Climate Change Resilience Plan

Vulnerability Assessment & Response Strategies

2017 | Working Document 2.0

Prepared for
MAGIC Regional Council
http://www.mapc.org/magic

Prepared by
Metropolitan Area Planning Council
60 Temple Place, 6th Floor
Boston, Massachusetts 02111
Tel (617) 451-2770
www.mapc.org

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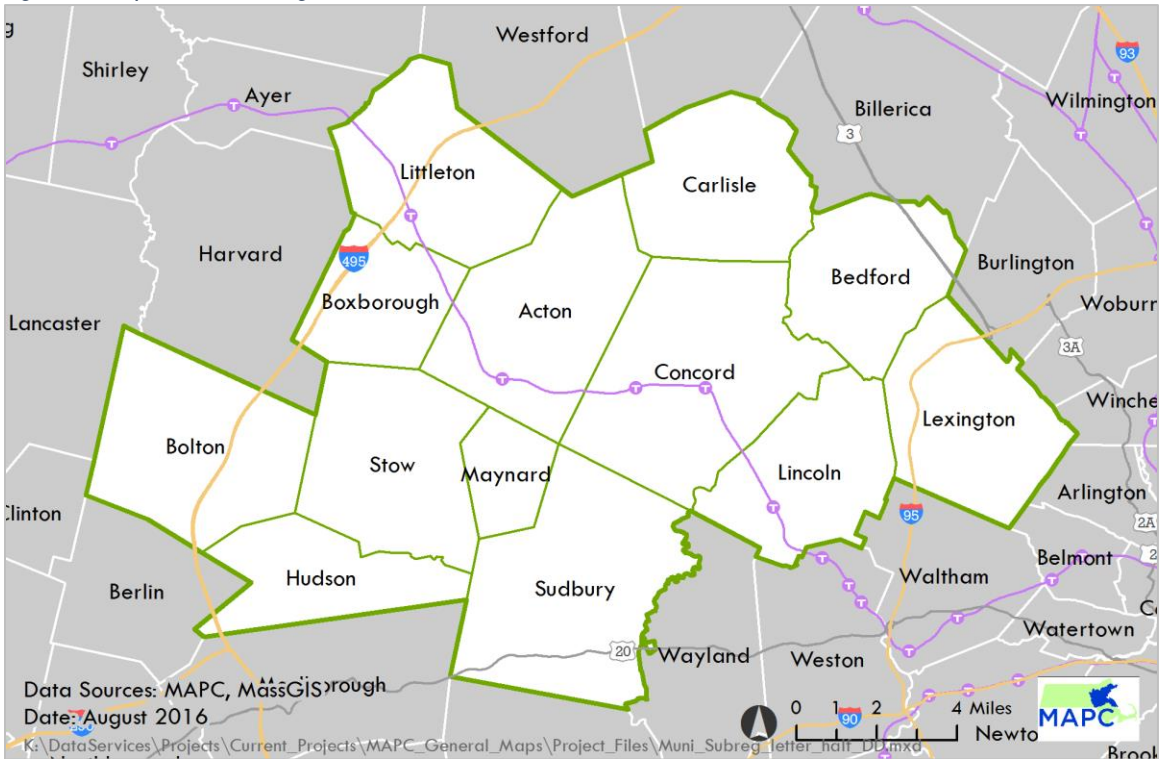
CONTEXT

Why Plan for Climate Change in the MAGIC Region?

The Minuteman Advisory Group on Interlocal Coordination (MAGIC) is a regional group of 13 municipalities,[1] located northwest of Boston (Figure 1), which since 1984 has collaborated on issues of regional concern. The group has worked collectively to address issues related to transportation, economic development, conservation of natural resources, and housing.[2]

Figure 1. Map of MAGIC Region



Source: MAPC

The collaborative work has strengthened the region as a whole and the towns individually, and reflects the assets in the region, including median household income and educational levels that are higher than the state's. In addition, the work, especially conservation activities, has reflected the importance of agriculture to the region's heritage and history. Despite these assets and cooperation, the region still faces a real threat from climate change. The impacts of climate change present risks to the social, economic, and environmental well-being of the MAGIC region.

Threats posed by climate change – in particular, rising temperatures and changing precipitation patterns – are likely to affect how towns and their residents, natural resources, and local

[1] The group includes the towns of Acton, Bedford, Bolton, Boxborough, Carlisle, Concord, Hudson, Lexington, Lincoln, Littleton, Maynard, Stow, and Sudbury.

[2] MAGIC is one of eight subregional committees that MAPC works with to address local and regional issues on topics such as transportation, housing, environmental protection, municipal services, and public health, http://www.mapc.org/subregions.

economies operate in the short- and long-term. For example, in March 2010, many MAGIC towns experienced extreme flooding as nearly 10 inches of rain fell over a three day period (March 13-15) and then was followed by additional higher volume rain events.[3] As a specific example, during this period in March, the Town of Concord recorded at total of 16 inches of rain. In the MAGIC region, there were significant disruptions to the transportation system as major roads like Route 2, 117, and 119 all were interrupted partially or wholly by flooding, liming travel options for motorists and other roadway users. Middlesex County as a whole experienced over $35 million in property damages as a result of these precipitation events.[4] By contrast, these same towns were then under a drought advisory later that year due to lower than average rainfall.[5] The conditions of 2010 and the contrasts they present are in line with the changes in precipitation predicted by 2030 and beyond.

While it is essential for communities to reduce greenhouse gas emissions in order to limit the predicted changes in climate as much as possible, it is necessary to simultaneously build resilience to these changes in order to minimize social disruption and economic and environmental damage. Climate change planning represents an opportunity for the MAGIC region to build this necessary community resilience through adaptation and mitigation strategies. The planning recognizes some key premises:[6]

1. The climate has already changed and changes will continue to occur.[7]
2. Municipal representatives, staff, and residents are making major decisions today that may have long legacies and that can influence future vulnerabilities.
3. Climate change will not observe political borders, so regional efforts that foster local action will be most effective
4. Planning in advance can save money, while inaction now may lead to higher costs in the future.
5. Planning for uncertainty and future variability can be integrated into current planning processes and decision-making; however, it will likely require new methods, funding, and tools
6. There are many opportunities for co-benefits when planning for climate change adaptation and mitigation as well as emergency preparedness
7. One of the best predictors of resilience is the vitality of social networks and community cohesion.

Planning Process

MAGIC and the Metropolitan Area Planning Council (MAPC) initiated a planning process to assess vulnerabilities from the predicted impacts of climate change (i.e., changing precipitation and

[3] National Weather Service," Flooding in Massachusetts," accessed September 19, 2016. http://www.floodsafety.noaa.gov/states/ma-flood.shtml

[4] NOAA National Climatic Data Center, Storm Events Databased for Middlesex County, MA 1996 – 2016, accessed August 27, 2016, https://www.ncdc.noaa.gov/stormevents/

[5] Town of Concord Public Works and Light Plant, "2010 Annual Report," accessed September 19, 2016

[6] Based on similar principles from, San Mateo County, "Climate Action Plan: Climate Change Vulnerability Assessment," 2011

[7] Executive Office of Energy and Environmental Affairs, "Massachusetts Climate Change Adaptation Report," 2011

temperatures), and to develop an action plan for implementing adaptation and mitigation strategies. The project was a unique opportunity to apply climate assessment and planning methodologies to the issues faced by inland areas (e.g., those unrelated to sea level rise) and provide a model for the other MAPC subregions and other areas in the Commonwealth.

The MAGIC Climate Change plan includes three main elements: a vulnerability assessment, development of adaptation and mitigation strategies, and stakeholder and community engagement. The results of the process will guide MAGIC in taking regional action and help towns in the region integrate climate change considerations into their local policies, regulations, incentives, and projects. The process will also strengthen networks among stakeholders from various sectors – including the built environment, natural resources, clean energy, public health, and government – in order to share knowledge and build a base of support for further action.

Developing a Vulnerability Assessment

A climate change vulnerability assessment is a process to determine the degree to which systems, sectors, or populations are susceptible to and unable to respond to predicted climate change impacts. The assessment provides the best available information about the predicted changes and their likely impacts, which is essential in order to understand where and how to take action (e.g., protect, accommodate, and retreat). The assessment informs actions in two ways. It identifies specific elements that are likely to be impacted, integrating anecdotes and experiences with data and research to explicitly identify vulnerabilities. And it provides an overview of connections and relationships between different vulnerabilities that allows for prioritization and a systems approach for response strategies.

The vulnerability assessment includes three primary components:

- **Exposure** is a determination of whether a specific changing climate condition or impact will be experienced.
- **Sensitivity** is the degree to which the system, sectors, or populations would be impaired by the impact if it were exposed.
- **Adaptive capacity** is the ability of the system, sectors, or populations to change in order to maintain its primary functions even as it is exposed to an impact.

Exploring each provides a more holistic understanding of how vulnerable a particular item may be. For example, if a historic building is likely to be flooded (exposure) and is built from older materials that are easily damaged (sensitivity) and has limited financial support for flood proofing (adaptive capacity), it could be assessed as highly vulnerable. Conversely, if flood proofing or protection measures are already in place, the building would have a greater existing adaptive capacity that would lower its vulnerability assessment. These concepts are described in more detail in the Vulnerability Assessment section.

This assessment specifically looks at the impacts faced by the MAGIC region. It examines how these impacts are shared across jurisdictional lines and how they differ between towns. Based on data and feedback collected through the process, the following focus areas were identified for this vulnerability assessment:

1. Terrestrial Habitats and Species
2. Aquatic Habitats and Species
3. Drinking Water Infrastructure
4. Stormwater Infrastructure
5. Wastewater Infrastructure
6. Land Use and Buildings
7. Transportation Infrastructure
8. Energy Infrastructure
9. Human Health and Welfare
10. Outdoor Workers
11. Agriculture
12. Local Economy: Healthcare
13. Local Economy: Tourism
14. Local Government

Identifying Adaptation and Mitigation Strategies

Climate change mitigation and adaptation planning is a process to determine how best to respond to predicted climate impacts and identified vulnerabilities. The process promotes actions that anticipate changes and build resiliency rather than supporting reactive measures. Resiliency is defined as "the capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption".[8]

Developing adaptation and mitigation strategies first requires looking at existing strengths, such as current policies and regulations, practices, and community initiatives that bolster climate resiliency. It then involves evaluating how these strengths compare to the identified vulnerabilities. Where there are gaps, new strategies are proposed in order to protect environmental resources, ensure public health and safety, direct economically feasible and sustainable growth to appropriate locations, and reduce potential disparities. When combined, the existing strengths and new strategies will enhance the region's capacity for resiliency.

Engaging Stakeholders for Guidance and to Build a Stronger Social Network

The project involved collaboration with staff and representatives from MAGIC municipalities, including planners, conservation agents, and those serving on elected and appointed boards and committees (e.g., Board of Selectmen, Energy Committee, etc.). The project was also conducted in collaboration with local stakeholders, residents, and subject matter experts who represented business owners, environmental protection advocates, state agency representatives, and clean energy advocates, among others. The collaboration ensured that the plan was informed by a cross-section of perspectives.

[8] U.S. Climate Resilience Toolkit, "Glossary," accessed August 26, 2016, http://toolkit.climate.gov/content/glossary

More details about specific elements of the engagement process are provided below and input from the process is referenced throughout the document.

Climate Resilience Plan Working Group

A working group was formed at the outset of the project to provide guidance on the planning process and the content of the plan. Members attended three working group meetings where the MAPC project team presented information on project progress and preliminary findings and discussed the challenges and assets in the MAGIC region. The working group also played an active role in sharing information about the project and recruiting residents to participate in a climate change survey for the region and to attend the Community Summit.

A list of working group members is provided in the Appendices.

Community Summit

A Community Summit was held on November 19, 2015 to inform a broader set of community members and stakeholders of the project. The summit included presentation on climate change impacts that could affect the region and engaged attendees in an interactive activity in order to solicit feedback regarding their particular climate impact concerns. A wrap-up discussion was held with attendees to discuss their primary concerns regarding climate vulnerabilities and what planning outcomes would prove most useful to the communities.

Materials and highlights from the summit are provided in the Appendices.

Regional Survey

The MAGIC Region Climate Change Adaptation & Mitigation Survey was conducted between January and April 2016 to offer another opportunity for resident and stakeholder feedback. The survey was provided online via SurveyMonkey and distributed through variety of channels, including MAGIC regional communications (e.g., newsletter), distribution of the link by Working Group members, and promotion through multiple other channels including town websites, regional newsletters, and community meetings.

Nearly 300 people participated in the survey, and the majority of respondents (80 percent) indicated that they lived in single family homes in the MAGIC[9] region. While at least one response was received from each town in MAGIC, two towns made up more than one-third of the respondents: Lincoln and Sudbury. Four towns had four or fewer responses: Carlisle, Lexington, Hudson, and Littleton.

In response to question about the urgency to respond to and prepare for climate change, two-thirds of respondents said climate change is a very urgent issue with another 20 percent believing it is a somewhat urgent issue. Respondents who chose "other" provided a mixture of comments.

[9] Some of the survey questions limited respondents to one response while others allowed multiple choices. In the case of the multiple response questions, percentages of responses represent those that there were selected most and totals will not add up to 100%.

One commenter considered climate change an emergency, another said that they supported mitigation in addition to preparation and response, and several said they didn't believe that climate change is man-made. When asked which climate impacts caused concern, respondents indicated that impacts to ecological systems was of most concern (74 percent) (Table 1). Public health (41 percent) had the second highest response percentage, followed by effects on agriculture (35 percent) and Economy and the Built Environment. Definitions are provided below for the impact categories.

Table 1. Survey Climate Change Impact Categories of Concern

Category	Description
Ecological systems	Damage to protective ecological systems: drinking water quantity and quality, loss of habitat and green spaces, degraded waterbodies and recreation areas, plant and animal species changes.
Public Health	Threats to public health: respiratory, cardiovascular, allergies, and other illnesses (particularly of elderly, children and outdoor workers).
Effects on Agriculture	Effects on agriculture: decrease and or/changes in food production due to heat and drought conditions.
Economy and Built Environment	Damage to the economy and built environment: business closures and lost wages, and damages/loss of property and infrastructure (transportation, energy, water).

Source: MAGIC Region Climate Change Adaptation & Mitigation Survey

The full results from the survey, including respondents' comments on climate change impacts and potential resiliency actions, are included in the Appendices.

MAGIC Regional Council

Climate change was identified as the number one priority for regional action by the regional council that directs MAGIC. Consequently, the council was frequently informed about the status and findings of the project through presentations, sharing materials that went to the working group, and discussions about specific vulnerabilities and response strategies. The work also included a discussion at MAGIC's annual legislative breakfast, during which MAPC and partners gave a brief presentation on the plan and invited the elected officials and other participants to give their input.

Starting Points for the Region

The following four recommended actions are ones the MAGIC region can begin to implement now to bolster regional and municipal climate resilience. These recommended actions were identified through the feedback received from stakeholders during the planning process, and are informed by the vulnerability assessment findings. Recommended climate actions propose areas for initial coordination toward regional climate resilience, and they leverage and build on municipal initiatives and efforts already in place. The four actions are discussed in greater detail in the Adaptation and Mitigation Strategies section, and are presented alongside a broader range of strategies that MAGIC municipalities are encouraged to implement as the region advances a climate resilience strategy.

Recommended Action	Desired Outcome
A. Designate Municipal Climate Leads and Establish a MAGIC Climate Sub-Committee	A network of municipal stewards that lead local climate resiliency efforts and hold towns responsible in their decision-making as it relates to local and regional action to prepare for climate change. In addition, a formal body, recognized by MAGIC, that acts as peer exchange network and an advisory group for regional advocacy on state and federal legislation that affect climate change resiliency.
B. Engage in Regional Green and Clean Infrastructure Planning	A 13-town action plan for preservation and protection of natural resources, with a specific focus on open space and water resources and clean energy infrastructure. The plan would serve as a recommended investment plan for land protection and clean energy investments at the local level in service of regional climate change resiliency.
C. Prioritize Active Transportation Investments	Adoption of standard active transportation policy and performance targets for the region that produce reduction in GHG emissions and increase redundancy of existing personal motor vehicle infrastructure.
D. Build and Bolster Community-Level Climate Resiliency	Residents, regardless of income, background, or ability, have the capacity to meet their needs and assist neighbors prior, during, and after climate change-induced weather events. Although this work with begin through community organizations, its purpose would be to enhance informal neighbor-to-neighbor social connections that can be activated in the event of anticipated climate change impacts.

DOCUMENT GUIDE

The MAGIC Climate Resiliency Plan has three main components:

- **Vulnerability Assessment:** provides background on the MAGIC region, the projected effects of climate change on the region, and how various sectors, systems, and population could be affected. It is intended to give context for the proposed impacts and the ability to identify if, where, and how the region and specific municipalities could be impacted.

