with rules and regulations that will allow the flexibility needed for development and redevelopment to occur in a smart, sustainable manner within appropriate areas. Designing communities that are compact and walkable, with high degree multi-modal transportation connections, builds stronger social networks and healthier communities- all outcomes that can increase community resilience and adaptive capacity.

There are numerous, innovative regulatory measures that can be implemented to protect economic assets within a community. A number of these measures have previously been explained under strategy A; Mitigation as Adaptation, such as regulation to allow for Green Infrastructure, and energy and water conservation measures. Additional, effective regulatory measures that the RCCAS Advisory Committee recommends as priority measures to protect development include:

- Revisions to State Building Code and Plumbing Code to allow for innovative flood proofing and water conservation and reuse measures;

- Inclusion of metrics/standards regarding climate change impacts in the Massachusetts Environmental Policy Act regulations;

- Review of local regulations and zoning to make required cross-sectional changes to eliminate prohibitions of climate resiliency measures;

- Establishment of an Urban Service Boundary to delineate areas of growth versus confinement of development in areas most vulnerable to climate impacts;

- Implementation of impact fees in areas vulnerable to climate impacts where fees are used to implement adaptation measures;

- Creation of zoning incentives to return impervious surfaces to permeable (e.g. parking for an abandoned mall to grass surface);

- Establishment of High Hazard or Floodplain Zoning (i.e. inclusion of the 500-year flood zone or "climate impact zone"); and

- Creation of more aggressive setback areas in floodplains. (Note: a buffer of at least 100 feet is needed to effectively remove nutrients and sediments.)

IV.D.1.a) STORMWATER MANAGEMENT

Stormwater management deserves some additional explanation due to its feasibility in protecting developed areas from various climate impacts; flooding, sea level rise, heat island effect, etc. As previously discussed, innovative green infrastructure can reduce runoff rates and volumes, retain coastal floodwaters, and reduce heat from vegetation cover.

Unfortunately, there are numerous municipalities across the region that do not have their own stormwater management bylaw/ordinance or regulations. These municipalities rely on the Massachusetts Stormwater Handbook to manage stormwater on public and private properties. In doing so, they can only manage stormwater in areas of jurisdiction under the Wetlands Protection Act, which authorizes the Massachusetts Stormwater Handbook, and it's Standards, for properties being permitted for development or redevelopment purposes. In addition, the current state Standards, while progressive, do not require that redevelopment projects design stormwater management facilities for the 100-year storm; which is now widely accepted as a much more frequent storm under climate change conditions.

Furthermore, in implementing the Stormwater Standards, DEP currently relies on Technical Release 55 (TR-55); a guide for estimating peak rates of discharge published by the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS). While the TR-55 manual is a useful reference containing curve number tables and rainfall maps, more advanced and/or accurate hydrology software is required to account for climate change conditions such as HydroCAD. Furthermore, the current NRCS method relies on a hypothetical rain event known as a "design storm" for their rainfall input. This single, hypothetical storm event is based on a compilation of local or regional rainfall data recorded over an extended time period. However, this rainfall data has not been updated in some time to account for more intense and frequent precipitation.

All residents, property owners and businesses have some impervious surfaces on their properties (rooftops, walkways, driveways, roadways) that contribute to the production of stormwater. Additionally, 99 of MAPC's 101 municipalities will be required to meet the conditions of the impending new National Pollutant Discharge Elimination System (NPDES) Small Municipal Separate Storm Sewer (MS4) permits for Massachusetts Watersheds. The concept of establishing a drainage service fee, whether administered under a new stormwater utility entity or existing department, has proven to provide a stable and equitable source of financing for stormwater programs. MAPC and project partners developed a Stormwater Financing/Utility Starter Kit to help municipalities take control of local water quality issues via a long-term funding source for stormwater management, which is encouraged by the EPA and DEP.

Step D.1) a: MAPC and its partners will work cooperatively to implement the list of priority regulatory changes on page 56 above.

Step D.1) b: MAPC will continue to help municipalities establish progressive stormwater management laws and regulations that include an option for the implementation of a fee or utility.

Step D.1) c: MAPC will continue to help municipalities establish a reliable long-term funding source for stormwater management (i.e. drainage fee and/or utility) where funds generated are used to implement GI techniques.

Step D.1) d: MAPC will work with DEP, USGS, and other partners to update the Standards to reference and/or require the use of advanced hydrology software and updated rainfall data.

Step D.1) e: MAPC will work with state grant program managers to include a requirement that local comprehensive plans include the mapping of natural hazards and natural environmental features, and identification and analysis of goals and objectives, and implementation steps to increase climate resiliency. Land use planning policies within Plans should also guide future growth away from high risk locations.

Step D.1) f: The Massachusetts Emergency Management Agency, in dispersal of FEMA Planning Grants, will require that updated Hazard Mitigation Plans are referenced within local comprehensive plans, and vice-versa.

IV.D.2. D.2) Low Impact Development Techniques

Low Impact Development (LID) is a term used for a specific type of development practice that has natural resource protection at its heart. Although the most protective measure is clearly a lack of over-development and the full protection of natural resources, in a densely populated region such as Metro-Boston, it is unlikely that significant natural resources areas will be protected as pristine. Therefore, the next best thing to protection is ensuring that wherever appropriately located development occurs (i.e. infill development, redevelopment, and development of degraded areas first and foremost), is protective of natural resource functions and values. As stated previously, these values are critical to climate resiliency as they provide the best defenses from flooding, increased heat and wind, and sea level rise in coastal areas.

It should be noted that the term "Green Infrastructure" has sometimes been interchanged with the term LID. We view these practices as complementary, but not interchangeable, as they focus on best practices for natural resource protection at different scales. Low Impact Development is a concept of how to best include practices – within a development area – that are less destructive to the

environment. Green Infrastructure practices include a series of tools to ensure that natural resource protection is achieved under a variety of conditions: at LID development/redevelopment sites, within pristine natural areas, and when retrofitting traditional or "grey" water management infrastructure. (A full explanation of Green Infrastructure is provided in the above sections.)

The state, through the efforts of EEA and numerous members of the former Low Impact Development Working Group including MAPC, have worked very diligently on promoting the importance and use of LID over the past decade. In 2003 EEA and partners developed the Smart Growth / Smart Energy Toolkit, which provides critical guidance regarding smart growth and smart energy practices such as LID. MAPC created a companion guidebook regarding LID practices in its LID Toolkit. Recently, the links between climate mitigation and adaptation through these techniques have been fully understood as critical measures that municipalities can take within both the short and long term to provide climate resiliency. Therefore, the following sections provide specific recommendations for the use of key LID tools for climate resiliency.