  Municipal and civic leaders and groups should scan the assessment and determine where there is opportunity to partner on issues (e.g., transportation infrastructure, protection of aquatic resources) and where a more local approach is needed (e.g., drinking water infrastructure, municipal light plant).

- **Adaptation and Mitigation Strategies:** provides a catalogue of strategies that respond to the identified vulnerabilities. The strategies are not intended to be a one-to-one match of the various sectors, systems, and population called out in the vulnerability assessment. Instead this section offers strategies that address multiple vulnerabilities at once. Tree planting programs are an example. They are an intervention that addresses issues related to precipitation, temperature, and air quality all at once. The Adaptation and Mitigation Strategies section also recognizes that many great interventions and response strategies are in place. It identifies where there is potential to enhance and scale existing efforts and where there are opportunities to address gaps.

  Municipal and civic leaders and groups should use this section to see how their current efforts can be strengthened (e.g., low impact development regulations, clean energy investments) and to see what new strategies are necessary to prepare for the effects of Climate Change (e.g., cooling centers, removal of impervious surfaces).

- **Appendices:** There is information and reference materials not included in the Vulnerability Assessment and the Adaptation and Mitigation Strategies. However, this content offers important information about the process and the plan itself. The appendices are repository for the additional information and materials and is a resource for those looking to learn more about climate change planning in the MAGIC region.

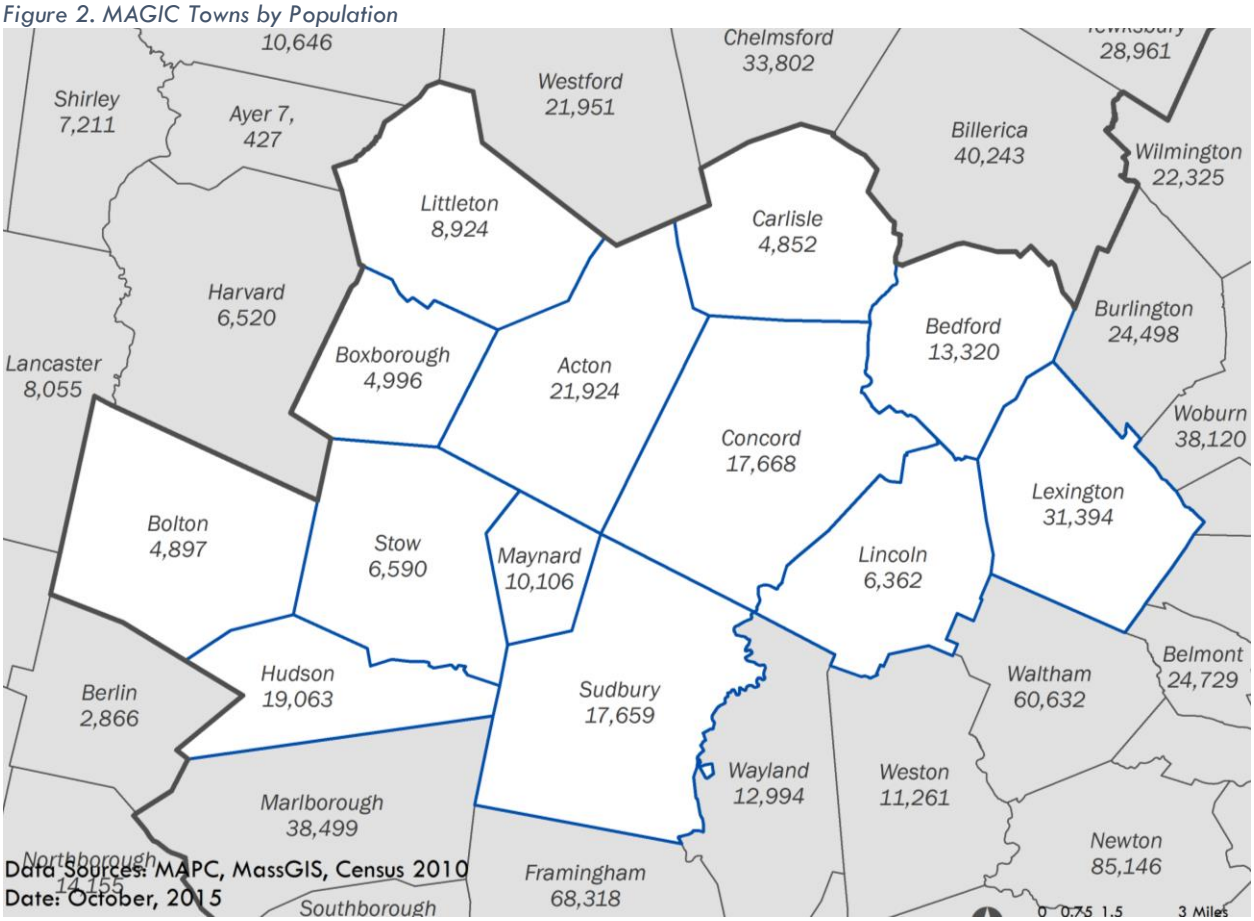
MAGIC Climate Change Resilience Plan:

Regional Profile

REGIONAL PROFILE

The Minuteman Advisory Group on Interlocal Coordination (MAGIC) is a regional group of 13 towns, located northwest of Boston, which since 1984 has collaborated on issues of regional concern. The group includes the towns of Acton, Bedford, Bolton, Boxborough, Carlisle, Concord, Hudson, Lexington, Lincoln, Littleton, Maynard, Stow, and Sudbury.

Figure 2. MAGIC Towns by Population



Source: MAPC

The following section provides a brief overview of geographic, natural and built environment, social, economic, and governance characteristics in the MAGIC region. The profile sets the context for the climate change vulnerability assessment and for developing mitigation and response strategies. Information and data in this section are referenced and expanded on in other sections of the report, in particular the specific vulnerability assessments.

Local Government

The executive branch of each MAGIC town is an elected Board of Selectmen (BOS) and a Town Manager or Administrator who is appointed by the board. MAGIC BOS have either three or five selectmen who are responsible for setting policy and appointing members to unelected boards and committees. Some also have the power to approve or veto Town Manager appointments and municipal contracts. Typically, the Town Manager or Administrator is the chief administrative officer and appoints department heads and other employees, prepares budgets, awards

contracts, oversees administration, negotiates with unions, and is a voting member of the school committee on union contracts.

Legislative decision-making occurs through Town Meetings. In MAGIC, all towns but one operate with an Open Town Meeting, where any voter may attend and vote on legislative matters. Lexington holds a Representative Town Meeting, where voters elect a limited number of legislative representatives to vote on town legislative matters.[10]

Demographics

MAGIC's population has grown slowly over the recent 10 to 15 years, resulting in larger populations of older adults and a more ethnically diverse population. According to the 2010 US Census, the MAGIC region is estimated to have 167,755 residents (Figure 2). Between 2000 and 2010, the MAGIC region grew by nearly four percent compared to three percent growth in the MAPC region. The average age of MAGIC residents has gradually increased during this timeframe.

MAPC's Stronger Region population projections show that older adults will account for over 23 percent of the population by 2030.[11] MAGIC is mostly white, but in recent years populations of color have increased about 74 percent and the number of Hispanic residents has increased by about 52 percent. Asian Americans, Hispanics, and African Americans account from 9.7 percent, 2.8 percent, and 1.5 percent, respectively, of people of color. Other than English, the five most common languages are Chinese, Spanish, Portuguese, French, and Korean.

Health Status

Health data from 2008 and 2012 suggest that MAGIC residents are generally healthier when compared to Massachusetts residents. MAGIC hospitalizations for hypertension, asthma, diabetes, and mental health were less than on the state level. Mental health hospitalizations in the region closely mirror state prevalence rates. It is worth noting that the prevalence of diabetes hospitalizations were higher within the southern and western areas[12] of MAGIC. Similarly, asthma hospitalizations were more prevalent in the western part of the region.[13] Mental health hospitalizations were more prevalent in the southern and northern parts[14] of the region as a whole.

Vulnerable Population Groups

Vulnerable populations groups are those that may already experience a disparity and those who may be more susceptible to societal and environmental changes. Limited financial resources, weak social networks, existing health conditions, historic or geographic factors, and more can compromise a person's or family's ability to recover from disasters. Similarly, populations including minorities, foreign-born, the very young, older adults, people who are disabled, and

[10] Massachusetts Municipal Association, "Municipal Forms of Government," accessed on August 18, 2016, http://www.massmanagers.org/sites/mmma/files/file/file/mma_form-of-gov3.pdf; Massachusetts Municipal Association, "Forms of Local Government, Commonwealth of Massachusetts," accessed on August 18, 2016, https://www.mma.org/resources-mainmenu-182/doc_view/29-forms-of-local-government-in-massachusetts

[11] MAPC population projections, stronger region

[12] Sudbury and Maynard (South Quadrant), and Stow, Hudson and Bolton (West Quadrant)

[13] Stow, Hudson and Bolton (West Quadrant)

[14] Sudbury and Maynard (South Quadrant) and Littleton, Boxborough, Acton, and Carlisle (North Quadrant)

those that are socially isolated can be more susceptible to new exposures (e.g., worse air quality) due to communication and transportation barriers.

Population groups in MAGIC that are most vulnerable to climate change include its growing numbers of older adults, those living alone, residents with limited English, those with chronic health conditions, and those with lower or fixed incomes. Compared with state averages, Maynard's population has a greater percentage of its people living alone (one person households) and Hudson has a higher number of residents who are linguistically isolated. These populations may be less apt or have less resources to change practices and understand projected future conditions. Outdoor workers in agricultural, construction, landscaping, or recreational (i.e. golf course) industries will be at greater risk of climate impacts such as increased heat, vector-borne diseases, and industry volatility. Though it is difficult to precisely count, around 4,000 employees in MAGIC work in primarily outdoor industries.

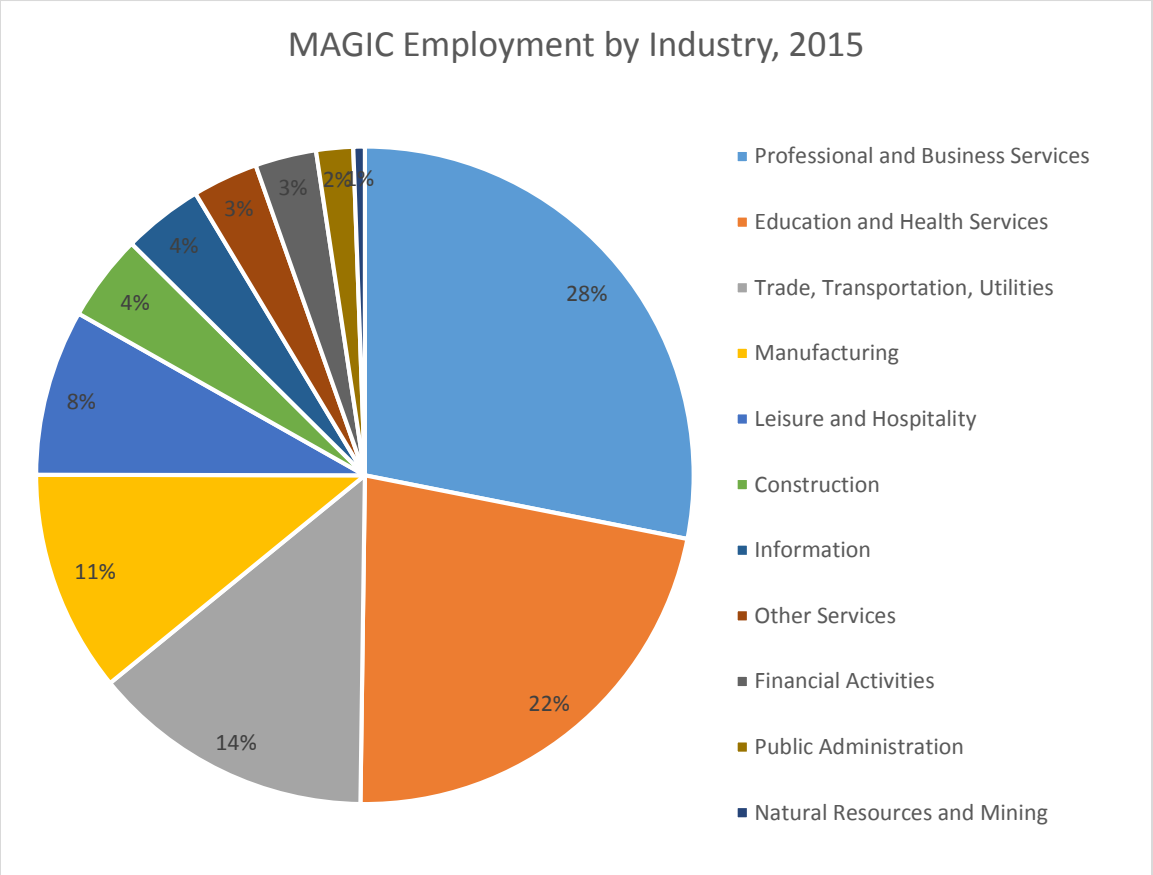
Economy

MAGIC is an affluent region of Massachusetts, with an estimated median annual household income above $100,000 in most of towns, compared to the state's estimated median of $67,846.[15] Although the annual median income in Maynard and Hudson are lower than other MAGIC municipalities, the median incomes in these towns ($74,000) are still higher than the state's. Less than five percent of the residents in MAGIC live below the poverty line, while it is estimated that state's average is 11 percent. Further, the MAGIC region is well-educated, with over 67 percent holding at least a bachelor's degree and nearly five percent holding master's degrees. This is higher than the state's estimated averages of approximately 40 percent and three percent, respectively.[16]

Professional and business services, education, and health services represent the largest regional employment sectors, constituting approximately half of the employment (Figure 3). In MAGIC, some of the largest employers within these sectors are The Mitre Corporation, a technology and security corporation in Bedford; and Emerson Hospital in Concord.

[15] American Community Survey, 5-year estimates, 2010-2014
[16] ACS 2010-2014

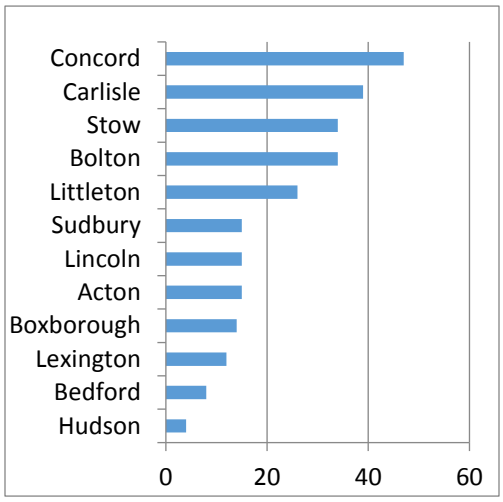
Figure 3. MAGIC Employment by Industry, 2015



Source: EOWLD, ES-202

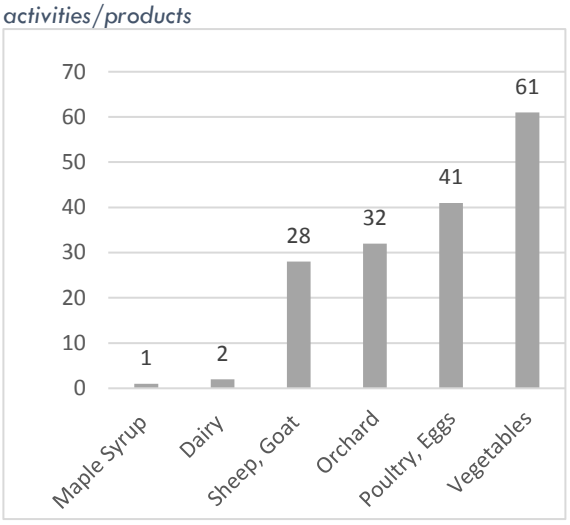
Agriculture is a defining part of MAGIC's history and heritage, and an important part of the local economy. There are more than 250 farms in operation in the region, cultivating nearly 8,000 acres (Figure 4, Figure 5). An estimated 633 acres are permanently protected for agricultural uses. The majority of farms are under 50 acres and mostly raise and cultivate vegetables, livestock, and orchards. Approximately 450 people are employed by MAGIC's farms. The region has several non-profit farms that provide educational and community programming in addition to producing food and several farms that have been in operation for several generations. Local products are made available in the region at farmers markets and farm stands and through CSAs, farm to school programs, and agri-tourism.