The best site design practices should ensure that natural resources conservation measures and impact minimization is included. Implementation of these practices will provide protection of both natural resources and development from climate impacts. In addition, having adequate standards for best site design is the best approach to ensuring that Low Impact Development (LID) and Green Infrastructure (GI) approaches are implemented. The difference between a standard or conventional site design and a LID-based design is shown below in Figure 3.12. As shown, there are clear differences between the conventional design with large and widely distributed lots, versus the LID approach where natural green spaces and buffers are preserved, as well as use of GI for stormwater management.

Figure 3.12: Conventional site design (left) with an LID-based design (right).

Source: Puget Sound Partnership.

In communities that are weary of mandating these types of standards into site design, incentives may be included for developers to consider including LID practices into site planning in return for waivers or other review benefits such as:

- Reduced stormwater utility and/or application fees,

- Expedited project review and approval,
- Relief from specific development standards (e.g. density, lot size, etc.), or
- Property tax reduction for a given period.

Step D.2) a: MAPC and its partners will continue to work with municipalities to ensure that development and redevelopment occurs using low impact development standards. Specifically, MAPC will:

- Work with municipalities to include incentives for LID practices within new development or redevelopment areas in zoning/regulations (e.g., tax incentive, reduced impact fees, bonus density, and expedited review).
- Work with municipalities to ensure that LID is included as a mandate in local comprehensive plans.
- Research regional success stories for educational purposes and create educational materials that target homeowners, municipal officials, and academic institutions.

Step D.2) b: As needed or requested, MAPC will work with municipalities to create Development Site Design/Subdivision Guidelines that are inclusive of climate adaptation measures (i.e. LID and green infrastructure).

IV.D.3. D.3) Establish Green Building / Climate Resilient Design Guidelines

Although the U.S. Green Building Council has done a tremendous job in increasing the sustainability and energy efficiency of buildings, while decreasing carbon footprint, there are a number of techniques specific to climate resiliency that must be included in building design. Table 3.4 compares a list of USGBC site selection ("sustainable site") categories with items specific to climate resiliency.

Table 3.4. USGBC v. Adaptation Measures

	USGBC Measure	Adaptation Measure
Site Development—Protect or Restore Habitat	X	X
Open Space	X	X
Rainwater Management	X	X
Heat Island Reduction	X	X
Light Pollution Reduction	X	
Design and Construction Guidelines	X	X
Joint Use of Facilities	X	
Places of Respite	X	
Outdoor and Indoor Water Reduction	X	X
Flood Proofing		X
Water Reuse		X
Decentralized Wastewater		X
Alternative Energy Sources	X	X
Protect/Utilize Natural Resources		X
Green Infrastructure		X

IV.D.3.a) FLOOD PROOFING

Mandating or incentivizing flood proofing measures in development/redevelopment sites within floodplain areas is critical to protecting the public good, health and welfare of residents, and economic vitality of the community. Unfortunately, there are some existing barriers to allowing more innovative or progressive, yet necessary flood proofing measures, as described below.

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

- 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 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 not typically encouraged to adopt and enforce floodplain management ordinances or laws more stringent than the minimum requirements.

Step D.3) a: MAPC and its partners will work with municipalities to include the following building specifications within floodplain areas to reduce or eliminate flooding/sea level rise 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*.

Step D.3) b: MAPC will also assist coastal communities with implementation of the following design and siting considerations:

- 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.
- 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.

IV.D.4. D.4) Protect Critical Infrastructure

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).

IV.D.4.a) Water Infrastructure

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."

Protection of drinking water sources and infrastructure from floodwaters and increased heat are critical measures 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.

Wastewater collection and treatment systems could also 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. It is also important for communities to eliminate combined sewer overflow (CSO) systems, which could increasingly overflow due to increased storm events and intensity.

As noted previously, stormwater management is in the forefront of municipal leaders' minds because it represents the initial stages of climate change impacts. 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 innovative stormwater techniques, reusing rainwater and managing stormwater at the site (rather than through a piped system).

EPA cost estimates associated with protective measures for potable water in the Northeast ranges from $70 to 90 billion. They estimate the costs associated with wastewater adaptation strategies (capital and operation and maintenance) to range from $31 to 61 billion. These estimates nearly triple the current $38 billion gap in funding to merely upgrade and repair existing water infrastructure in Massachusetts.[56]

Due to these financial and resource-based constraints, it is recommended that municipalities consider a long-term integrated water management (IWM) approach to protecting water resources. As described previously, IWM includes looking holistically at drinking water, stormwater and wastewater systems along with water resource management. In the case of developed areas, the goal of IWM is to maintain watershed integrity and waterbodies natural flood protection functions. Resources can be shared amongst water, wastewater and stormwater managers. In addition, innovative techniques that provide mutual benefits to each water management division are possible under an IWM plan. For example, policies mandating or incentivizing reclaimed wastewater or rainwater harvesting would reduce water demand.

Step D.4) a: MAPC will assist DEP and local water managers to implement the following critical adaptation measures to protect existing water supplies and wastewater facilities:

- Plan and make resiliency investments (e.g., local, sustainable water supplies; additional wastewater treatment and/or reuse; and ecosystem restoration).
- Monitor and regulate existing systems (e.g., ecological monitoring and protection, pollution control, monitoring population growth).
- Maintain, rehabilitate, and re-engineer existing systems for climate adaptation (e.g., dams, pumps, tide gauges, streams/beds, and wetlands).
- Modify and reduce demands on existing systems (e.g., rainwater harvesting, water conservation, pricing, regulation, basin planning, funding for ecosystem services, stakeholder participation, consumer education and awareness).
- Introduce more efficient technologies for water supply, is needed (e.g., desalination, biotechnology, and wastewater reuse and recycling).

[56] Massachusetts's Water Infrastructure: Toward Financial Sustainability. Water Infrastructure Finance Commission. Feb. 7, 2012.

Step D.4) b: MAPC will work with DEP and other partners to publicize adaptive water supply strategies including:

- Additional treatment and filtering,
- Reconstruction, removal, or relocation of vulnerable infrastructure; and
- Development of protective walls around key infrastructure and treatment facilities.

Step D.4) c: MAPC will work with its partners to persuade DEP to consider the re-design of septic system standards in floodplain areas to offset climate change Impacts (i.e. saltwater intrusion, elevated groundwater table, flooding, etc.)

Step D.4) d: In addition to the IWM strategies previously included, MAPC will promote the following IWM measures to protect development and infrastructure:

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

Step D.4) e: The Water Infrastructure Alliance should work with legislators to establish funding (e.g. State Revolving Fund) and guidance for climate resilient water/wastewater infrastructure projects such as elevation of structures, watertight doors and windows, submersible pumps, and emergency back-up provisions.

IV.D.4.b) TRANSPORTATION

Transportation is typically viewed as one of the "causes" of climate change due to the sector contributing a full third of total carbon dioxide emissions released in the United States.[57] Therefore, emphasis on mitigation techniques has been the focus of not only climate change policy but also transportation planning. However, it is widely recognized that adaptation practices protecting existing and future transportation facilities must be implemented in order for many mitigation measures to be effective.