Figure 4. Number of Farms in MAGIC Towns



Source: USDA 2007 Agriculture Census

Figure 5. Number of farms and their primary activities/products



Source: USDA 2007 Agricultural Census

Natural Resources

The MAGIC region is rich with water resources and overlaps six major watersheds, with the majority (approximately 70 percent) of the region part of the Sudbury, Assabet, Concord (SuAsCo) River basin. The SuAsCo Watershed is an important regional water supply and an ecologically important regional watershed that includes segments that are federally-designated Wild and Scenic Rivers. The SuAsCo Watershed also supports two river-dependent wildlife refuge, and is the home of the wild, native Eastern Brook Trout and other cold-water fisheries.[17]

Nearly one-third (39,650 acres) of land in MAGIC is in conservation. This land includes properties protected to preserve the area's rural character and agricultural uses, conserved land to safeguard ecological resources, and open spaces meant to provide recreational opportunities. In addition to locally protected open spaces, there are a number of federal and state natural resource areas in the region.

The two federal wildlife refuges are the Great Meadows and Assabet River National Wildlife Refuges. The Great Meadows NWR includes freshwater wetlands along the Concord and Sudbury Rivers in Sudbury, Lincoln, Concord, Carlisle, and Bedford. The Assabet River NWR includes wetlands and forested land in Sudbury, Stow, Maynard, and Hudson. The MAGIC region is also home to the Minute Man National Historical Park, which includes 970 acres of protected land across the towns of Lexington, Lincoln, and Concord.

State lands in the region include the Walden Pond State Reservation, Great Brook Farm State Park, and Delaney Wildlife Management Area, among others, which represent preservation of past uses (e.g., farming) and protection of terrestrial and aquatic species and habitats.[18]

[17] See K: Hudson SuAsCo 2013 SWMI Grant FINAL
[18] USDA Forest Service, "An Assessment of the Forest Resources of Massachusetts," 2010. http://www.mass.gov/eea/docs/dcr/stewardship/forestry/assessment-of-forest-resources.pdf

Built Environment

The towns in the MAGIC region are characterized as either Maturing or Developing Suburbs, according to MAPC's categories of community types developed for the MetroFuture Regional Plan (Table 2). Maturing suburbs are municipalities with moderate-density residential communities and a dwindling supply of vacant developable land. Developing Suburbs are less-developed municipalities with large expanses of vacant developable land which have recently experienced high rates of growth, primarily through the development of large lot single-family homes.[19]

Table 2. MAGIC Towns Community Types[20]

Town	Community Type	Sub-Type
Acton	Maturing Suburbs	Established Suburbs
Bedford	Maturing Suburbs	Established Suburbs
Bolton	Developing Suburbs	Country Suburbs
Boxborough	Developing Suburbs	Country Suburbs
Carlisle	Developing Suburbs	Country Suburbs
Concord	Maturing Suburbs	Established Suburbs
Hudson	Developing Suburbs	Maturing New England Towns
Lexington	Maturing Suburbs	Established Suburbs
Lincoln	Maturing Suburbs	Established Suburbs
Littleton	Developing Suburbs	Maturing New England Towns
Maynard	Maturing Suburbs	Mature Suburban Towns
Stow	Developing Suburbs	Country Suburbs
Sudbury	Maturing Suburbs	Established Suburbs

Source: MAPC

MAGIC has a history of working collaboratively on efforts to manage growth and development across the region, focusing on addressing conflicting and compatible land uses. Teardowns in MAGIC are a particular issue, where culturally- or historically-significant homes are demolished and new, large homes are built in their place.

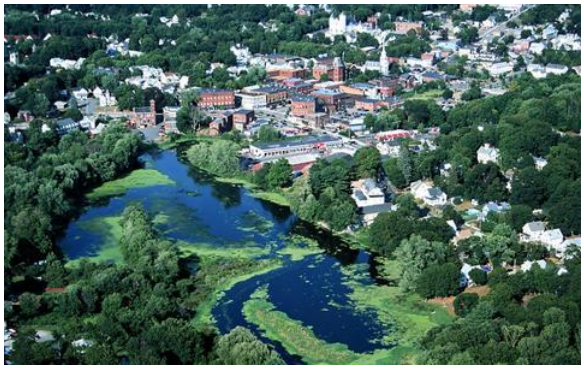
Transportation

The region is served by two major highway routes: Interstate 495, traveling north-south through the western portion of the region, and MA Route 2, travelling east-west through the center of MAGIC. The region is served by public transit provided by the Massachusetts Bay Transit Authority (MBTA), specifically the Fitchburg Commuter Rail line, which runs service between Boston and Fitchburg, stopping in Littleton, South Acton, West Concord, Concord, and Lincoln. According to the 2010 US Census, it is estimated that an average of 85 percent of MAGIC residents commute to work by car (with approximately 95 percent of households owning at least one car), and 3.5 percent of commuters use public. The region is also served by a transportation management association (TMA), Crosstown Connect, which coordinates a number of local transit

[19] For more information, please see *MetroFuture, Making a Greater Boston Region,* http://www.mapc.org/sites/default/files/MetroFuture_Goals_and_Objectives_1_Dec_2008.pdf

[20] More details, a map, and municipal classifications according to community type can be found here: http://www.mapc.org/sites/default/files/Massachusetts_Community_Types_-_July_2008.pdf

options, including Cross-Acton Transit in Acton, the MinuteVan Dial-a-Ride service, and council on aging (COA) shuttles in Acton, Boxborough, Littleton, and Maynard.



Sources: John Boyd, OARS; Town of Hudson website; Cucurbit Farm, Thomas Cooper

A Perspective on Sustainable Growth

During the planning process in MAGIC, a perspective on the growth and development was offered for consideration by the working group. The perspective was intended to elevate how growth and development places greater burden on human, ecological, social, and municipal systems. It was also meant to place growth in the context of regional needs and the changes that are expected to accompany a changing climate. The perspective is offered below.

"While formally addressing growth is outside the scope of this [working] group's scope, we felt it important to recognize growth as an issue and to define what we mean by "sustainable growth". Unsustainable building in one town has a regional impact on other towns. We cannot currently dictate growth limits at the region level, but we can raise awareness about the impacts on natural resources, in the hopes that more sustainable planning can be achieved on a voluntary basis.

The natural eco-system, like any system, has limits. To achieve sustainability, we must respect natural limits and constrain construction so that growth is "sustainable". In this plan, we refer to this as "sustainable growth." We believe that "sustainability" includes respecting the rights of nature, including the rights of human beings as part of the eco-system. As such, we believe that "sustainable growth" must include basic, healthy, and truly affordable food and housing for all, which is, at the same time, economically viable.

To live within a framework of sustainability, we are developing a regional understanding of the factors which contribute to the limits of nature. We are developing an understanding of what percentage of each town's land must be preserved for things like water recharge, tree carbon sink, and food security, to be able to achieve sustainability regionally. We are developing an understanding of the limits on water capacity. We are developing an understanding of housing needs that are not being met. As we do this, we will need towns to help us understand specifics for each town.

With this understanding, we will prepare recommendations for towns to help achieve sustainability at the municipal level, and to help towns be "good neighbors" in a regional community by doing what they can to minimize negative impacts of unsustainable growth on neighboring towns. We can help towns develop plans that provide for the needs of the community while simultaneously preventing land-use policies which result in unsustainable building. Some communities may have already zoned to a level that is impossible to support. We urge those towns to modify land use policies, as soon as possible, to minimize unsustainable growth. In this plan, we hope to provide specific suggestions on how to do that."

The views expressed are those of the author(s) and are not intended reflect the views of the towns in the MAGIC Subregion, municipal and community representatives to the MAGIC Subregional Council, and the Metropolitan Area Planning Council.

MAGIC Climate Change Resilience Plan:

Projections and Impacts

CLIMATE CHANGE PROJECTIONS AND IMPACTS TO MAGIC REGION

This section provides a background on climate change modelling and existing resources for Massachusetts that are relevant to MAGIC and describes climate change information included in the vulnerability assessment. It presents an overview and projections for two changes in the climate — temperature and precipitation — and the potential effects of these changes.

Climate Change to Date

The world has experienced increases in annual average temperatures, altered precipitation patterns, and sea level rise over the past century. Temperatures have increased an average of 1.4°F since the 1880s, with two-thirds of the warming having occurred since 1975.[21] More precipitation is falling now that it did a century ago. In that time period, precipitation has grown by five percent in the US and two percent worldwide.[22] Since 2000, Massachusetts has exceeded the 20th century average for rainfall 13 times. Three of those times, the state exceeded the average by 10 inches or more of rain.[23]

While not directly applicable to MAGIC, sea level has been rising globally an average of nearly an inch per decade. The US coastline has registered increases of nearly eight inches since 1960[24] and Massachusetts has seen a sea level rate of approximately 10 inches per decade. These changes are altering the length and timing of seasons, natural ecosystems and communities, and operations within the economy.

These trends – warmer temperatures and altered precipitation patterns – are expected to continue into the future, and the rate of change is expected to increase. Given this, it's important to explore how these trends may play out and how specifically they will impact the MAGIC region.

Climate Change Modelling

Predicting future climate conditions is a very complex undertaking based on a number of interacting models and assumptions. Because the way humans behave now will influence the climate in coming decades, there is no single set of climate predictions. Instead, climate scientists publish a series of projections for changes in global temperature or precipitation based on a set of possible actions humans might take over coming decades. In calculating these projections, scientists begin with a set of assumptions such as total amount of energy people will use and the mixture of renewable energy and fossil fuels that people will use. These assumptions are fed into Integrated Assessment Models[25] to create Greenhouse Gas (GHG) emissions scenarios, or

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[21] NASA Earth Observatory, "World of Change: Global Temperatures," http://earthobservatory.nasa.gov/Features/WorldOfChange/decadaltemp.php , accessed September 11, 2016

[22] EPA, "Climate Change Indicators: U.S. and Global Precipitation: U.S. and Global Precipitation," https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-precipitation, accessed September 11, 2016

[23] NOAA, "Climate at a Glance", https://www.ncdc.noaa.gov/cag/time-series/us/19/0/pcp/12/12/1895-2016?base_prd=true&firstbaseyear=1901&lastbaseyear=2000&trend=true&trend_base=10&firsttrendyear=1895&lasttrendyear=2016, accessed January 2016.

[24] EPA, "Climate Change Indicators: U.S. and Global Precipitation: Sea Level," https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-precipitation, accessed September 11, 2016

[25] "In assessment of climate change, integrated assessment refers to that activity that considers the social and economic factors that drive the emission of greenhouse gases, the biogeochemical cycles and atmospheric chemistry

estimates of the amount of GHGs that may be introduced into the atmosphere over time.[26] GHGs include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases.[27]

The Intergovernmental Panel on Climate Change (IPCC), the leading international body for the assessment of global climate change, recently released a report outlining a series of four GHG emissions scenarios, which they term "Relative Concentration Pathways," or RCPs. GHG modelling indicates that if people do not adopt policy changes to reduce emissions, continue to have a high population growth, and continue to rely heavily on fossil fuels, this would lead to a "High Emissions" scenario (high emissions, RCP 8.5, Table 3).[28] If people instead meet ambitious targets to lower fossil fuel consumption, increase renewable energy use, and maintain a lower population worldwide, G2G emissions could be much lower (RCP 2.6). The climate projections referred to in this report are generally based on the GHG emissions scenarios outlined by the IPCC.

Table 3. Greenhouse gas scenarios for IPCC climate modelling.

Emissions Scenario	Scenario Name	Potential Policy Changes	Assumptions about Human Activity	GHG Conditions by 2100
High	RCP 8.5	No policy changes to reduce emissions	Low rate of renewable energy use	3 x today's CO_2 emissions
			World population of 12 billion	Increased methane emissions
High Intermediate	RCP 6	Some energy efficient technologies adopted and encouraged	Continued reliance on fossil fuels	CO_2 emissions peak in 2060, then decline
			Increased use of croplands	Stable methane emissions
			Decreased use of grasslands	
Low Intermediate	RCP 4.5	Stringent climate policies	Decreased use of croplands	CO_2 emissions decline starting in 2040
		Strong reforestation programs	Decreased use of grasslands	Stable methane emissions
Low	RCP 2.6	Ambitious GHG emissions reduction policies	Declining use of oil	CO_2 emissions decline beginning in 2020
			World pop. of 9 billion	Reduced methane emissions
			Croplands used for bio-energy production	

Source: IPCC 2011

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that determines the fate of those emissions, and the resultant effect of greenhouse gas emissions on climate and human welfare. More specifically, the two defining characteristics of a climate change integrated assessment are 1) that it seeks to provide information of use to decision makers rather than merely advancing understanding for its own sake; and 2) that it brings together a broader set of areas, methods, styles of study, or degrees of certainty, than would typically characterize a study of the same issue within the bounds of a single research discipline." Center for International Earth Science Information Network, "Thematic Guide to Integrated Assessment Modeling of Climate Change", accessed August 17, 2016, http://sedac.ciesin.columbia.edu/mva/iamcc.tg/TGHP.html

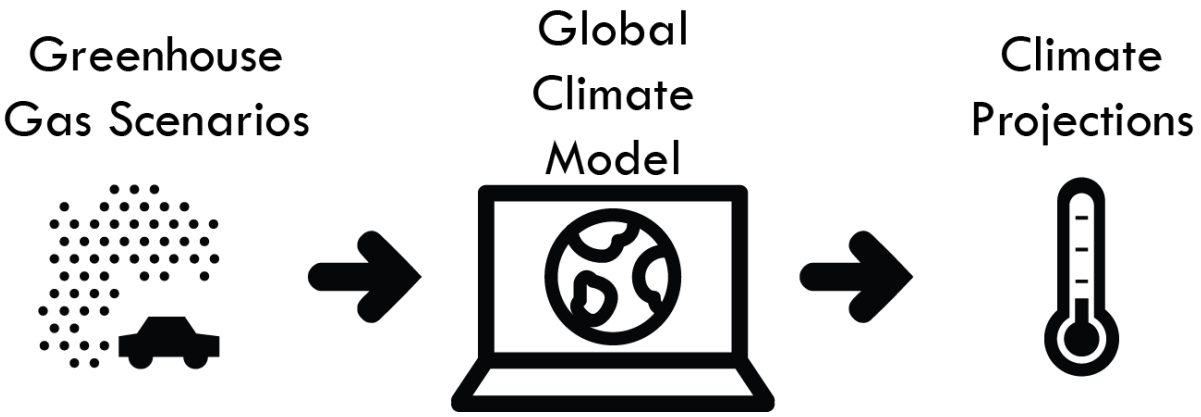
[26] IPCC, *Climate Change 2014*, 52

[27] EPA, "Overview of Greenhouse Gases", https://www.epa.gov/ghgemissions/overview-greenhouse-gases, accessed January 5, 2017

[28] The numbers assigned to the Relative Concentration Pathways refer to the amount of "radiative forcing" that would result from that emissions scenario. A higher amount of radiative forcing would cause more extreme changes in the climate sooner than a lower amount. See van Vuuren et al 2011 for details on RCPs.
Detlef van Vuuren et al. "The representative concentration pathways: an overview," *Climatic Change* 109 (2011): 5-31.

The estimated global GHG concentrations[29] from the GHG emissions scenarios are fed into Global Climate Models, which are a complex mathematical representations of the reaction of the earth's environment to various amounts and mixtures of GHGs over time. These models output a set of climate projections for each GHG scenario, including metrics such as increased temperature and precipitation (Figure 6). Essentially, the climate models answer the question "if human activities emit a certain amount of GHGs into the atmosphere over the coming decades, how will the global climate respond?"

Figure 6. How climate projections are calculated.



Source: MAPC

Climate projections based on the IPCC GHG emissions scenarios encompass changes across the globe, which means the geographic scale is very broad. A single set of temperature and precipitation projections may be available across all of New England, for example. This is the scale of projections available in the latest report from the IPCC and from the U.S. National Climate Assessment. This geographic scale masks a lot of variation—climate conditions along the Boston Harbor may be a lot warmer and wetter than conditions in western Massachusetts, for example. Because of this local variation, scientists must then "downscale" projections to account for local variation.

Developing a Regional Climate Change Scenario for the MAGIC Region

Over the past decade, a lot of interest has developed in Massachusetts around preparing and planning for climate change. Four recent key efforts are:

- Massachusetts Climate Change Adaptation Advisory Committee
- Regional Climate Change Adaptation Strategy
- City of Boston/Boston Research Advisory Group (BRAG)
- City of Cambridge Climate Change Vulnerability Assessment (CCVA)

Each of these efforts collected information, produced regional and local relevant climate change projections and data, and engaged public and private sector organizations.

[29] This is a simplification. The output of the Integrated Assessment Models is an amount of radiative forcing.