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

[57] Ewing, R., Bartholomew, K., Winkelman, S., Walters, J., and Chen, D. (2008). Growing Cooler: The Evidence on Urban Development and Climate Change. Urban Land Institute, Washington D.C.

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.

Step D.4) f: MAPC will work with Mass DOT and MA DPH partners to develop non-motorized transportation options that are essential to reducing environmental implications of climate change AND promoting human health.

Step D.4) g: MAPC will work with its municipalities and Mass DOT to:

- Establish a distribution network, refueling stations, storage facilities, structures and methods for transporting, and charging stations,
- Increase toll facilities and high occupancy toll and vehicle lanes with electronic surveillance systems for monitoring these lanes,
- Encourage behavioral changes in mode choice through increased transit/pedestrian/cycling.

Step D.4) h: MAPC will provide critical transportation planning guidelines to municipalities to ensure that:

- Collaboration across multiple disciplines occurs including environmental agencies, air quality or natural resource agencies, freight carriers, operating agencies, local government authorities, emergency response teams, etc.
- Promotion of compact and transit-oriented development patterns through the development of travel demand forecasts, population projections, and a regional vision.
- Inclusion of performance measures within Long Range Transportation Planning efforts and the transportation improvement program (TIP) that are tied to mitigation and adaptation of climate change impacts.

IV.E. E. Safeguard Health and Human Resources

There is a critical link that must be connected between the public health and medical field and climate change impacts. As we've learned from our public health partners, the most critical threats to public health from climate change include various illnesses caused by increased Ozone (O3); Particulate Matter (PM); and Greenhouse Gasses: Carbon Dioxide – CO2 (fossil fuel combustion), Methane - CH4 and Nitrous Oxide - N20 (production of coal, natural gas, and oil), and Fluorinated Synthetic Gases (industrial processes). Ozone occurs when chemical reactions occur, in the presence of sunlight, between Oxides of Nitrogen (NOx) and Volatile Organic Compounds (VOC) caused by emissions from industrial facilities and motor vehicle exhaust. Primary Particulate Matter is emitted directly from a source such as construction sites, unpaved roads, fields, and smokestacks or fires. Secondary Particulate Matter is formed in complicated reactions of chemicals such as sulfur dioxides and nitrogen oxides that are emitted from industries and motor vehicles. All of these gases, particulates, and chemicals cause premature death in people with heart or lung disease, heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory

symptoms such as irritation of the airways, coughing or difficulty breathing. In addition to the above issues, lengthened seasons will exacerbate asthma and allergic responses.

Increased sea level rise and more intense and frequent storms also create a whole host of public health impacts such as water pollution from flooding and inadequate stormwater management, and injuries and death caused by severe storm events. Another critical water-related public health impact is the increased potential for food-related illnesses caused by increased pollutants in fish and shellfish.

Vulnerable Populations are particularly susceptible to these impacts for numerous reasons, as described in the vulnerability assessment. It is critical for climate leaders to assess vulnerabilities within environmental justice, low-income, minority, and disabled or ill populations to determine how best to minimize their impacts, particularly since these populations typically lack access to funding or community support. Across the board, mitigation and adaptation of climate changes will not only decrease public health impacts, it will also lower or in some cases eliminate costs associated with caring for patients that have been impacted.

The sub-sections below describe implementation measures to address public health impacts.

IV.E.1. E.1) Identify and Protect Vulnerable Populations

Commonly, the neighborhoods that are home to vulnerable populations have the least amount of green spaces, natural areas, and other forms of urban greening such as street trees. Providing green infrastructure to these areas can help protect against flooding, reduce polluted runoff, lessen heat impacts, and provide green space for recreation and community gardens. Investments in green infrastructure will be a community asset whether or not a neighborhood endures the most extreme impacts of climate change. New, expanded, and improved parks and other green, open spaces that meet residents' needs are co-benefits of green infrastructure investments.

Increasing heat island effects punctuated by more instances of life-threatening heat waves make air conditioning less of a luxury and more of a public safety necessity than in previous times, especially for elderly, children with asthma, and those with other health issues. There are a number of ways for how programs could be structured, from bulk procurement of air conditioning units, to the provision of grants or low-interest loans to households in need, to direct assistance installing units in buildings. We must overcome the long-standing bias against providing air conditioning in public and subsidized housing, and recognize that it is increasingly a necessity for good health.

Historically, the neighborhoods of vulnerable populations have borne a disproportionate share of land uses with adverse human health and environmental effects. As a result, many neighborhoods still have industrial and other uses that could be particularly dangerous in a storm or flooding event. Inventorying where high risk toxic release sites are in relation to vulnerable populations and enhanced climate risks and requiring the sites posing the most risks to make acceptable preparations is essential to protecting vulnerable populations. Failure to prepare for such emergencies could carry significant public health risks.

While climate change brings enormous risks to people's health and safety, it can also have large economic consequences. This comes not just from the initial destruction that may occur, but from the prolonged economic disruptions that may follow a climate event. These economic tolls will be more difficult to bear for those already struggling economically and with the least resources to use for recovery efforts. Loss of property is only one such effect of major climate threats. Another effect is the potential impact on the jobs of low income workers. This may be in the form of short term job

hiatuses for hourly wage earners which are very harmful to those living from paycheck to paycheck. In addition, there may be long-term job losses as a local economy struggles to rebound from a larger event such as Hurricane Katrina or Superstorm Sandy. The economic damage also extends to businesses that serve as local employers as well as providers of vital goods and services to low income communities. Small farms are also vulnerable to economic loss due to climate changes.

Local business owners are less likely to have the resources to prepare for and rebound from adverse climate events and so there is a role for government to help either with financial assistance or providing information and guidance. An example of this would be offering technical assistance, grants, or low interest loans for retrofitting buildings.

Physical labor under extremely high temperatures or excessive wind or rainfall has severe health implications for those who are forced to work, either by their employer, or by their own financial need. Weather extremes can also significantly reduce income if work days are curtailed due to dangerous working conditions or the inability to get to work due to transportation shut-downs.

Step E.1) a: Plan for climate change with vulnerable populations in mind. Climate change will result in disproportionate impacts on those with the least resources to adapt, therefore; planning for climate change must account for the differences in physical vulnerability of developed areas across various geographical locations, but also the differences in social vulnerability of different populations, described in Step E.1.b) h below.

Step E.1) b: Climate change vulnerability analyses in the region should be informed by social vulnerability indices. A social vulnerability index will show locations within a region where populations have the least capacity to prepare for, cope with, and respond to climate change impacts. The data for climate hazards and social vulnerability taken together can reveal "hotspots" – places where both high levels of social vulnerability and high risk for hazardous climate events overlap. Identifying and classifying hotspots is one way to prioritize and target strategies to increase resilience in places where they would be most effective.