The following sections draw on these reports to describe climate change effects and vulnerabilities for the MAGIC region. Projected impacts are premised upon the emission scenario used for Boston and Cambridge and data for the Boston Metro region that includes the MAGIC region.[30] Although the data and respective climate impact projections were created primarily for the Greater Boston Harbor area and may not be as localized as are desired for the region, this information and data is the best available for the MAGIC region, given existing resources. While some changes may affect Boston and Cambridge differently than MAGIC towns, precipitation will not vary greatly within a 30-40 mile radius and the information regarding relative changing temperature and precipitations conditions holds as a starting point.[31]

Temperature

Heat

The average annual temperature (46–50°) is expected to increase by 3-4° in the next 15 years and 6-9° in the decades leading up to the year 2100 (Table 4). While there is consensus about the temperature changes in the next few decades, the increase after 2030 is less clear, as the emission scenarios come more into play. For example, a higher emission scenario projects faster temperature rise while a low scenario could slow the warming trend.

Temperature changes will vary on a seasonal basis (Table 4). Average winter temperature are predicted to generally not fall below freezing. Rather, they are projected to rise from a historic range of 23–28°F to 34–42°F by 2100.[32] Summer temperatures will also rise from the current average of 69 °F to a range of 70-84 °F by 2100 **Error! Reference source not found.**). urthermore, the frost-free summer agricultural growing season is expected to lengthen in New England by the end of the century by as much as a month, which has implications for the agricultural sector in MAGIC.[33]

Table 4. Boston Area projected increases in average temperature.

	Baseline 1961–2010	2010–2030	2035–2064	2070–2100
Annual Average	46–50°F	53–54°F	------	56–59°F
Winter Average (Dec., Jan., Feb.)	23–28°F	30–33°F	30 to 36°F	34–42°F
Summer Average (Jun., Jul., Aug.)	68–69°F	70–72°F	71–76°F	74–84°F

Source: Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston

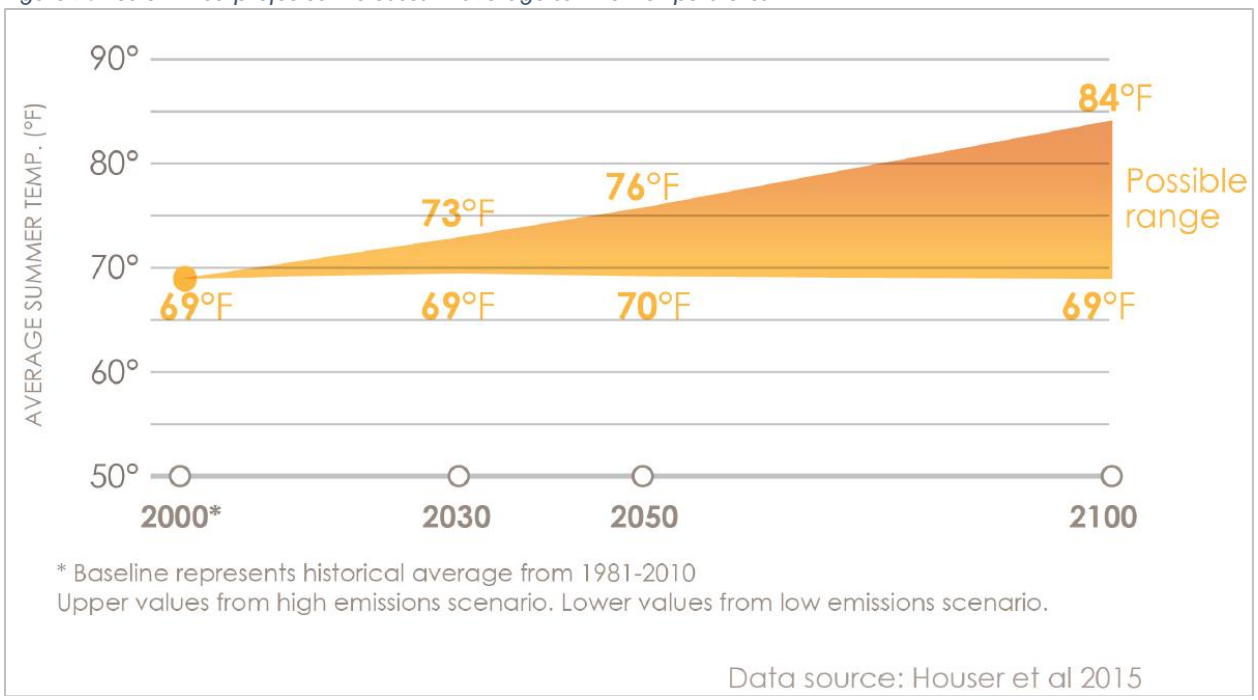
[30] Two scenario – a highest emissions scenario and a lower emissions scenario – were used in the Boston and Cambridge in order to provide a range of likely scenarios for projected changes in temperature and precipitation. When a range is presented

[31] When any advances are made in the factors that contribute to the climate projections or downscaling, the resulting projections are affected. It is therefore very important to monitor new research and data as it is released. For example, the BRAG recommends revisiting projections every two years.

[32] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016

[33] Under a high emissions scenario. National Climate Assessment

Figure 7. Boston Area projected increases in average summer temperatures

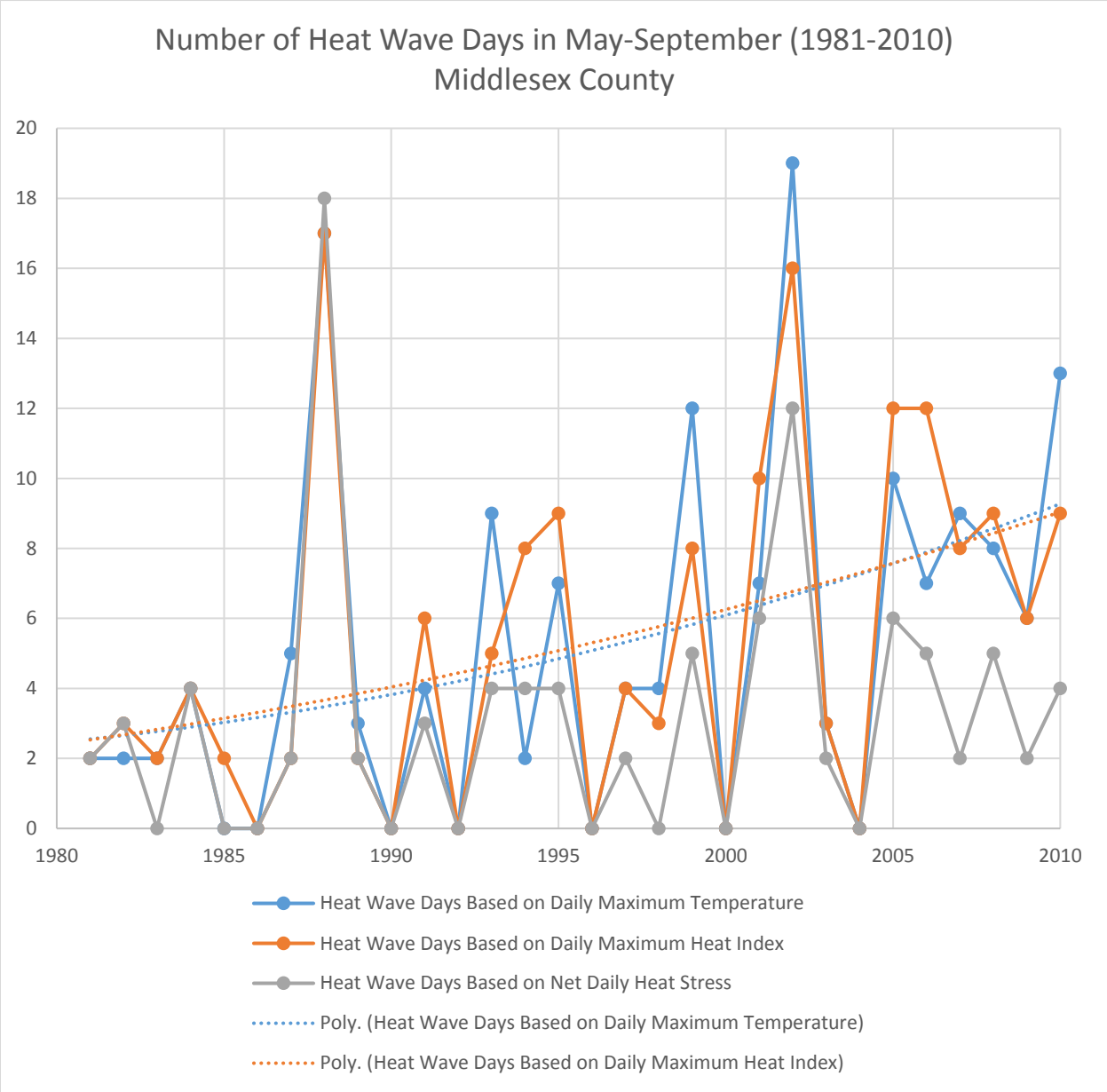


Source: Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston

The rise in average temperature will be accompanied by an increase in the number of hot (≥ 90°F) or extremely hot days (≥ 100°F). Currently, the Boston Metro region experiences roughly 11 days at or above 90°F each year. By the 2030s, this number may increase to 20–40 days per year, which is currently normal for Virginia and North Carolina.[34] By the 2070s, this number may increase to 25–90 days per year, which is more common in parts of Georgia and Alabama today.[35] Also, the Boston Metro region currently experiences roughly one day at or above 100 degrees every year.[36] By the 2030s, we may experience up five days above 100 °F, and by the 2070s, we may experience between up to 33 of these extremely hot days each summer. In addition to the data for the Boston Metro, data for Middlesex County seems to already be on a similar upward trend of experience high heat days over the past couple of decades (Figure 8).

[34] Southeast Regional Climate Center, "Number of Days with Max Temperatures Equal to or Above 90°F for Selected Cities in the Southeast," accessed on August 19, 2016, https://www.sercc.com/climateinfo/historical/mean90.html
[35] Under RCP 4.5 conditions. City of Cambridge, *Climate Change Vulnerability Assessment*, (City of Cambridge, 2015), http://www.cambridgema.gov/CDD/Projects/Climate/climatechangeresilianceandadaptation.aspx cited in BRAG.
[36] Boston Indicators, "Trends in Climate Change, Metro Boston and New England," http://www.bostonindicators.org/indicators/environment-and-energy/5-4clean-energy-and-climate-stability/5-4-1trends-in-climate-change-metro-boston, accessed March 25, 2017

Figure 8. High Heat Days in Middlesex County



Source: CDC WONDER Online Database[37]

Compounding this issue is the heat island effect, which occurs when dark surfaces - particularly pavements and tar roofs - absorb heat during the hottest part of the day. This heat is later released throughout the evening and night, keeping the air temperature higher than it would be in a more rural area.[38] Although the MAGIC Region is not particularly urbanized, the heat island effect will occur in any areas with increased impervious surfaces, such as large parking lots and

[37] National Climate Assessment - Extreme Heat Events: Heat Wave Days in May - September for years 1981-2010 on CDC WONDER Online Database, released 2015. Accessed at http://wonder.cdc.gov/NCA-heatwavedays-historic.html.

[38] EPA, "Heat Island Effect," accessed July 27, 2016, https://www.epa.gov/heat-islands

town center districts. The public health implications of the drastic increase in extreme heat days and of the heat island effect, will be described in later sections.

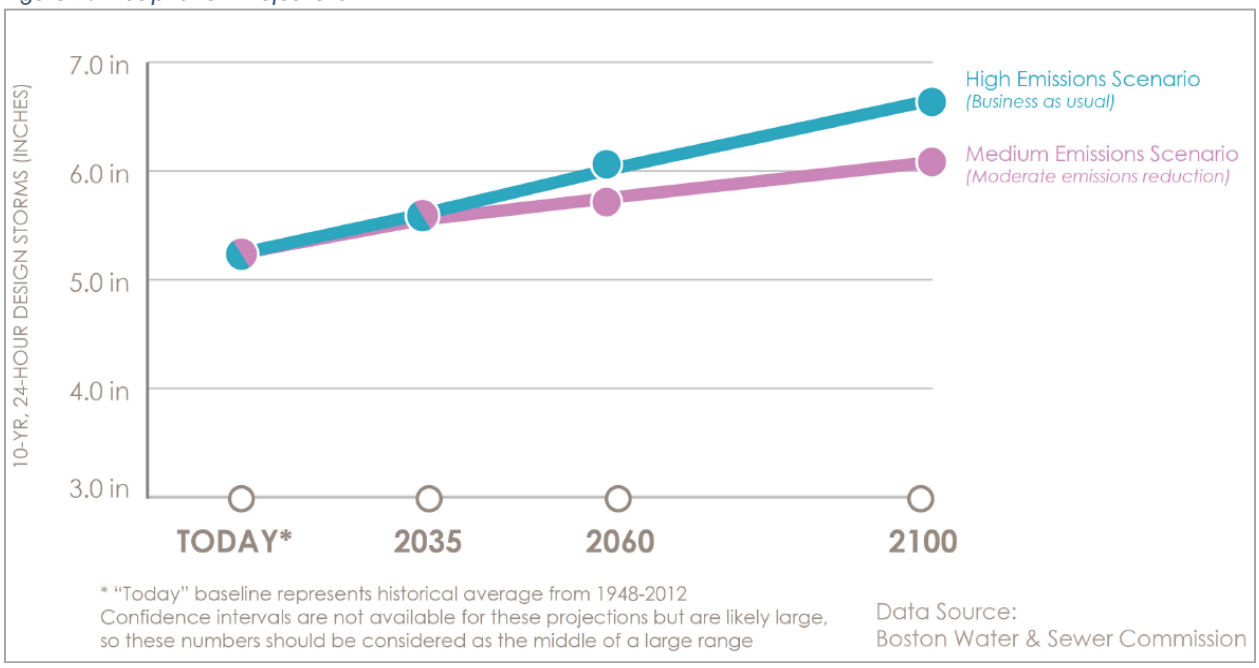
The MAGIC region will also continue to face variabilities in temperature (hot and cold) under climate change conditions. For instance, the number of extreme heat days will string together into longer heat waves. Alternatively, cold snaps may not decrease in coming decades. The region may not see a decline in periods of extreme cold until 2100.[39]

Precipitation

Rainfall

New England has already experienced a documented increase in both heavy rainfalls and flooding in recent decades.[40] Projections indicate that in the coming decades the region can expect the amount of rainfall during large storm events to significantly increase (Table 5). As with the temperature projections, the change in emissions – high being the status quo and low being the result of emissions reductions – will impact the magnitude of the increase beyond 2030 (**Error! eference source not found.**).

Figure 9. Precipitation Projections



Source: Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston

Currently, a "large storm event" is described within the state's stormwater standards as an amount of rainfall within a 24 hour period that is so large that it has only a 10 percent likelihood of occurring in a given year. In other words, we could expect a storm of this severity to occur roughly

[39] E. Kodra, K. Steinhaeuser, and A.R. Ganguly, "Persisting cold extremes under 21st-century warming scenarios." *Geophysical Research Letters*, 38, no.8 (2011), cited in BRAG, 31.
[40] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016.

once every 10 years. A storm of this likelihood will drop 4.9 inches of rainfall based on historic data (Table 5). However, the frequency of these extreme precipitation events will increase, thereby shifting the "10 year storm" to the one year (likely to occur each year). According to the Boston Research Advisory Group Report, by the 2030s, the "10-year storm" is projected to drop 5.6 inches of rainfall over the course of 24 hours, and by the 2070s, there will be 6.4 inches.

Table 5. Precipitation during 24 hour storm events of varying return periods.

	Baseline (1971-2000)	2015-2044	2055-2084
10% (10yr)	4.9 in	5.6 in	6.4 in
4% (25yr)	6.2 in	7.3 in	8.2 in
1% (100yr)	8.9 in	10.2 in	11.7 in

Source: City of Cambridge, "Climate Change Vulnerability Assessment," November 2015

It should be noted that due to slight variations in land uses, topography, etc., the MAGIC region already receives slightly less rainfall per year than Boston. According to data published by the Northeast Regional Climate Center,[41] an expected large storm event in the MAGIC region is currently roughly 0.5 inches less than in coastal parts of the City of Boston.[42]

Snowfall

As winters become warmer, snow accumulation is expected to decline regionally. Total snow accumulation during a given winter is expected to drop an estimated 31percent to 48 percent by 2100.[43] This decline does not necessarily indicate an end to extreme weather events such as those occurring during the winter of 2014-2015. Based on current projections, it is possible that, even with warmer winters and less total snowfall, large snowstorms may continue due to complex interactions between climate change effects, temperature, and atmospheric moisture.[44]

Drought

Currently, no detailed projections for droughts are available for Boston or the surrounding region. However, larger-scale projections suggest that medium- and short-term droughts may increase, especially during summer and fall seasons. These droughts would be similar to what was experience in the region in the latter half of 2016.[45] This will be exacerbated by predicted high temperatures, high evapotranspiration rates by vegetation, and a longer growing season. Since significant groundwater recharge occurs only during the spring and fall (when the ground is not frozen and the trees have leaves), the observed reduction in late summer and early fall storms may result in reduced recharge (NOAA, Northeast River Forecast Center). Unless significant new measures are taken to recharge stormwater, more intense precipitation will also reduce groundwater and aquifer recharge.