Step E.1) c: All levels of government should plan for climate change adaptation, engaging vulnerable populations throughout planning processes. There are a variety of ways to incorporate climate adaptation planning within other local planning processes such as hazard mitigation plans, capital improvement plans, open space plans, and master plans. Ensuring that vulnerable populations are themselves included in planning and decision making around climate change is essential at all levels of planning.

Step E.1) d Municipalities should ensure that vulnerable populations are prepared for climate change by taking the following steps:

- Disseminate information about potential climate impacts widely and effectively.
- Ensure that disaster preparedness materials are translated into languages that represent minority populations within their communities.
- Proactively identify and develop relationships with partners that serve vulnerable populations.
- Enable vulnerable residents to evacuate when needed, as well as employing specific procedures to handle communications with vulnerable populations during a disaster.

Step E.1) e: Municipalities should invest in green infrastructure in areas with concentrations of vulnerable populations and require or encourage green infrastructure to be incorporated into private developments.

Step E.1) f: State and local governments and affordable housing financiers should work to ensure that housing occupied by low-income households is weatherized, through the following steps:

- Ensuring that new and redeveloped affordable housing includes elevated utility panels and equipment, pervious areas and green infrastructure, insulation to keep buildings cool or warm during power outages, and back-up or alternative energy generation.
- Provide financial assistance (low interest loans or grants) to owners of properties where vulnerable populations reside to perform climate proofing measures.
- Modernize and retrofit state-owned affordable housing in vulnerable areas.
- Create financial and technical assistance programs to help low-income households acquire, install and run high-efficiency air conditioning units.

Step E.1) g: The State should require sites harboring toxic chemicals to do a climate change vulnerability assessment and a site specific climate preparedness plan.

Step E.1) h: State, regional and local governments should work together to address the economic threats of climate change to the livelihoods of at-risk populations.

Step E.1) i: Governments should work with small and medium sized local businesses in communities with concentrations of vulnerable populations to help them prepare for climate related threats.

Step E.1) j: State and local governments should create policies and programs to address issues faced by laborers that will be most affected by extreme weather events, such as:

- State guidelines to protect non-essential workers in both the private and public sectors from being required to work during high heat conditions, flooding, and other extreme weather conditions.
- Local guidance to employers on worker safety during climate events, such as issuing advisories during storms or heat waves. These could contain specific recommendations such as limiting heavy manual labor in a heat wave.
- State programs, such as an unemployment style fund, that provides low income workers with paycheck insurance when work is curtailed by extreme weather events.
- Public transportation authorities should have contingency plans in place for components of their systems most relied upon by vulnerable populations to make sure there are as few service disruptions as possible during and after weather events as safety allows.

IV.E.2. E.2) Build and Bolster Community Resilience

While there is the potential for significant changes in the environment, there is a clear role for social connectedness in helping populations prepare for, respond to, and recover from the impact from climate change. As witnessed in the recovery from several recent natural disasters, communities

that had stronger ties and networks have reacted faster to meet needs and begin recovery efforts. These community responses have also occurred in the context of overwhelming need throughout a region and in the absence of trained emergency personnel who were not able to cover entire communities. Additionally, there is a growing body of evidence that social cohesion is a protective health factor as those with stronger connections typically experience healthier outcomes.

It is also critical for the general public to have a better understanding between weather variations, climate change, and public health impacts to best protect and adapt. Currently there has been very little general public outreach regarding climate change, aside from media attention in the aftermath of devastating natural disasters such as the European Heat Wave (2003), Indian Ocean Tsunami (2004), Hurricane Irene, Hurricane Katrina (2005), and Superstorm Sandy (2012). The following implementation steps must be set in motion to ensure that public education to all populations, including specific materials for non-English speakers and those with disabilities (i.e. sight or hearing impaired).

Step E.2) a: Municipalities and regional partners will utilize community-based groups and trade organizations should be utilized as part of outreach and education about the risks of climate change and actions that can be taken to prevent and respond to these risks such as vector-borne diseases and inhaled allergens.

Example: These groups and organizations typically serve in an organizing role for their constituents and as such are often at the center of personal and professional networks. Moreover, there are community based groups throughout the region that specifically serve vulnerable populations. With these groups serving a communication point, education and information campaigns to target vulnerable populations and provide information about nearby cooling centers, neighborhood programs, and resources to reduce risks for their homes and other assets.

Step E.2) b: Municipalities and regional partners will develop or enhance existing programs to encourage community connectedness related to natural hazard preparedness and response.

Example: Many cities and towns across the state already conduct trainings for Community Emergency Response Team (CERT), which enhances the ability of citizen volunteers to assist relatives and neighbors with disaster response. This model could be used to build additional capacity around community preparedness and recovery. It could also range from a lower investment program that primarily shares information, but could also be a more intensive program that provides specific skills training. Additionally, this model could be used within specific population groups, or organizations that serve these groups, to ensure that there is broad community participation and knowledge of the program. For example, rather than just requesting participants, a program could partner with a cultural organization to host a training or make the training available for non-English speakers.

E.3) Ensure Access to Food Supplies

The changing weather and temperature patterns that are predicted to accompany climate change will alter the Commonwealth's and New England's food system both positively and negatively. Existing crops may no longer be feasible, whereas other crops that typically could not be cultivated in the state may now be possible. The monitoring effort should address the quality of our food production as well as the potential health impacts as it moves through the system. Food supplies should be monitored for potential disease outbreaks, especially to identify the occurrence of new diseases and disease patterns. Therefore, it will be critical for public health partners to implement

steps to monitor and respond to changes related to our current food resources while creating the space to embrace new opportunities.

Step E.3) a: Conduct research to verify baseline conditions related to food-borne diseases and begin to explore and estimate if other diseases could be introduced into the system as a result of new environmental conditions or changing policies and regulations.

Step E.3) b: Provide technical and financial support to those in the production sector of the food systems. For example, farmers should be provided with opportunities to learn how to transition to new crops and what new infrastructure might be required.

Step E.3) c: Implement elements of the MA Food System Plan aimed at maintaining local sustainable food systems. These resources would increase the capacity of local units of governments, neighborhoods, and communities to reduce reliance on foods that rely on long distance distribution networks. The added capacity would provide a source of food in the event that the transportation networks were disrupted or if local access to grocery store and other food access points was restricted. Partners could include school and community centers, housing authorities, Mass in Motion coalitions, Community Development Corporations, and Homeowner Associations among others.

E.4) Prepare for Worsening Air Quality

As the climate changes, air pollution is predicted to get worse and conditions will likely become more hospitable to allergens. For example, increased temperatures can make smog pollution worse and lead to more "bad air days" and put many at risk for eye, nose, and lung irritation. In particular, the worsened outdoor air quality makes it more dangerous for people with respiratory diseases like asthma. Similarly, rising carbon dioxide levels are expected to cause plants to produce more pollen which will increase exposure for those with allergies. Several actions can be taken to address changes in outdoor air quality:

Step E.4) a: Implement strategies to reduce the amount of vehicular travel occurring in the region; concurrent with transportation strategies.

Step E.4) b: Explore the potential for the use of hypoallergenic species as part of green infrastructure investments. Hypoallergenic trees and shrubs are those the produce little to no pollen (typically female). Examples of trees and shrubs that can meet this description are Azaleas, Red Maples, Yellow Poplars, Hydrangeas, Spruce, and Firs. Depending on site conditions, public and private investments to increase ground cover should consider the use of hypoallergenic species in order to minimize allergen exposure.

IV.E.3. E.5) Weatherization & Green Building Measures

As a first step, it is critical to retrofit existing, and include in new, low income and public housing with proper weatherization, energy conservation, and efficiency upgrades. These measures improve the ability of buildings to better protect residents from exposure to severe weather events and increased heat, and humidity that causes mold, pollen, and other allergens. In addition to reducing public health impacts, these measures provide clear economic benefits in reducing energy usage and expenses on energy usage.

The Green Justice Coalition (GJC) is a multi-city partnership of over 50 community and environmental groups, labor unions and other organizations that support a sustainable, equitable, and clean energy

economy. The GJC has argued that state energy efficiency program processes and benefits have been handled inequitably. Although everyone pays the electric service benefits charge, which funds state energy efficiency programs, evidence suggests that beneficiaries have primarily been the very poor or the middle class, but leaving out a wide swath of households who are of moderate income, but nevertheless priced out of participating in these programs. For renters, the problem is that they are at the mercy of landlords on building upgrades. In fact, landlords often make the least energy efficient choices because energy costs are almost always the responsibility of tenants.

Step E.5) a: Municipalities will work with property owners to retrofit existing, and include in new, low income and public housing with proper weatherization, energy conservation, and efficiency upgrades.

Example: A recent initiative, which was spearheaded by GJC, calls for a new and open system of data collection and data sharing, including geographical identifiers (e.g. Census tract or ZIP code) so that program participation and delivery of weatherization and energy efficiency programs can be tracked at the neighborhood level, especially in low and moderate income neighborhoods.

Step E.5) b: MAPC, municipalities and climate adaptation partners will promote the use of heat island effect reduction strategies. The purpose of these strategies is to minimize heat magnification, especially those that occur in areas with significant amounts of impervious cover and that are lacking in vegetation. These strategies could include the use of cool/white roofs and green roofs, the introduction of green spaces and shade trees, and other pieces of built and natural infrastructure that increase ground cover and reduce heat abortion. Reduction of the heat island effect will reduce heat stress on buildings as well as the buildup in neighborhood. A good resource for strategies to reduce heat islands is the USEPA's *Reducing Urban Heat Islands: Compendium of Strategies* (http://www.epa.gov/heatisland/resources/compendium.htm).

Step E.5) c: State agency partners and legislators will develop technical assistance and grant/loan programs for water damage and mold abatement at private residences (e.g. Solarize MA).

IV.E.4. E.6) Ensure Coordination and Collaboration

The importance of collaboration between public health organizations; local, regional, state, and federal governments working on environmental, transportation, and land use planning; physicians; academia; and community groups cannot be underemphasized. Climate change affects all sectors of our society, and therefore; coordination is essential to planning and implementing climate adaptation and mitigation policies. This includes strengthening the connections between those working in the public health field as well as building stronger ties to other sectors such as environment, transportation, and land use planning, and emergency preparedness and to community groups.

It is also critically important that organizations working closely with vulnerable populations are coordinated with early in the process of planning and implementation such as public housing associations and affordable housing advocacy organizations, elderly associations, nursing home trade organizations, minority/immigrant groups, and disabled assistance.

Step E.6) a: Public health officials and organizations should begin to incorporate climate vulnerabilities into existing plans. These vulnerabilities may be the amplification of existing issues and the introduction of new health issues, like new vector-borne diseases that are made possible by warmer weather condition and more frequent heat waves. State, regional, and local health organizations should begin to research, document, and integrate climate vulnerabilities into

documents such as community health needs assessment, community health improvement plans, and emergency operations plans. In some cases, the health department may not be directly for some of these planning documents, so it is encouraged that officials participate in other related process such as those led by hospitals and health care providers.

Step E.6) b: As a foundation is set to anticipate and respond to new vulnerabilities, the state and municipal health infrastructure should build on the existing surveillance and health outcome tracking in order to identify and monitor health impacts related to climate change. The surveillance program will assist in identifying if expected, or unexpected, changes are occurring and evaluating if planned response measures are having the intended effects.

Example: At the state level, the DPH has the Environmental Public Health Tracking (EPHT) Network which includes health and environmental datasets. This network as well as other surveillance systems like those run locally and through universities should be updated to include new indicators for climate vulnerabilities. The increased surveillance capacity will allow for more accurate tracking of climate related mortality and illnesses and environmental risks. Additionally these updated tracking systems could include indicators for protective factors and adaptive capacities, which could provide early information about best practices for reducing risk.

Step E.6) c: Mechanisms should be used to provide technical advice and communicate the health-related aspects of climate change, including risks and risk reduction. Existing communication methods to provide alerts via traditional and social media should continue, such as the dissemination of air quality ratings and heat advisories. These should be supplemented information on how the public can be proactive to address predicted events and reduce potential risks. Often, information and resources on how to respond are provided while these extreme events are happening; resources need to be provided in advance and on multiple occasions in order to have a prepared populace. Additionally, notice and resource information must be accessible to all residents (i.e., translated from English to other relevant languages) and may need to be framed appropriately to reflect cultural and age norms.

IV.F. F. Local Economy and Government

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.

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 important to ensure that cross-departmental collaboration occurs. The handbook *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*[58], developed by King County, Washington offers excellent guidance on how municipalities can work within existing programs when planning for climate change. The United Nations Office for Disaster

[58] http://cses.washington.edu/cig/fpt/guidebook.shtml

Risk Reduction (UNISDR) released an excellent resource, *Making Cities Resilient Report 2012*[59], which offers critical strategies that local governments around the world are using to build resilience and to act on climate change adaptation.

In addition, there are many ways in which municipalities can integrate climate change planning into local regulations and policies to better ensure their local economic and government operations function efficiently and effectively in the face of climate change, in particular after major storm events.

IV.F.1. F.1) Internal Coordination

It is important for municipalities to consider assigning a single climate change preparedness "point person" in order to ensure that there is management, monitoring, and oversight of the municipality's climate preparedness efforts. This person can be an existing municipal staff member or a newly hired individual with expertise in climate change and emergency preparedness to carry out the task. A municipal planner or member of the Planning Board can take on this role due to their experience in tackling a wide range of planning issues.