[41] The mission of the Northeast Regional Climate Center is to facilitate and enhance the collection, dissemination and use of climate data and information, as well as to monitor and assess climatic conditions and impacts in the twelve-state, northeastern region of the United States. The center is based at Cornell University.
[42] Northeast Regional Climate Center, "Extreme precipitation in New York and New England: an interactive web tool for extreme precipitation analysis," accessed on July 6, 2016, http://precip.eas.cornell.edu/
[43] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016
[44] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016
[45] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016

Riverine Flooding

For the purposes of this assessment, the planning team is utilizing a definition of flood that stems from the Federal Emergency Management Agency's National Flood Insurance Program (NFIP) definition: *A general or temporary condition, of partial or complete inundation, of one or more acres of typically dry land from overflow of inland waters or accumulation or runoff or mudflow from any source.*

To date, a methodology for determining the amount of expansion of riverine floodplains due to climate change has not been established for the Boston Metro or MAGIC region. MAPC has been working with academic and government partners to discuss potential methods, and this work will continue through 2016 and into 2017. Therefore, this level of analysis was not possible to complete for this project.

Existing floodplain delineations are based on past precipitation patterns and flooding and can only suggest where future riverine flooding conditions could be projected. Riverine floodplain zones are determined during the development of Flood Insurance Rate Maps (FIRMs) by FEMA, for the purposes of the NFIP. This was last done for the Concord basin in 2014. Methodologies for the development of these zones include hydrologic studies to determine the amount of water flowing during precipitation events and hydraulic analyses to determine water surface elevations. Riverine flood zones include the following typologies (illustrated in Figure 10):

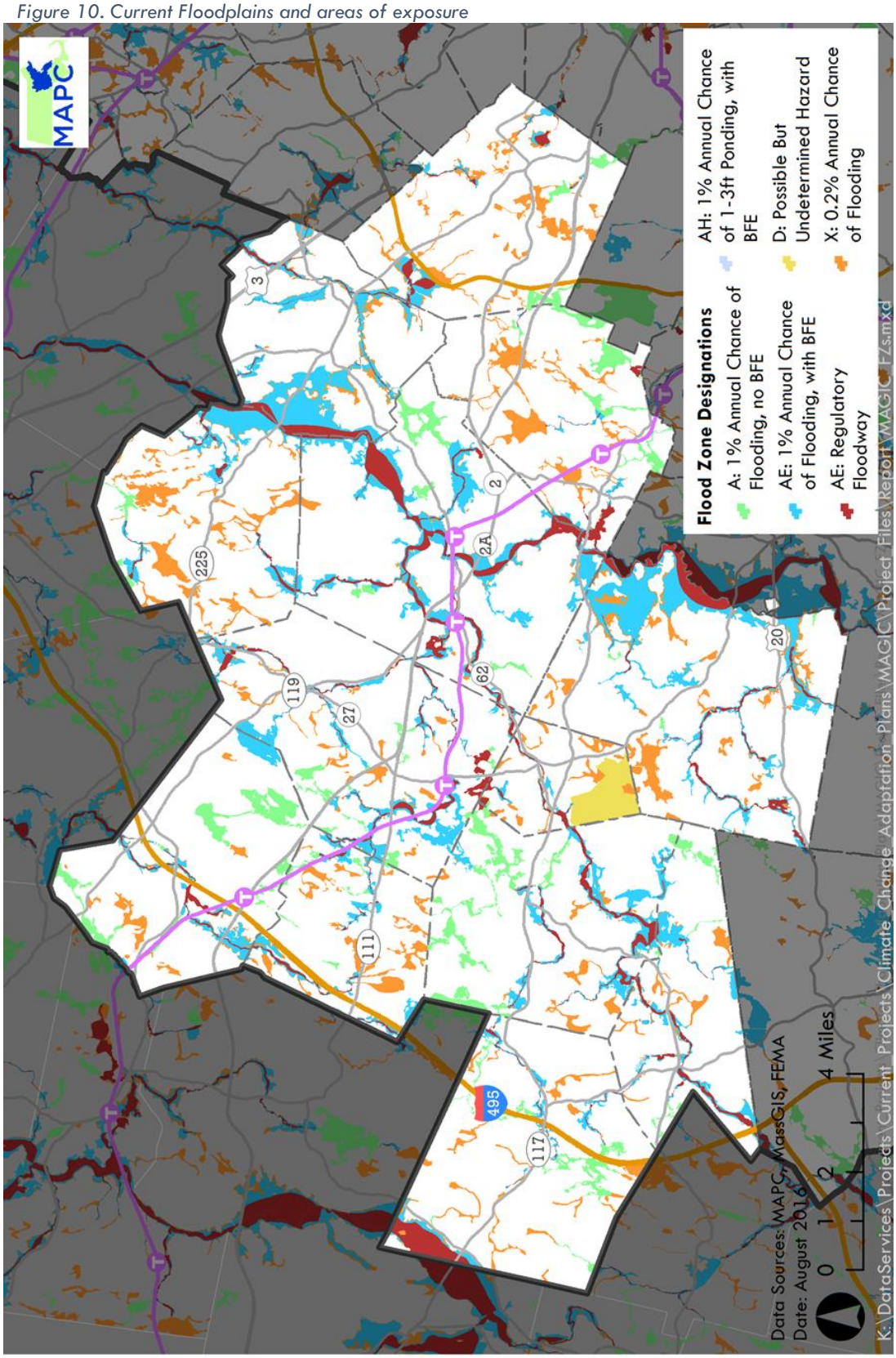
- High Risk Areas:
    - Zone A: These are areas defined by FEMA as having "a 1% chance of flooding in any given year, and a 26% chance of flooding over the life of a 30-year mortgage." They further clarify that "because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones."
    - Zone AE (formerly A1-A30 Zones): These are Zone A floodplains where base flood elevations have been provided.
    - Other A Zones:
        - AH: Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from one to three feet.
        - AO: River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from one to three feet.
        - AR: Areas with a temporarily increased flood risk due to the building or restoration of a flood control system such as a levee or a dam.
        - A99: Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system where construction has reached specified legal requirements.
- Moderate to Low Flood Risk Areas:
    - Zone X – shaded (formerly Zone B): These areas have a 0.2% chance of flooding in any given year and usually are between the limits of the 100-year and 500-year floods. They are used to designate base floodplains of lesser hazards (e.g., areas protected by levees or shallow flooding areas).

- Zone X – unshaded (formerly Zone C): usually depicted on FIRMs as above the 500-year flood level, which may have ponding and local drainage problems that don't warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood area.

It should be noted that although Zone X is designated as low-moderate flood risk, FEMA recognizes that these areas are subject to flooding due to problems with stormwater infrastructure, and therefore "the failure of a local drainage system creates areas of high flood risk within these rate zones."[46]

[46] US Federal Emergency Management Agency, National Flood Insurance Program. *Answers to Questions about the National Flood Insurance Program.*

Figure 10. Current Floodplains and areas of exposure



The relationship between precipitation and flooding is complex. Flash floods and urban flooding may be caused directly by heavy downpours, but river flooding also depends on factors such as the amount of impervious surface cover, soil type, and soil saturation.[47] In New England, a rainstorm may produce flooding in winter when the ground is frozen, when a storm of the same size would not flood the same river in the summer, for example.[48] This means that the amount of flooding that could be expected may not be directly proportionate to the expected increases in precipitation reported above.

Because the Sudbury-Assabet-Concord river system flows northward, river flooding during summer/fall storms that move from south to north is exacerbated.[49] The few studies that have projected changes in river flooding volume show moderate increases by 2055 and larger increases by 2085 (Table 6).

Table 6. Projections for changes in river floods.

Flood Type	2055	2085
Small Floods (2 year)	0–20%	20–50%
Larger Floods (100 year)	-10–35%	15–70%
Flood frequency (floods/year)	Increases	Increases

Source: Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston

One rule of thumb that the City of Cambridge is using until more precise information is available predicts that 100-year floods will occur at the current 500-year flood level. The city requires developers to build to avoid flood damage at one time period, e.g., 2030, and to be able to recover from flooding at a later time period, e.g., 2070. This document takes this same approach and presents the potential of impact of flooding in the current 100-year and 500-year flood zones.

[47] U.S. Global Change Research Program, "National Climate Assessment 2014," accessed July 29, 2016, http://nca2014.globalchange.gov/report

[48] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016

[49] NOAA, Northeast River Forecast Center

MAGIC Climate Change Resilience Plan:

Vulnerability Assessment

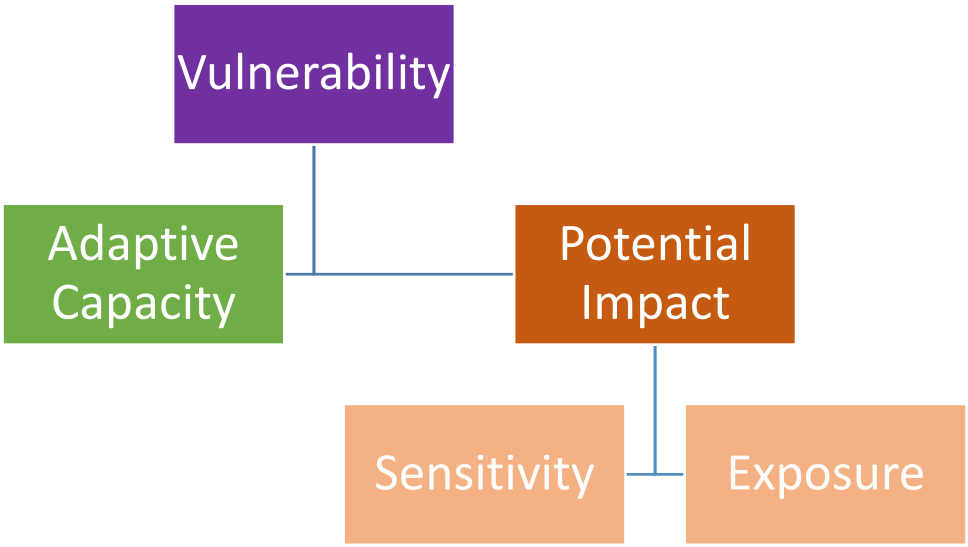
VULNERABILITY ASSESSMENT

The vulnerability assessment seeks to determine to what degree a system, sector, or population is susceptible and adaptable to the predicted effects of climate change. This assessment relies on the information presented in the previous section, a climate change scenario that represents a best guess at how local conditions will be affected, and an understanding of existing conditions across the systems, sectors, or population groups. Most importantly, public input from municipal representatives, residents, and involved subject matter experts provides a basis for what is assessed and how to arrive at findings.

Assessment Approach

The assessment considered three factors to decreasing vulnerability: exposure, sensitivity, and adaptive capacity (Figure 11).

Figure 11. Assessment approach



Source: MAPC, adapted from Glick et al. 2011

Exposure

Exposure is a determination of whether a system, sector, or population is expected to experience climate change effects. It is an accounting of elements that could be weakened, damaged, or irrevocably changed due the impacts of climate change. For example, climate change is expected to increase sea level rise along coastlines. Sea level rise is not addressed in this assessment due to the location of the MAGIC region. Exposures considered for this assessment are the predicted changes in precipitation and temperature.

Sensitivity

Sensitivity describes the degree to which a system, sector, or population could be expected to suffer due to exposure to climate change effects. A high sensitivity conveys that system, sector, or population would be expected to suffer more than those with a low sensitivity. Or to put it another way, sensitivity looks to distinguish differences between those that are highly or minimally impaired by the same changes in climate (e.g., longer periods of drought).

Adaptive Capacity

Adaptive capacity characterizes the ability of a system, sector, or population to adjust to changing climate conditions. It includes how these elements may be able to decrease potential damages, take advantage of changes, or cope with consequences. A high adaptive capacity implies that the system, sector, or population could adjust more easily to new conditions, while a low adaptive capacity indicates that the system, sector, or population is likely unable to acclimatize to the new conditions.

Adaptive capacity is distinct from climate change adaptation. Adaptive capacity is based on an existing feature or features, while adaptation is something enacted in response to potential climate impacts and changing conditions.

Vulnerability

The vulnerability assessment takes into account sensitivities and adaptive capacities as it relates to exposure to higher temperatures and changing precipitation patterns. At this time, the assessments are qualitative characterizations based on the available information and input. Assessed vulnerabilities are characterized as follows:

- High Vulnerability, which indicates the system, sector, or population is expected to be greatly affected while being minimally able to accommodate predicted impacts.
- Moderate Vulnerability, which indicates the system, sector, or population is expected to be affected and will be able to accommodate for some of the predicted impacts.
- Low Vulnerability, which indicates the system, sector, or population is expected to be minimally affected and will be sufficiently able to accommodate predicted impacts.
- No Determination, which indicates sufficient information is not available for an assessment.

Unlike a traditional risk assessment, a climate change vulnerability assessment is a snapshot at a certain point in time and in the context of an evolving set of predictions and potential impacts. As such, the assessment for the MAGIC region should be considered a work in progress. It should be updated regularly as more information become available.

Alignment with other plans

The MAGIC Vulnerability Assessment relies on work from ongoing municipal climate projects (Climate Ready Boston and Climate Change Preparedness & Resilience) and completed projects such as the state's adaptation plan and MAPC's Regional Climate Change Adaptation Strategy. While this plan does not match up specifically with the categories or geographies in these plans (e.g., inland vs coastal, Natural Resources vs Terrestrial Habitat and Species), each system, sector, or population that is explored can fit into one or multiple defined categories used in the other efforts.

VULNERABILITY ASSESSMENT FINDINGS

The following sections present the findings from the vulnerability assessment of 14 systems, sectors, or populations. These individual assessments are based on research, data analysis, a review of literature, and information provided by project stakeholders, in particular the MAGIC Climate Change Working Group.

Findings of the vulnerability assessments are presented in the following order:

1. Terrestrial Habitat and Species
2. Aquatic Habitats and Species
3. Drinking Water Infrastructure
4. Stormwater Infrastructure
5. Wastewater Infrastructure
6. Land Use and Buildings
7. Transportation Infrastructure
8. Energy Infrastructure
9. Health and Welfare
10. Outdoor Workers
11. Agriculture
12. Local Economy: Tourism
13. Local Economy: Healthcare
14. Local Government

Terrestrial Habitat and Species

Assessment Summary

- The Terrestrial Habitat and Species systems has been assessed as moderately vulnerable
- Potentially highly-vulnerable aspects include vegetation and smaller animal species native to the MAGIC region.
- Vulnerabilities are due to sensitivities to changing average temperatures, availability of water for existing species, introduction of non-native insects, disease vectors, and plants.
- Adaptive capacities include significant amount of preserved open spaces and continued funding for open space acquisition, past and ongoing tree planting initiatives, and the monitoring and management of some invasive plant species.

Terrestrial Habitat and Species Vulnerability Assessment

Sensitivity

Forests

The extremes that are predicted as a result of climate change will affect terrestrial ecosystems, including vegetation and animals in the MAGIC region. The changes are likely to impact the habitats that current species rely on, alter the diversity of species that are currently present, and contribute to new threats to and opportunities for terrestrial life.

Climate change will affect habitability for tree species (Figure 12). The composition of deciduous trees characteristic of the Northeastern U.S., which include maple, birch, and beech forests, is likely change as the region becomes more habitable to trees characteristic of southern forests such as oak and hickory trees.[50] A range of other factors, including the introduction of destructive insects or diseases and deforestation for development may reduce the number and size of tree stands.[51] Table 7 below provides lists of which tree species will be more suited to warmer climate conditions (termed as "winners") and which will be less suited (termed as "losers"), based on projected impacts.[52] According to the U.S. Forest Service, various species of oak and pine will become better suited to the New England climate, while species of maple, birch, and beech will become less well-suited.