Step F.1) a: MAPC will develop a template of responsibilities for municipalities to adopt while appointing a climate change preparedness "point person".

Step F.1) b: MAPC will explore the possibility of assigning shared point persons in capacity-challenged communities to deal with climate change and preparedness issues.

Step F.1) c: Whenever feasible, local governments will assign a local point person that has 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.

Since climate change impacts affect a multitude of local sectors including development and business, environmental resources, public health, agriculture, tourism, etc., it is important to create a working group of individual that can assist the local planner or point person to prioritize and implement strategies.

[59] http://www.unisdr.org/we/inform/publications/28240

Step F.1) d: Local governments will establish task forces, committees, or working groups comprised of key municipal officials and local stakeholders to address climate preparedness.

Step F.1) e: MAPC will investigate the effectiveness of a regional resilience board with members from various local sectors.

Example: The city of Barcelona has established a 'Resilience Board' that encompasses 37 institutions across a variety of sectors to manage coordinated and collective responses. Another example was identified in Tucson, AZ, where a Climate Change Advisory Committee was established in 2006[60]. The committee, which includes experts from the public, private, and nonprofit sectors is responsible for developing a Climate Change Mitigation and Adaption Plan; identifying and prioritizing concerns and issues related to long-term environmental, social and economic sustainability; reviewing the City's Sustainability Strategic Plan; framing priorities for sustainability that balance environmental protection, economic vitality, social equity; and more. Cities and towns in the MAPC region should adopt similar structures to ensure that all perspectives are considered in a municipality's climate change preparedness efforts.

IV.F.2. F.2) Budget and Resources Allocation

In addition to institutionalizing climate adaptation and risk mitigation functions, one of the biggest challenges that cities and towns in MAPC's region will face is the availability of resources for doing this kind of work. It is imperative that municipalities identify ways to finance risk reduction initiatives, and the UNISDR *Making Cities Resilient Report* identifies two ways of incorporating funding in municipal budgets.

The first method is to have a distinct budget for climate change mitigation and recovery, channeled through a third party agency. Beirut, Lebanon is one example of a city that allocated a special budget for disaster risk reduction. Alternatively, climate adaption and resilience funding can be integrated across the budgets and projects of existing municipal departments. This is an approach that has been utilized successfully both in Quito, Ecuador and in Cape Town, South Africa.

Municipal budgeting will provide a solid base with which to fund climate adaptation work, but it is equally important to take advantage of state-wide and national grant initiatives. Massachusetts' Office of Environment and Energy has demonstrated a strong commitment to Climate Change, dedicating $50 million in grant funding[61] to promote comprehensive climate change preparedness initiatives across the Commonwealth. This grant will be administered by the Department of Energy Resources (DOER).

Step F.2) a: MAPC will work with communities to identify which municipal budgeting structure is most effective through:

- Researching what has worked in other cities and towns
- Functioning as a clearinghouse of information for municipal climate change funding mechanisms

Step F.2) b: MAPC will assist communities with applying for state and national funding to implement climate adaptation projects.

[60] http://www.tucsonaz.gov/ocsd/climate
[61] http://www.mass.gov/governor/pressoffice/pressreleases/2014/0114-climate-change-preparedness-investment.html

IV.F.3. F.3) Identify, Support and Protect Assets Critical to an Functioning Economy

Prolonged disruption of economic activity due to climate change, particularly during and after severe storm events, can result in long lasting repercussions on local and regional economies. It is crucial that communities prepare for and adapt to changing climate conditions, including their ability to "bounce back" quickly and efficiently. They must be resilient.

Municipalities should work collaboratively with public and private sector partners to identify the critical economic assets most likely to be impacted by climate change, including municipal/public safety facilities, critical infrastructure (energy, communications), transportation networks, cultural assets, and local businesses, and develop strategies to mitigate impacts.

Crucial to maintaining economic activity is the hardening of critical infrastructure to ensure reliable service delivery (electricity, communications, distribution), particularly in the aftermath of an emergency/severe weather event. Additionally, building regulations should be revised to require techniques and materials that better respond to changing climate conditions and that are better able to withstand impacts from major storm events (e.g. flooding, wind, heavy rain and snow, and/or drought events).

Step F.3) a: MAPC will convene municipalities and regional entities in an effort to identify critical regional economic assets and systems, including key infrastructure that require hardening to prevent disruption of economic activity.

- Map critical regional assets so that municipalities can better address needs.
- Prioritize "hardening "of critical systems against water and/or drought through the use of weather resistant materials, placement of key electrical/communications infrastructure underground, and locating critical systems (HVAC, back-up generators) on higher floors, etc.
- Ensure transportation infrastructure is designed and constructed to withstand climate impacts from prolonged periods of drought or precipitation, extreme heat or cold, and severe storm events, etc.
- MAPC will assist communities with applying for state and federal funding to assist municipalities to "harden" infrastructure.

Step F.3) b: MAPC will work with communities to incorporate changes to building regulations that will better enable them to function before, during and after a severe storm event.

- Require key systems (electrical, HVAC, communications) in new buildings or renovations to be located on higher floors above flood zone levels to avoid internal service outages.
- MAPC will work with municipalities to identify funding sources to assist property owners with flood and storm proofing critical systems.

IV.F.4. F.4) Create Resilience Networks and Cultivate Partnerships

Augmenting shared strategic partnerships among the public and private sectors with regional networks can further leverage climate change resources, planning and implementation. 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 institutions engaged in these partnerships include Antioch New England, Cornell University, Columbia University, Rutgers University, Manomet Center for Conservation Studies, the Nature Conservancy, ICLEI and Clean Air/ Cool Planet. A local example was identified in the North Shore of Massachusetts, where 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*.

Step F.4) a: Communities should engage with MAPC and other regional partners such as Chambers of Commerce, Watershed Associations, and the MAPC Subregional Council Members to devise a subregional outreach program regarding the development of adaptation plans and mitigation planning.

Collaborating towns and cities that have identified climate change preparedness issues, or individual communities, should contact relevant state agencies and Regional Planning Agencies (RPAs) or Council of Governments (COGs) to help them support, facilitate and fund climate preparedness planning. Regional approaches are warranted for discussion due to the wide-spread geographic nature of climate impacts.

Additionally, the nature of climate change and adaptation is such that it transcends local geographical boundaries. It is therefore imperative that state partners, RPAs, and municipalities work together to identify regional solutions to climate change, such as organizing a circuit rider type of assistance program where an experienced climate planning professional could provide focused assistance to municipal staff and boards. 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.

Step F.4) b: MAPC will continue to be a resource to its municipalities to help them progress with their climate adaptation efforts by offering guidance on best practices.

Step F.4) c: MAPC will engage in knowledge exchange with other RPAs in Massachusetts and the greater New England region to identify regional solutions to climate change, and facilitate the organization of a circuit rider assistance program for climate planning training programs.

Step F.4) d: MAPC will assist local governments in providing critical, targeted outreach and education to key stakeholders that are needed as partners in implementing climate adaptation and mitigation measures. Specific audiences and measures include:

- 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. Internal and public presentations can be created from information provided in this report. 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/Property Owners: 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.

- Developers/Agents and Businesses: 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 is critical to current business owners, as well as developers. 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.

IV.F.5. F.5) EMERGENCY PREPAREDNESS

Local governments and municipalities have a great responsibility in ensuring that they are prepared to deal with emergency and disaster response. Hurricane Sandy was a grim reminder of the important role that municipalities in the MAPC region will need to fill in order to ensure that communities are well-prepared and well-equipped during large-scale weather emergencies.

One of the key goals of emergency planning, as described in the UNISDR *Making Cities Resilient Report*, is to ensure that in the event of any emergency, institutions, organizations, schools and the general public have the knowledge and capabilities to be able to reach a place of safety. Municipalities will need to install early warning systems to ensure that communications are critically conveyed. This has historically been done through loud speakers and broadcast warnings on local radio stations, although more cities are taking advantage of mobile device penetration and utilizing services such as SMS and Twitter to disseminate hazard warnings effectively.

In the event of an emergency, first responders such as police, fire, and ambulances can very easily face a situation where their local capacity is exceeded. As identified in the Massachusetts' state-wide *Climate Change Adaptation Report*[62], support is consequently requested and provided by the next higher level of government. However, there are several ways in which regional planning agencies such as MAPC can enhance the emergency management capabilities of its member cities and towns, such as increasing education and outreach; ensuring that critical sectors are well-equipped; helping cities and towns procure emergency equipment and services; and facilitating the sharing of emergency services when applicable.

[62] http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html

Step F.5) a: MAPC will work with municipalities to increase citizen awareness and enrollment in local and state sponsored emergency notification systems.

Step F.5) b: MAPC will work with municipalities to increase awareness existing regional emergency preparedness resources including training and exercise opportunities, equipment, and planning assistance.

Step F.5) c: MAPC will develop regional guidance on ensuring that sectors such as energy, which are critical to the function of first responders and other critical services, are able to function seamlessly in case of emergencies:

- Promote the use of micro-grids and renewable energy at vital service stations such as hospitals
- Promote the use of solar energy at pump stations for emergency service vehicles
- Encourage the development of distributed energy generation sources to support emergency centers such as schools

Step F.5) d: MAPC will continue assisting municipalities in identifying emergency preparedness planning and resources gaps and will work to address these gaps through technical assistance or regional procurement services.

Also, see Section F.3 for more on infrastructure hardening (transportation and communication networks), a crucial component for effective emergency preparedness and response.

IV.F.6. F.6) Protect Agricultural Resources and Agro-Tourism

Forces of climate change and development threaten the state's land-based agriculture, commercial fishing, the economy and the environment. In the face of these challenges, adapting farm and fishery production practices and leveraging government policies and program services will help protect Massachusetts' agricultural and marine production and facilitate its resilience.

The sub-sections below describe implementation steps to protect agricultural and commercial fishing resources.

IV.F.6.a) AGRICULTURAL LAND CONSERVATION AND ACTIVE USE

Decades' trends in Massachusetts show farm acreage loss[63] that continues to pose a major threat to agricultural food production and the agricultural economy. As farmers age and plan for the future of their farm operations, Massachusetts is faced with the need to incentivize farmland preservation, and enable young farmers to gain farmland access. Federal, state and local programs are in place to halt the loss of agricultural land and encourage expanding this land base. The land conservation measures addressed earlier in this report in 'Protect and Preserve Natural Resources' should be applied here. Specific to agricultural preservation, the following programs and policies should be integral to an adaptation strategy.

Table 3.5: Programs and Policies for Agricultural Adaptation

Program / Policy	Administration Level	Function
Federal Farm and Ranch Lands Protection Program[64]	Federal	This program provides matching funding to state and local agencies to purchase conservation easements that preserve agricultural land and prohibit conversion to non-agricultural uses.
Agricultural Preservation Restriction Program (APR)[65]	State	This program pays farmland owners the difference between "fair market value" and "agricultural value" of land to preserve agricultural land and prevent non-agricultural development.
Zoning for Urban Agriculture	Municipality	Boston[66] and Somerville[67] are two examples of municipalities that have reformed zoning to allow for urban agriculture and keeping small livestock as a means to enable and protect urban food production enterprises.
Farmland Matching Programs	Independent Agencies	Agencies like Land For Good[68] and New Entry Sustainable Farming Project[69] facilitate connecting landowners to those seeking agricultural land. These programs can serve to either increase the agricultural land base, or transition existing farmland to a new operator.

IV.F.6.b) FARM RESILIENCE

Farming is inherently risky, and with increasing weather volatility, agricultural production is made more vulnerable. Changing temperatures and more intense periods of precipitation or drought have impacts on crop and livestock durability, and can create conditions for the introduction of new pests and disease. On-farm interventions and precautions can serve to minimize these impacts of climate change and make farming operations more resilient. To identify context-specific strategies to be taken in Massachusetts for livestock and crop operations, more research will be necessary.

[63] American Farmland Trust, Farmland Information Center (2014). Census of Agriculture, Total Land Area (acres). Retrieved May 26, 2014 from http://www.farmlandinfo.org/statistics/Massachusetts.
[64] http://www.nrcs.usda.gov/wps/portal/nrcs/main/ca/programs/easements/farmranch/
[65] http://www.mass.gov/eea/agencies/agr/land-use/agricultural-preservation-restriction-program-apr.html
[66] http://www.bostonredevelopmentauthority.org/planning/planning-initiatives/urban-agriculture-rezoning
[67] http://www.somervillema.gov/sites/default/files/Ord%202012-06%20_Zoning-Urban%20Agriculture_.pdf
[68] http://landforgood.org/who/farm-seekers/
[69] http://www.nesfp.org/farmland/how-farmland-matching-service-works

Table 3.6: Programs to Assist Farmers/Ranchers with Adaptation

Program / Policy	Administration Level	Function
Federal Crop Insurance Corporation Programs[70]	Federal	Administered by the USDA's Risk Management Agency, the Federal Crop Insurance Corporation provides crop insurance for farming operations. A new pilot program, Whole-Farm Revenue Program[71] allows farmers to insure mixed and specialty crops and livestock – different from traditional crop insurance that insures individual crop commodities.
Natural Resources Conservation Services (NRCS)[72]	Federal	NRCS provides several conservation programs to farms to reduce soil erosion, reduce excessive water or drought damage, improve grazing and coastal lands and generally improve sustainability.
Massachusetts Farm Energy Program[73]	State	This program provides farming operations with solutions to reduce energy use and costs and produce renewable energy.
UMass Amherst Extension Programs[74]	State	The UMass Amherst Extension provides research and services that address crop-based agriculture issues in Massachusetts, from plant disease diagnosis to soil fertility and pest management.
Community Supported Agriculture Programs	Farm	Through farm-operated Community Supported Agriculture (CSA) programs customers invest in the farm in exchange for a 'share' of farm products or produce for the duration of the agricultural season. This provides the farm with a determined market base that in theory shares the risks and rewards of the farming; depending on the how the farm implements the program, CSA customers may partake in both the benefits of increased production as well as the risks of crop failure.