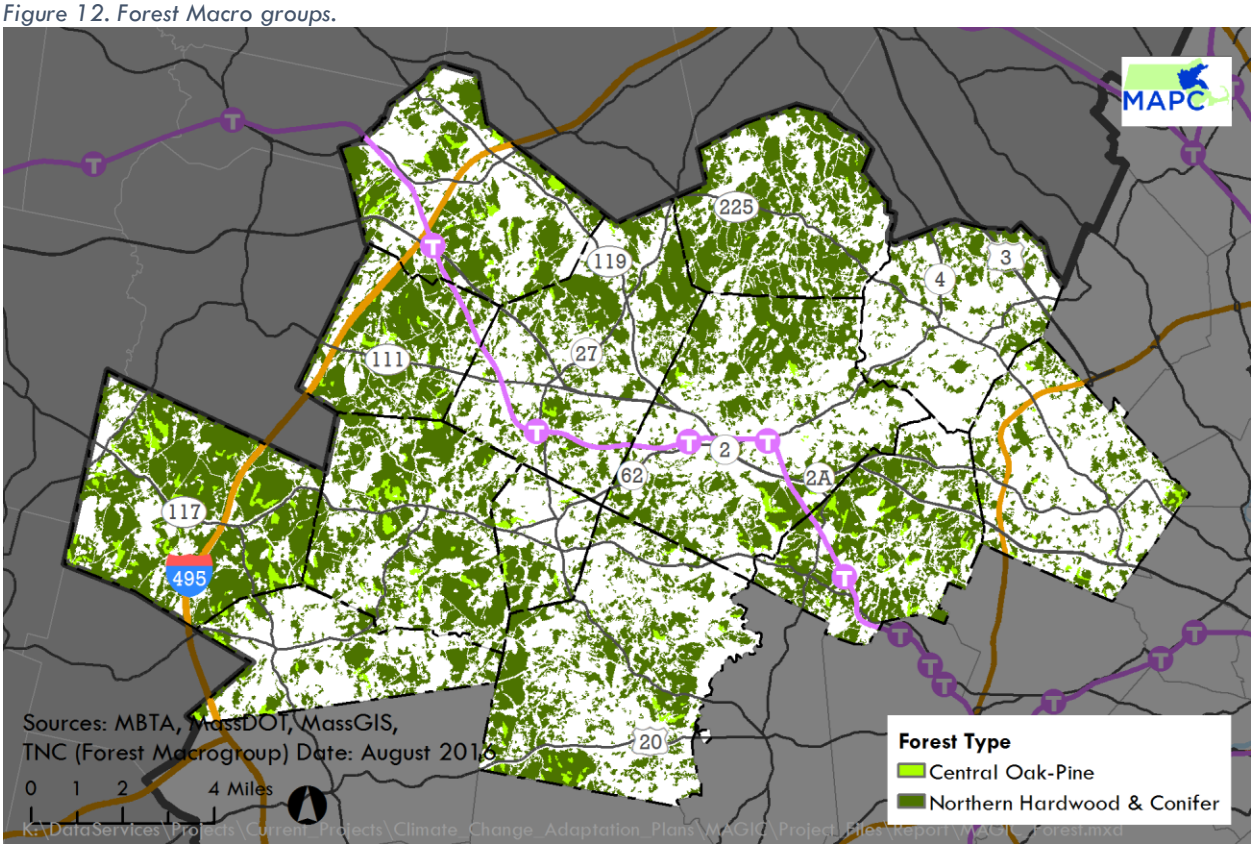
Table 7. "Top 10" Winner and Loser Tree Species

Winners High Emissions Scenario	**Losers High Emissions Scenario**		**Winners Low Emissions Scenario**	**Losers Low Emissions Scenario**
Post Oak	Red Maple		White Oak	Red Maple
Sweetgum	Eastern White Pine		Sweetgum	Eastern White Pine
Loblolly Pine	Northern Red Oak		Eastern Red Cedar	Eastern Hemlock
Eastern Red Cedar	Eastern Hemlock		Flowering Dogwood	Northern Red Oak
Common Persimmon	American Beech		Yellow Poplar	Paper Birch
White Oak	Black Cherry		Post Oak	Yellow Birch
Winged Elm	Sugar Maple		Loblolly Pine	Balsam Fir
Black Hickory	Sweet Birch		Common Persimmon	Quaking Aspen
Flowering Dogwood	White Ash		Chestnut Oak	American Beech
Shortleaf Pine	Paper Birch		Sassafras	Striped Maple

Source: US Forest Services' Climate Change Tree Atlas

[50] U.S. Forest Service, "Changing Climate, Changing Forests," 2011
[51] Future Forests
[52] U.S. Forest Service, "Climate Tree Atlas," accessed on August 19, 2016, http://www.nrs.fs.fed.us/atlas/tree/MA_mean_fz_winlose.html.

Figure 12. Forest Macro groups.



Source: MAPC

Longer and drier growing seasons for forests may increase the risk of forest fires and outbreaks of insects and plant diseases that could harm overall forest health.[53] While not directly explored in this assessment, wind events may also increase under climate change, which could also harm certain stands of trees that are not able to withstand high winds.[54]

Healthy riparian forest corridors in the region (i.e., forest ecosystems that line rivers), inclusive of robust vegetation and vigorous soil structure, offer numerous benefits to its riverine system and adjacent natural and built environments. These highly vegetated resources "calm" floodwaters by trapping soil that stores, and later releases, precipitation. At present, these corridors are stressed by encroaching development and recent extreme weather patterns, which are likely to increase under changing climate conditions. Increased precipitation results in high runoff volumes that "downcut" into riverbanks and beds, thereby reducing the capacity of the existing floodplain. [55] If the natural flood attenuation function of these corridors is degraded, erosion and loss of habitat loss and other ecosystem functions will accelerate, offering less protection for terrestrial species and of adjacent and nearby buildings.

[53] US Forest Service, "Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers," 2012.
[54] US Forest Service, "Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers," 2012.
[55] Massachusetts Climate Change Adaptation Advisory Committee, "Massachusetts Climate Change Adaptation Report", 2011.

Terrestrial Species

Many terrestrial species need a particular habitat to thrive and require pathways between areas that are home to this habitat, such as a meadow or forest. For biodiversity, this means that it is critical to not only preserve the amount of undeveloped natural land, but also maintain its configuration.[56] Fragmented blocks of terrestrial habitats interrupted by paved roadways can block migration patterns and potentially isolate certain species or groups within a particular species.

The Massachusetts Wildlife Climate Action Tool, which is an initiative of the Massachusetts Climate Adaptation Partnership, is a resource for identifying the vulnerability of species and habitats due to climate change.[57] It is not comprehensive but it does provide a summary of species that have been assessed for vulnerability. The boundary of the MAGIC region was used to define a project area for the tool to identify potentially impacted species and their vulnerability. None of the sources for the vulnerability ranking were from Massachusetts, so information was pulled from the assessment of the nearest geography, starting with adjacent states (e.g., Vermont, New York, etc.) and then expanding outward (e.g., Michigan).

In general, most species identified with the tool are predicted to remain stable, although some smaller species were more likely to be vulnerable (Table 8). The Frosted Elfin moth, the Marbled Salamander, and the Snowshoe Hare were each assessed as being highly vulnerable with a high confidence level. The reasons cited for their vulnerability include the need for specialized habitat, the inability to disperse long distances across a habitat, and sensitivity to precipitation and changes in the seasons. Conversely, some species such as the wild turkey and coyote are identified for possible growth. These species can adapt to a variety of conditions and have the ability to spread out across long distances.

This list should not be considered comprehensive, but does start to form an initial picture.

Table 8. Vulnerability of Terrestrial Species and Habitats in the MAGIC region

Species	Ranking	Confidence	Source of Ranking	Time period:
American Beaver	Presumed Stable	High	Vermont	2050-2100
American Mink	Presumed Stable	Moderate	Maine	Not provided
American Woodcock	Presumed Stable	Very High	Maine	Not provided
Black Bear	Presumed Stable	Very High	Michigan	2050
Blue-winged Teal	Presumed Stable	Very High	Michigan	2050
Canada Warbler	Moderately Vulnerable	Moderate	Maine	Not provided
Coyote	Increase likely	Very High	Michigan	2050
Eastern Meadowlark	Moderately Vulnerable	Very High	Maine	Not provided

[56] Massachusetts Wildlife Climate Action Tool, "Freshwater wetlands: vernal pools," accessed August 19, 2016, http://climateactiontool.org/ecogroup/freshwater-wetlands-vernal-pools?extents=

[57] Massachusetts Wildlife Climate Action Tool, "About us," accessed September 19, 2016, https://climateactiontool.org/content/about-us

Species	Ranking	Confidence	Source of Ranking	Time period:
Frosted Elfin	Highly Vulnerable	High	New York	2050
Louisiana Waterthrush	Presumed Stable	Very High	Maine	Not provided
Marbled Salamander	Highly Vulnerable	Very High	New York	2050
Marsh Wren	Presumed Stable	Moderate	Maine	Not provided
Northern Long-eared Bat	Presumed Stable	Very High	Michigan	2050
Prairie Warbler	Presumed Stable	Very High	Maine	Not provided
Ruffed Grouse	Presumed Stable	Very High	Michigan	2050
Snowshoe Hare	Highly Vulnerable	Very High	Maine	Not provided
White-tailed Deer	Presumed Stable	Very High	Michigan	2050
Wild Turkey	Increase likely	Moderate	Michigan	2050
Wood Duck	Presumed Stable	Moderate	Michigan	2050
Wood Thrush	Moderately Vulnerable	Moderate	Maine	Not provided
Wood Turtle	Moderately Vulnerable	High	Vermont	2050-2100

Source: Massachusetts Wildlife Climate Action Tool

Invasive Species

Development that is not carefully designed and directed can introduce and encourage invasive species. As temperatures rise and extreme cold decreases, invasive insect species such as the Asian longhorned beetle, the emerald ash borer, or hemlock woolly adelgid may proliferate because they are no longer killed off over the winters (

Figure 13).[58] These species threaten the health of forests and the wildlife species that depend on habitats created by these trees.

Figure 13. Emerald Ash Borer, Asian Longhorn Beetle, Hemlock Woolly Adelgid (left to right)

Source: Photo credits USDA, USDA, Dan Nydick

The temperature change can make way for invasive plant species as well. Warmer temperatures and increased CO_2 levels allow non-native plant species to find more a welcoming habitat and

[58] Massachusetts Wildlife Climate Action Tool, "Stressors: invasive plants and animals," accessed August 19, 2016, http://climateactiontool.org/content/invasive-plants-and-animals

accommodate their ability to arrive earlier and persist later in the growing seasons. These plants, such as kudzu and Japanese stiltgrass, may then out-compete and displace native plant species.[59]

Adaptive Capacity

Open Space Planning and Protection

Each town in MAGIC has completed an Open Space and Recreation Plan (OSRP) in the past 15 years (Table 9). The OSRP provides a process and structure for municipalities to consider how and where to preserve undeveloped open space and recreation spaces over a five- to seven-year period. Having an OSRP is also a requirement to participate in state grant programs that provide funding for open space acquisition. While each town has had a plan at one point, seven have completed plans in the last five years and another two are in the process of updating their plans. Two towns – Bedford and Maynard – have not updated their plans since 2004.

Table 9: MAGIC Open Space Plans

Acton (2014-2021)	Lexington (2015-2021)
Bedford (2004-2008)	Lincoln (2017-2024)
Bolton (2010-2015)	Littleton (2016-2021)
Boxborough (2015-2022)	Maynard (2004-2009)
Carlisle (2013-2019)	Stow (2016-2023)
Concord (2015-2020)	Sudbury (2009-2014, plan update underway)
Hudson (2016-2023)	

Source: MAPC review

Tree Planting Initiatives

Tree planting programs provide multiple benefits related to climate change. They introduce vegetative cover, which counteracts potential heat island effects, and help manage and retain stormwater. These programs also help with carbon sequestration and reducing a key GHG. There were three current tree planting programs identified in MAGIC. The Towns of Lexington and Concord offer programs where residents can request a tree to be planted adjacent to a public way. Both programs are first come, first served as funding is limited. The Littleton Electric Light and Water District offers two shade trees per resident for free through Green Rewards program. This program was available to 100 applicants. While other programs were not identified, many of the other towns in MAGIC promote preservation of trees and new plantings through their development and conservation regulations. For example, Bedford has a Tree Preservation Policy which requires Conversation Commission approval before a tree can be removed in new developments.

Invasive Species Monitoring and Management

Invasive species monitoring programs are present in most MAGIC towns. These programs work to prevent the introduction of non-native species and, where these species are found, work to control

[59] Bradley Bethany A, Wilcove David S., and Oppenheimer Michael, "Climate change increases risk of plant invasion in the Eastern United States," http://europepmc.org/abstract/AGR/IND44367832/reload=0;jsessionid=geMUvZpMPs0zzRUz8D6h.2, accessed January 16, 2017.

or eliminate them. The focus of the work is to prevent the harm that these species – animal, vegetation, insect, or pathogen – could have on the native ecological system. Seven towns in MAGIC (Carlisle, Concord, Lincoln, Littleton, Maynard, Stow, and Sudbury) are part of the SuAsCo Cooperative Invasive Species Management Area (CISMA). The group has served as a peer, expert, and information sharing network (mainly for those in the conversation field) and have also partnered to seek funding to support their work. An example of this work is a Sudbury Valley Trustees project which is using mowing, cutting, and selective herbicide treatments to fight invasive species growth in the Gowing Swamp.[60]

Other towns have programs as well. In Acton, the tree warden annually surveys the town to assess compliance with the town's Vegetative Management Plan.[61] The warden includes the identification of invasive species in this survey. The Town of Lexington has developed the app OUTSMART Invasive Species, which allows residents to report invasive species with a location and an image.[62] The information is transmitted to the town and MassDEP.

Adoption of the Community Preservation Act

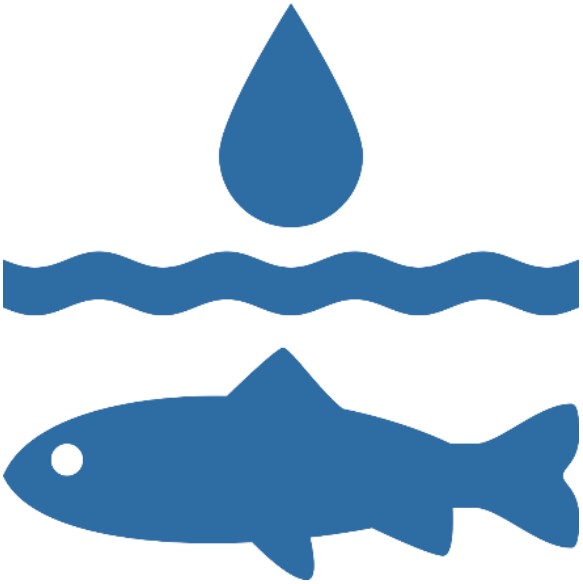
The Community Preservation Act (CPA) helps municipalities preserve open space and historic sites, create affordable housing, and develop outdoor recreational facilities.[63] Municipalities do this by establishing a local community preservation fund support through a municipal property tax surcharge of up to three percent, which then may be matched by state funds. Through the CPA, municipalities can acquire and preserve open space and invest in recreational spaces, which could assist with adapting to heat and precipitation impacts of climate change. In MAGIC, all but one municipality (Bolton) has adopted the CPA.

[60] SuAsCo CISMA grants: http://www.cisma-suasco.org/projects/grants/currentgrants, accessed April 17, 2016
[61] Pursuant to the Rights-of-Way Management Regulations (333 CMR 11.00) in order to apply pesticides to control vegetation to maintain Rights-of Ways, the Department of Agricultural Resources must approve a Vegetation Management Plan (VMP) and a Yearly Operational Plan (YOP). http://www.mass.gov/eea/agencies/agr/pesticides/vegetation-management-and-yearly-operation-plans.html
[62] Town of Lexington, "Report Invasive Species Sightings," http://www.lexingtonma.gov/invasive-species/pages/report-invasive-species-sightings, accessed August 29, 2016
[63] Community Preservation Coalition, "CPA: An Overview," http://www.communitypreservation.org/content/cpa-overview, accessed August 29, 2016

Aquatic Habitats and Species

Assessment Summary

- The Aquatic Habitat and Species systems as a whole is assessed as moderately vulnerable with potentially highly vulnerable aspects
- Highly vulnerable aspects include vernal pools and coldwater fish species
- Vulnerabilities are due to sensitivities to temperature changes, changes in precipitation, and limited mobility of aquatic species and habitats.
- Adaptive capacities present in the region include water levels and quality monitoring, and water conservation measures. However, it was found that the towns were not actively monitoring or acting to preserve waterways beyond complying with state level measures like the Rivers Protection Act.