IV.F.6.c) MARINE FISHERY RESILIENCE

Increasingly acidic and warmer ocean temperatures impact marine migratory patterns, compromise the health and development of marine life, and compromise fisherman livelihoods. Adaptation strategies such as Individual Fishing Quotas (IFQs), livelihood transition or expansion into aqua-tourism, brood stock cultivation to increase marine fishing stock, and advanced fishing technologies are being implemented to encourage resilience in commercial fishing industries in various parts of the world[75]. Adaptation strategies will need to be context-specific, remain flexible and be informed by marine ecosystem research to encourage industry and fishing livelihoods resilience in Massachusetts.

Table 3.7: Programs to Assist Fishermen with Adaptation

Program / Policy	Administration Level	Function
National Oceanic and Atmospheric	Federal and State	Under the US Department of Commerce, the NOAA conducts extensive research to monitor marine ecosystems and weather

[70] http://www.rma.usda.gov/fcic/
[71] http://www.usda.gov/wps/portal/usda/usdahome?contentid=2014/05/0100.xml&contentidonly=true
[72] http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/technical/
[73] http://massfarmenergy.com/
[74] http://ag.umass.edu/about
[75] Johnson, T. (2012). Fisheries Adaptations to Climate Change. University of Alaska Fairbanks. Retrieved May 26, 2014 from Doi: 10.4027/facc.2012.

Program / Policy	Administration Level	Function
Administration (NOAA) Programs[76]		patterns, and disseminates information to fishing and coastal communities; its programs enable timely responsiveness to changing conditions. Programs are administered by NOAA state offices.
Innovative Seafood Marketing	Independent Agencies	Companies like Red's Best[77] in Massachusetts are providing consolidated technology, logistics and marketing services for independent fisherman. Red's Best accesses unconventional markets, including Community Supported Fisheries, which enable fishing lesser-known, and whole-fish seafood; this approach contributes both to ecosystem sustainability and fishing livelihood viability.
Aqua-tourism	Independent Agencies	Companies like Island Creek Oysters[78] are diversifying their operations by offering fishing operation tours, creating an additional revenue stream that bolsters the operation.

Step F.6) a: In addition to implementing the MA Food System Plan, MAPC and partners will encourage agricultural resilience through the following steps:

- Facilitating farmland preservation and conservation efforts in MAPC-region municipalities
- Supporting risk management by encouraging farms purchase comprehensive crop and revenue insurance
- Encouraging improvements to technical and financial assistance programs
- Facilitating the transfer of agricultural research findings to municipalities

Step F.6) b: MAPC will work with municipalities, climate change experts, and industry leaders collaboratively to implement the following strategies to create resilient fishing/shellfishing industries:

- Research impacts to aquaculture and fishing industry, and identify species most susceptible to climate change (e.g. rising water temperatures and sea levels).
- Research mitigation techniques and provide guidance on how to maintain viability of fishing and aquaculture industries most at risk. (e.g., changes in harvesting processes and targeted fish stocks).
- Expand MAPC efforts in Gloucester around its maritime economy to have a regional focus and develop regional strategies for adaptation,

IV.F.7. F.7) Protection of Cultural and Historic Assets and Records

Cultural and historic assets play an important role in local economies, particularly as they relate to tourism, research and education sectors. Given that many MAPC communities hold significant cultural or historic resources, the economic impacts from climate change could be significant and must be addressed in a manner to ensure resources are protected.

[76] http://www.noaa.gov/index.html
[77] http://www.redsbest.com/
[78] http://islandcreekoysters.com/ico/farm/farm-visit/

As identified in the *Massachusetts Climate Change Adaptation Report,* historic and cultural assets are particularly vulnerable to impacts from sea level rise, higher temperatures (air and water), more extreme weather events, and increased humidity and precipitation. In particular works of art, historical documents and maps are vulnerable due to their sensitivity to more severe climate conditions such as humidity or dryness. Thus, additional or more powerful climate control systems may be required to maintain optimal conditions. Also, historic structures and landmarks located in low-lying areas along the coast or in flood prone areas could be lost or significantly harmed, particularly during extreme storm events, particularly from water and wind. Economic impacts could be considerable should their historical uniqueness and importance be diminished through damage or loss.

To address climate impacts on cultural resources, the COSTEP (Coordinated Statewide Emergency Preparedness) framework was developed by the Northeast Document Conservation Center[79], a nonprofit, regional conservation center specializing in the preservation of paper-based materials for libraries, archives, museums, and other collections-holding institutions, as well as private collections. The COSTEP framework provides a regional structure to coordinate emergency planning efforts in a manner that is unique to a specific region. Key steps include building relationships to assess the current status of emergency preparedness, identifying hazards and risk unique to the region, developing mitigation strategies and plans, and sustaining the procedures through ongoing training and communication.

Step F.7) a: MAPC will assist with the coordination of cultural and emergency management organizations to establish and implement a COSTEP framework for the MAPC region.

Step F.7) b: MAPC will work with communities to incorporate climate change impacts and adaptation strategies for historical and cultural assets into local and regional studies, as follows:

- Identify and prioritize cultural assets and historic sites most vulnerable to impacts from climate change.
- Include weatherproofing of historic and culturally significant sites in capital planning/investment, and offer incentives for private entities to do so.
- Identify grants and other funding mechanisms for weatherproofing, climate control systems, etc.
- Develop landscape strategies (shade trees, pervious materials, etc) for cultural and historical sites that aid in cooling and natural drainage.

Step F.7) c: Work with institutions and municipalities to identify funding sources to develop and implement a plan to digitally record documents and collections most vulnerable to changing climate conditions and severe weather events.

[79] COSTEP was developed by the Northeast Document Conservation Center in cooperation with the Massachusetts Board of Library Commissioners (MBLC), The Massachusetts Archives, the Chief Officers of State Library Agencies (COSLA), The Society of American Archivists (SAA), Heritage Preservation, and LYRASOS (formerly SOLINET)

V. 4. Funding Resources

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.

V.A.1. 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.

V.A.1.a) 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.

V.A.1.b) NATIONAL Oceanic and Atmospheric Administration

- 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.

V.A.1.c) 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.

V.A.2. State Funding and Technical Assistance Resources

V.A.2.a) 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.

V.A.2.b) 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.

V.A.3. LOCAL FUNDING RESOURCES

- **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.

VI. Appendix

To be Inserted.