Aquatic Habitats and Species Vulnerability Assessment

Sensitivity

Stormwater Runoff

Extreme variations in temperature and precipitation (i.e., rising temperatures, increased chances of droughts, and intense precipitation) will reduce water quantity and degrade water quality. Many aquatic species throughout the region thrive in cool, oxygen-rich water that sits in the deeper parts of surface water bodies. As groundwater is depleted by drought periods, rivers and streams will flow less and surface waters will become shallow, causing conditions such as oxygen depletion and higher water temperatures that adversely affect aquatic species. Alternatively, intense rainfall will likely result in increased surface water turbidity and a higher concentration of storm water pollution entering into waterbodies, which will cause eutrophication and fish kills.

While there is a plethora of water monitoring information generated by the OARS for the Assabet, Sudbury, and Concord River Watersheds organization, water quality data indicate current climate-related impacts are already manifesting. For instance, the OARS 2015 Water Quality Report used conductivity, a measure of the water's ability to conduct electricity, as an indirect indicator of pollutants such as effluent, non-point source runoff and erosion (e.g., higher conductivity would point toward a higher than expected concentration of chemicals which are necessary to carry the electrical current). The report explains that EPA studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 microsiemens per centimeter (µS/cm).[64] OARS data showed that "the range of mainstem conductivity readings was from 235 μ S/cm to 1343 μ S/cm in 2015 with the highest reading at Route 9 (ABT-301) in July."[65]

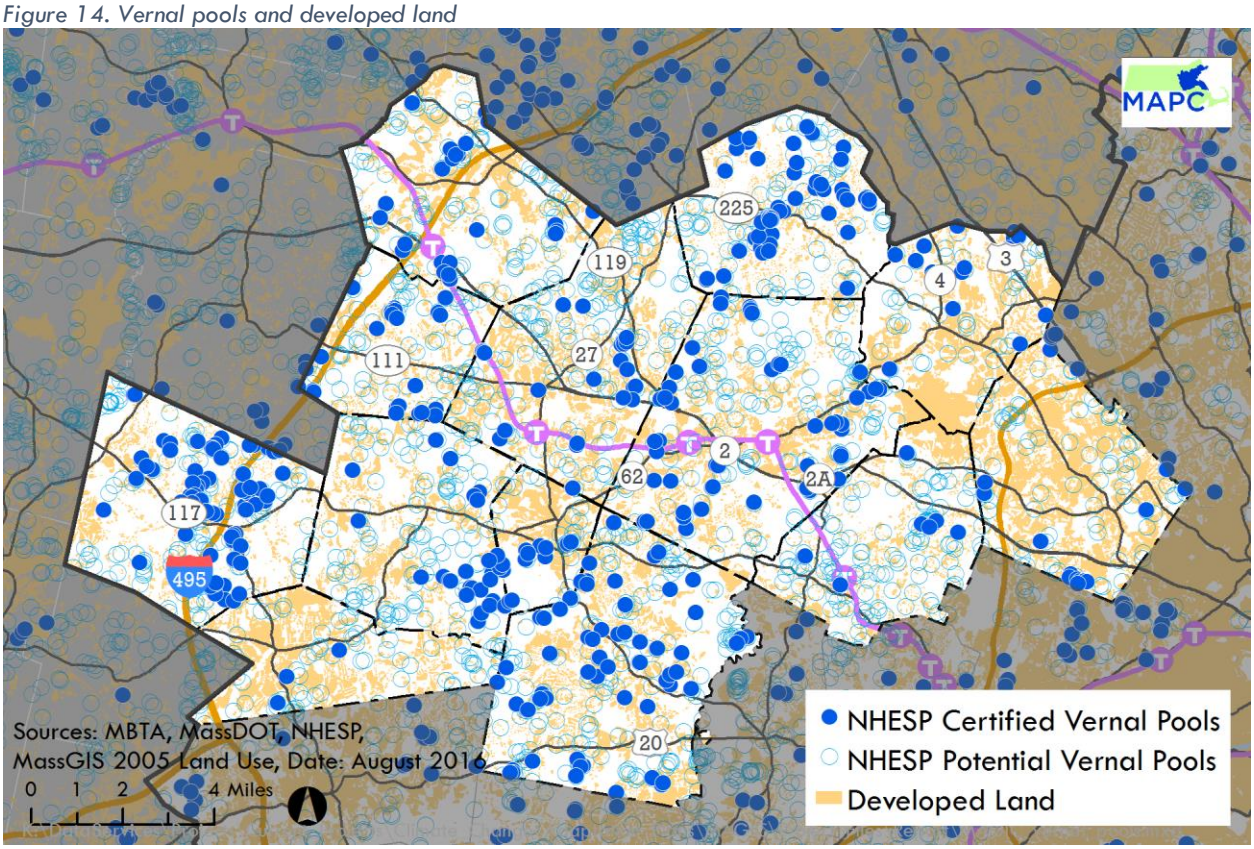
Vernal Pools

As shown in

[64] US EPA Monitoring and Assessing Water Quality: https://archive.epa.gov/water/archive/web/html/index-18.html.
[65] OARS, Water Quality Monitoring Program Final Report: 2015 Field Season. March 2016

Figure 14, the region is home to numerous vernal pool wetland resources, which are small seasonal wetlands that occur in depressions. According to the Massachusetts Natural Heritage and Endangered Species program, there are 378 vernal pools delineated throughout the region, and over 1,300 potential pool areas (visible on aerial photographs, yet not verified via wetlands delineation practices (Table 10). However small and isolated these pools seem, they are rich in diversity and serve as critical habitat to rare and threatened species such as the spotted salamander.

Figure 14. Vernal pools and developed land



Source: MAPC, Massachusetts Natural Heritage & Endangered Species Program

Table 10. Number of Certified Vernal Pools and Potential Vernal Pools by municipality.

Municipality	Vernal Pools	Potential Vernal Pools	Total
Bolton	69	151	220
Sudbury	60	163	223
Carlisle	53	88	141
Concord	48	154	202
Stow	26	125	151
Boxborough	24	73	97
Acton	23	142	165
Littleton	23	113	136
Bedford	16	46	62
Maynard	13	31	44
Lexington	12	77	89
Lincoln	8	126	134
Hudson	3	58	61
Total	***378***	***1347***	***1,725***

Source: Massachusetts Natural Heritage & Endangered Species Program

Changes in precipitation patterns would affect the viability of vernal pools. As adeptly described by Professor E.T. Bauder, San Diego University, "their hydrological characteristics are determined by a complex interaction between the highly variable climate and topographic relief."[66] Therefore, these wetland resources are highly susceptible to changes in precipitation patterns (such as event duration and frequency) and storm intensity.

The sensitivity of aquatic species due to climate change can be explored in a limited way through the Massachusetts Wildlife Climate Action Tool.[67] Similar to the process for the terrestrial sector, the tool was used to identify which - if any - species in MAGIC towns would be affected (Table 11). The identified species were:

Table 11. Vulnerability of Aquatic Species and Habitats in the MAGIC region

Species	Ranking	Confidence	Location of Assessment	Time period:
American Eel	Moderately Vulnerable	Low	NY	2050
Brook Trout	Highly Vulnerable	High	Vermont	2050-2100

Source: Massachusetts Wildlife Climate Action Tool

Adaptive Capacity

Water Quality Monitoring and Protection

Streamflow monitoring and controls provide the ability to understand how water resources are functioning for aquatic habitats and for water withdrawal. As climate change alters when and how precipitation falls, monitoring streamflow can serve as a guide for changes in natural preservation activities and water use by residents. OARS monitors the streamflow of five MAGIC towns and also provides services like water quality testing.[68] OARS monitors approximately 16 sites across these towns, including sites along each river and several tributaries, typically from May through October.

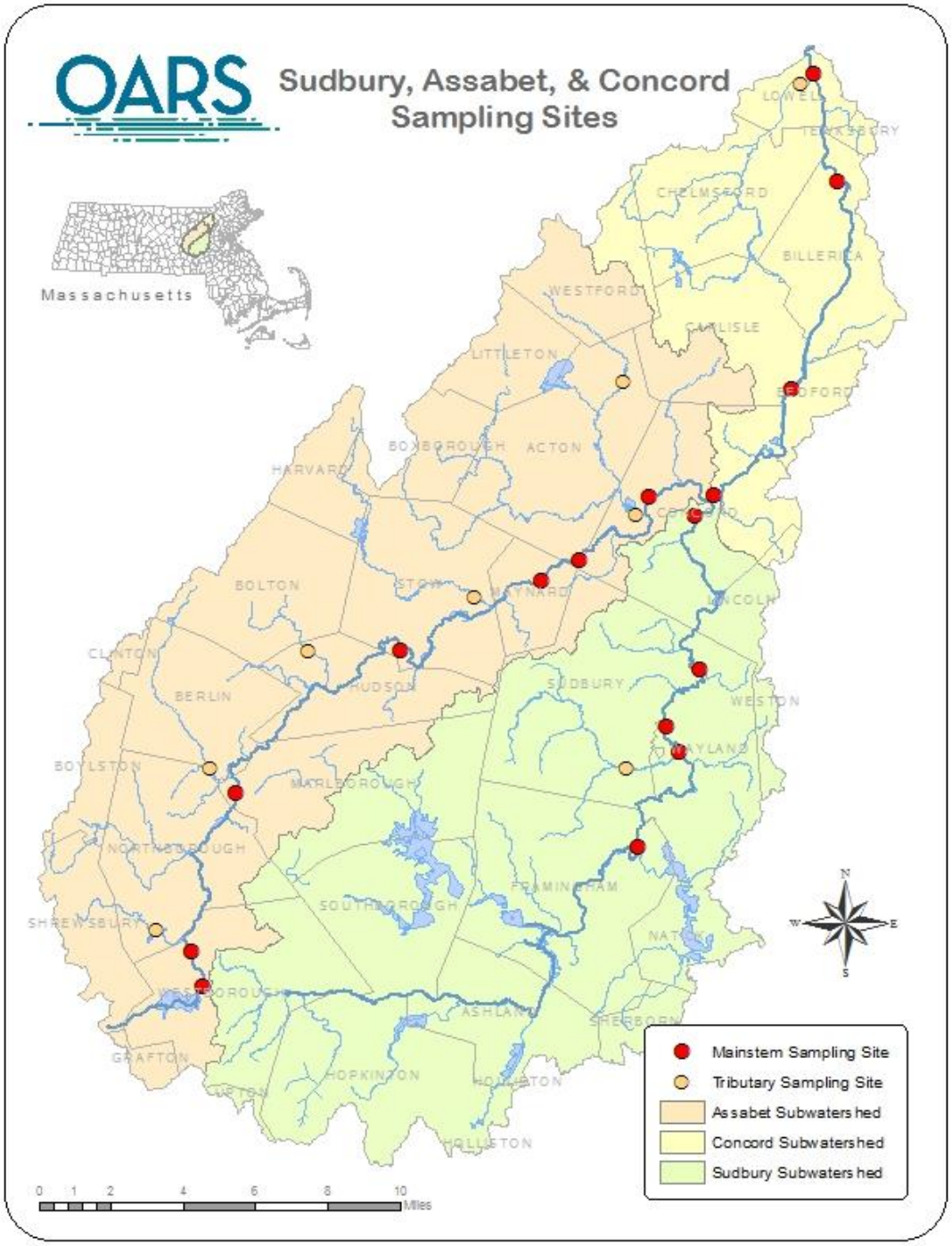
In four towns, the United States Geological Survey (USGS) monitors streamflow. These monitoring locations include:

- Bedford on the Shawsheen River near Hanscom Field
- Lexington on tributaries of the Cambridge Reservoir
- Lincoln on Hobbs Brook
- Maynard on the Assabet River

[66] E.T. Bauder, San Diego State University. "The effects of an unpredictable precipitation regime on vernal pool hydrology." *Freshwater Biology*, vol. 50, 2005.
[67] Presented here are species that must live in water. There are species such as the Marbled Salamander and Wood Duck that rely use aquatic environments and these were presented in the terrestrial habitat and species section. Additionally, the Climate Action Tool is not a comprehensive so the species presented do not represent all species that may be impacted.
[68] OARS is a 501(c)(3) non-profit organization whose mission is to protect, preserve, and enhance the natural and recreational features of the Assabet, Sudbury, and Concord Rivers, their tributaries and watersheds, and to increase public awareness of the rivers' values as important natural resources. http://www.oars3rivers.org/about

The Town of Littleton does not monitor streamflow itself but does follow information about the streamflow at the Merrimack River. When the river's level is low in Lowell, the town institutes water restrictions.

Figure 15. OARS Assabet, Sudbury, and Concord Sampling Sites



Source: Water Quality Monitoring Sites, OARS

Water Resources and Wetlands Protection

Policies to protect water resources and wetlands help maintain natural aquatic systems and the species that rely on them. These policies also play an important role in protecting the local waters that municipalities rely on for their drinking water supplies. There are several regulations at the state level that protect these resources. Key among them are the Massachusetts Wetlands Protection Act (WPA) and the Rivers Protection Act. These regulations serve as the typical basis for protection of water and wetland resources that most municipalities choose to rely on. However, these regulations do not protect all aspects of water resources and at this time do not account for changes that may accompany climate change.

Some municipalities have created their own, often more protective regulations. The review of MAGIC towns identified that seven of the 13 towns have a local wetlands bylaw and eight have a local water resource protection regulation (Table 12).

Table 12. Water Resources and Wetland Protection Regulations in MAGIC

Town	Wetlands Protection Bylaw	Other District Regulation
Acton	X	Groundwater Protection District
Bedford		Watershed Protection- & Aquifer Protection- Overlay District
Boxborough	X	Aquifer Protection- & Wetlands and Watershed Protection-Overlay District
Concord	X	Groundwater Conservancy Overlay District
Carlisle	X	
Hudson		Watershed Protection District
Lexington	X	
Lincoln	X	
Littleton		Aquifer and Water Resource District
Maynard	X	
Sudbury		Water Resources Protection Overlay District
Stow	X	Water Resource Protection Overlay District

Source: MA Association of Conservation Commissions; MAPC review of town bylaws and zoning regulations

The regulations are primarily overlay districts that supplement requirements and provisions of the underlying zoning. These regulations also primarily come into effect with new development or some threshold level of alterations to existing developments occur in the overlay district.

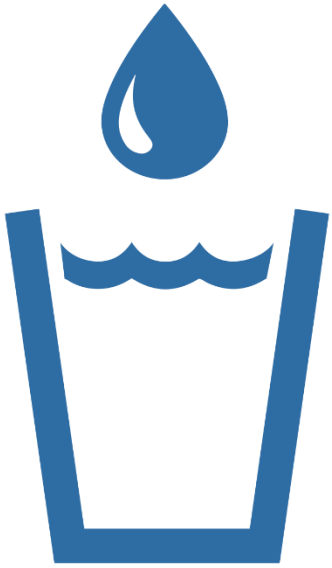
Water Conservation Measures

With the possibility that droughts will become more frequent in the future, water conservation measures or incentives will help reduce water demands and preserve resources. Having these measures in place now provides towns with the capacity to make adjustments as needed and systems for making future changes in response to new conditions. The scan of the towns revealed a mix of measures in place related to water conservation. Multiple towns (Acton, Boxborough, Concord, Lincoln, and Littleton) provide rebates to residents who purchase water-conserving appliances. The rebates are promoted both as a water saving measure and a cost saving measure for residents. Several towns, including Acton, Boxborough, and Concord, provide tools teaching residents how to conserve water. The towns with local water suppliers (eight of the 12) have alert systems that notify residents when voluntary or mandatory water use restrictions are put in place.

Drinking Water Infrastructure

Assessment Summary

- The Drinking Water Infrastructure system is assessed as highly vulnerable
- Vulnerabilities are due to sensitivities to changes in precipitation and occurrence of droughts, municipal control in towns served by private wells, and recharge of ground and surface waters across the region.
- Adaptive capacities present in the region include water conservation measures in towns with more centralized water supplies, water protection designations, and consideration and limited used of low impact development techniques.



Drinking Water Infrastructure Vulnerability Assessment

Sensitivity

Drinking Water

Most MAGIC municipalities have local water authorities that supply drinking water to their residents. The exceptions are Bedford (partially) and Lexington (wholly), which receive water from the Massachusetts Water Resources Authority (MWRA),[69] and Bolton, Boxborough, Carlisle, and Stow, which rely on private wells. Local water sources typically include public groundwater sources and some supplementary private wells.

Table 13. Water suppliers in MAGIC

Town	Public Water Supplier
Acton	Water Supply District of Acton
Bedford	Bedford Water Dept./ Hanscom AFB
Bolton	Private wells
Boxborough	Private wells / Small public water systems
Carlisle	Private wells
Concord	Concord Water Dept.
Hudson	Hudson Water Dept.
Lexington	Lexington Water Dept. (MWRA)
Lincoln	Lincoln Water Dept.
Littleton	Littleton Water Department
Maynard	Maynard Dept. of Public Works
Sudbury	Sudbury Water District
Stow	Private Wells

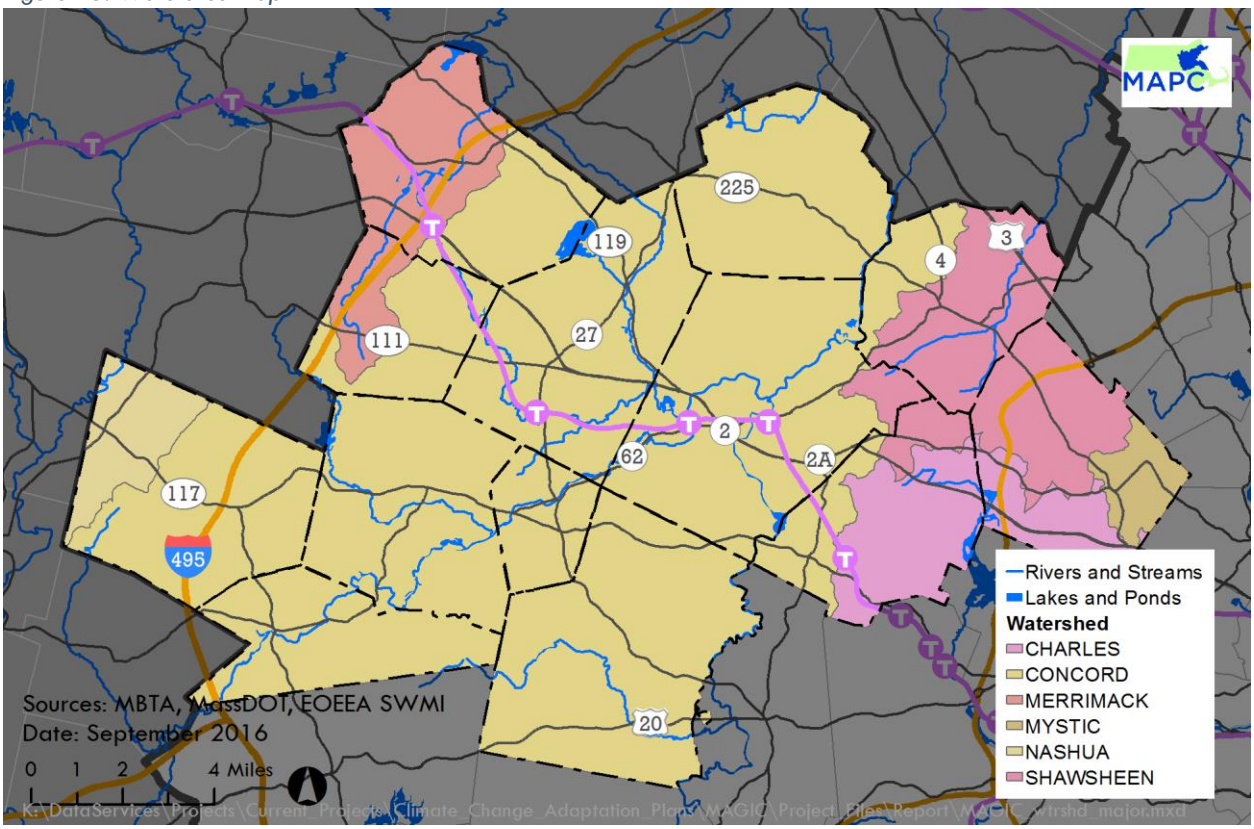
Source: MAPC review

Local water is drawn from surface waters and underground aquifers. The MAGIC region overlaps with six major watersheds:

- Merrimack (parts of Littleton and Boxborough)
- Nashua (part of Bolton)
- Shawsheen
- Concord (most of area lies within this watershed - Lexington is the only town that does not overlap with the Concord watershed)
- Mystic (eastern part of Lexington)
- Charles (parts of Lincoln and Lexington only)

[69] http://www.mwra.state.ma.us/02org/html/whatis.htm

Figure 16. Watershed map



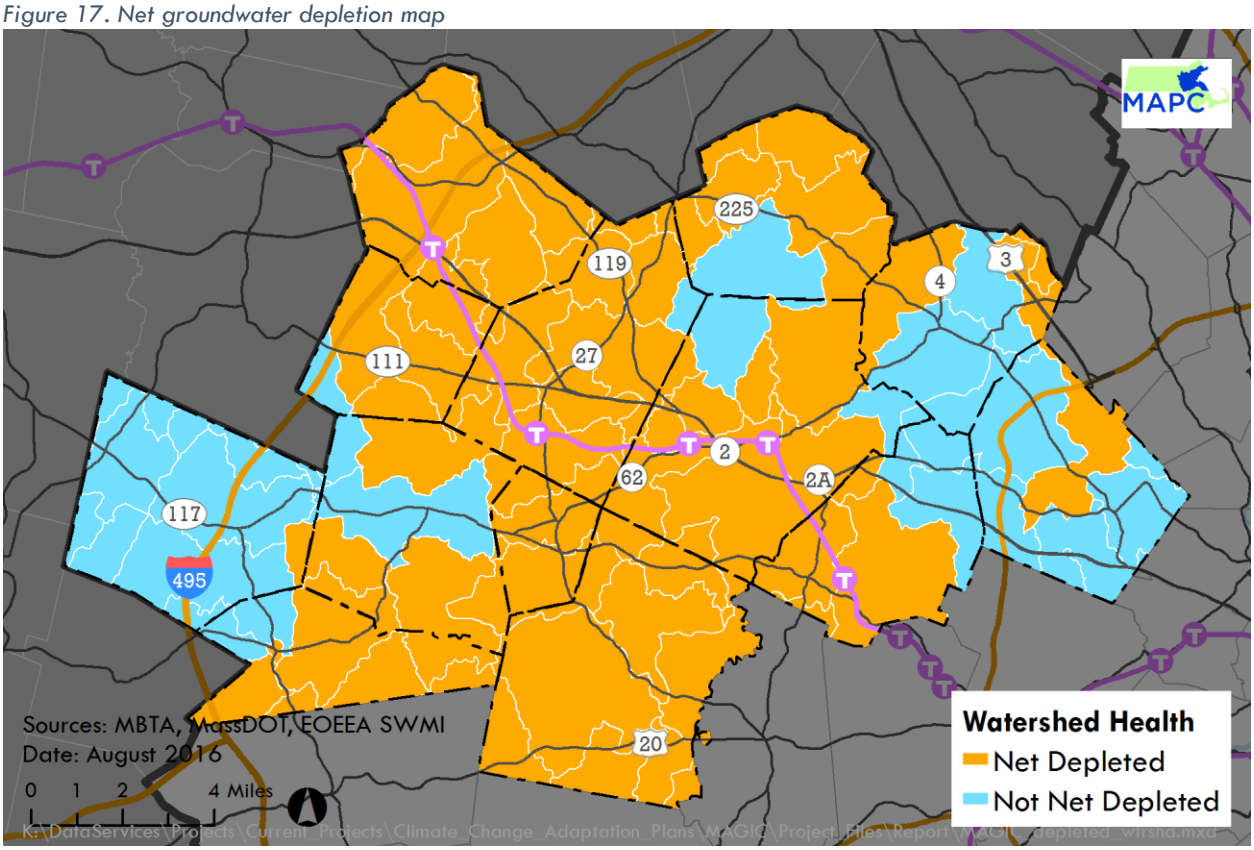
Source: MassGIS Major Watersheds

There are 71 sub-basins among these watersheds. The sub-basins represent smaller water drainage areas and provide more specificity about where local water withdrawals are occurring. Of these sub-basins, nearly one-third (23 sub-basins) are currently net depleted, according to the Sustainable Water Management Initiative (SWMI) criteria.[70] The net depleted measure indicates that groundwater resources are being withdrawn at a rate faster than water is being replenished. Effects of overdrawn groundwater resources can include wells drying, reductions in waterways and water bodies, and deterioration of water quality.[71]

[70] "Net Groundwater Depletion (NGD) is a measure of the influence of all groundwater withdrawals and discharges on stream flow. It is calculated by comparing a sub-basin's unaffected August stream flow to all groundwater discharges (septic system s plus DEP-regulated groundwater discharge facilities) and ground water withdrawals (public water supply wells, non-PWS wells such as industrial wells, and private domestic wells). NGD is expressed as a percent change in the unaffected August stream flow due to all groundwater withdrawals and discharges." Massachusetts Department of Environmental Protection, "Net Groundwater Depletion (NGD) for the Sustainable Water Management Initiative (SWMI)", accessed on August 19, 2016. http://www.mass.gov/eea/docs/dep/water/resources/n-thru-y/ngd.pdf

[71] U.S. Geologic Survey, "Groundwater depletion," http://water.usgs.gov/edu/gwdepletion.html, accessed August 28, 2016

Figure 17. Net groundwater depletion map

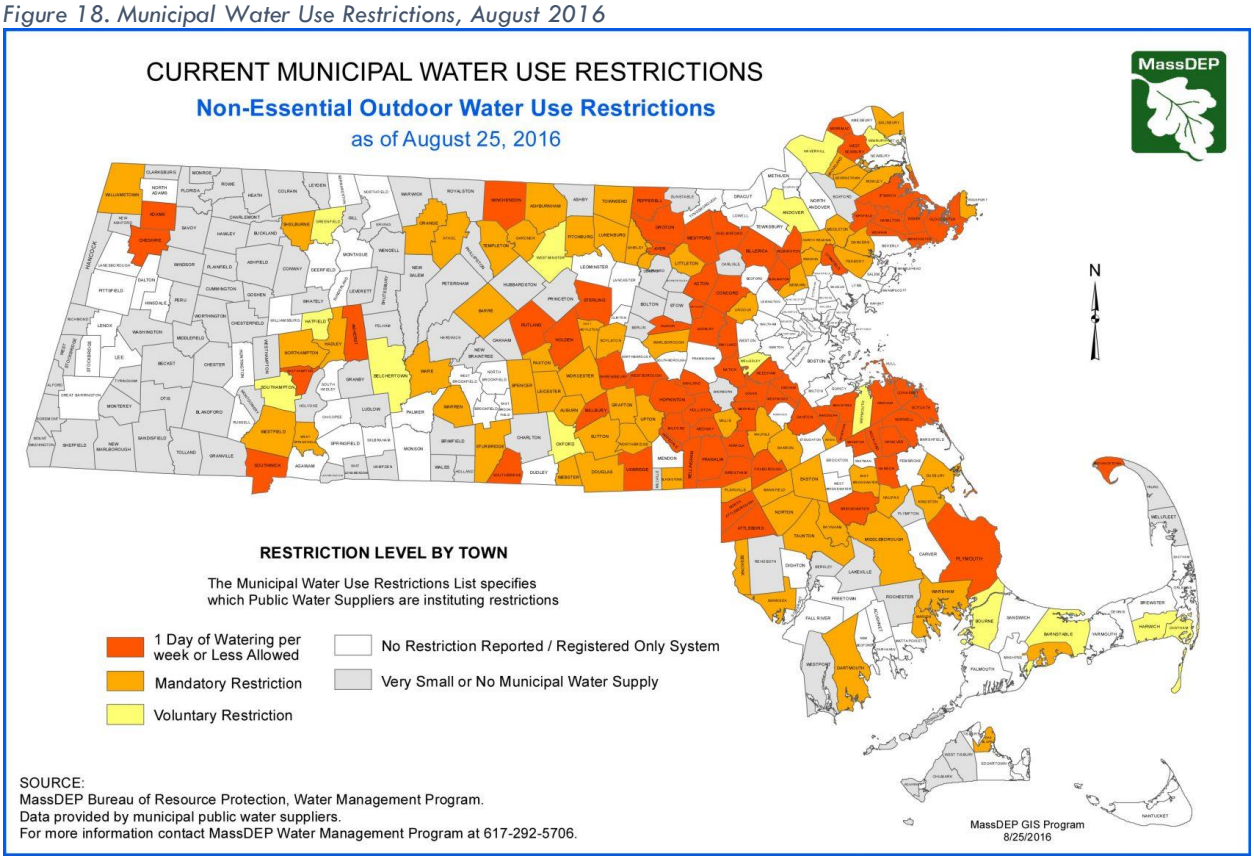


Source: Sustainable Water Management Initiative geospatial data

The depleted sub-basins are located across the region and have a greater concentration in the towns of Concord, Sudbury, and Maynard. Bolton is the only municipality whose sub-basins are not net depleted.

In the future, it could be expected that these sub-basins and water resources would have to operate during periods where rainfall will come in higher volumes and will potentially have to endure longer periods between recharge from rainfall and periods of drought. This would put a strain on the systems as water withdrawals continue and recharge cycles change. For those drawing water from these areas, especially the current depleted sub-basins, there could be more frequent voluntary and mandatory water restrictions. As an example, in August 2016, due to drought conditions, five MAGIC municipalities operated under mandatory water use restrictions and two had one-day restrictions pertaining to outdoor water use. These restrictions are put in place by suppliers to reduce consumption, preserve reduced drinking water resources, and protect natural resources.

Figure 18. Municipal Water Use Restrictions, August 2016



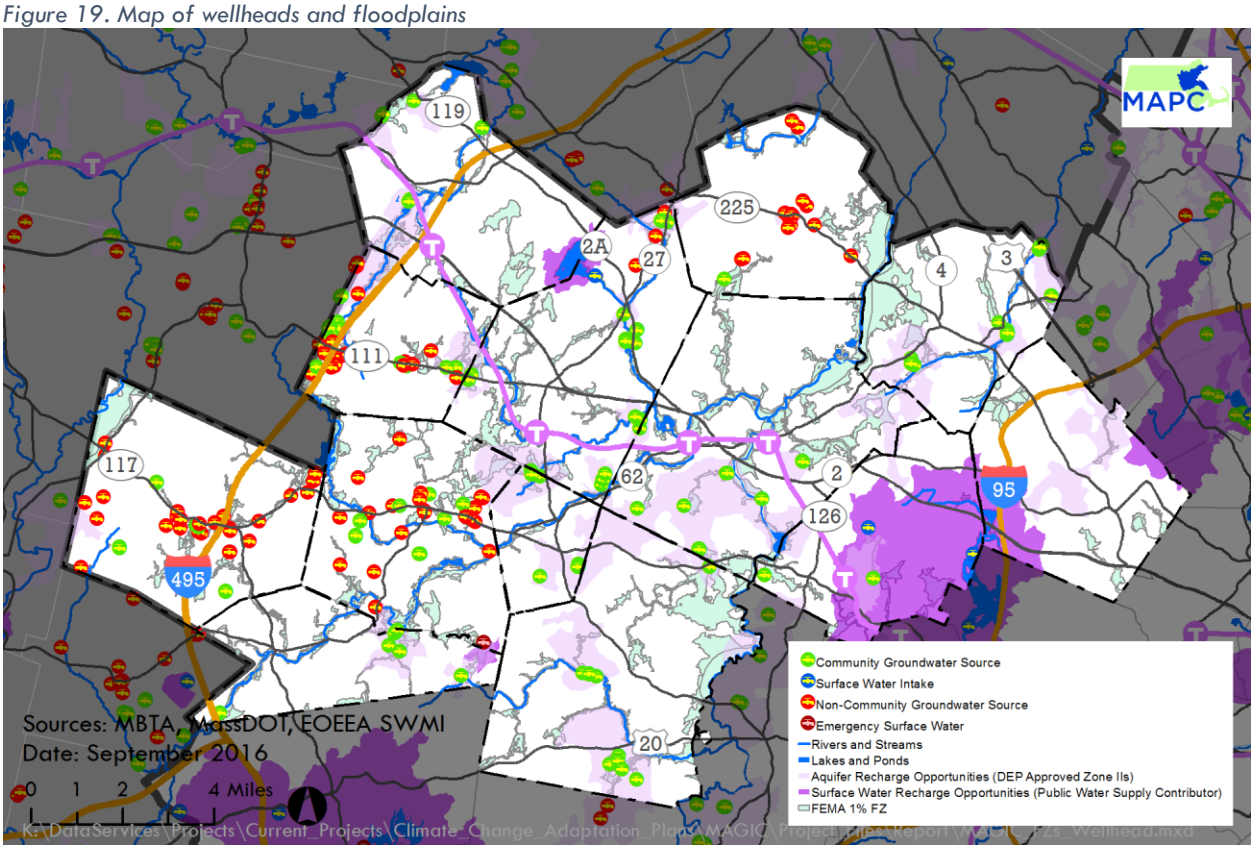
Source: MassDEP Municipal Water Use Restrictions[72]

Drinking water sources can be impacted by flooding as well. Local water authorities may have wellheads, which are the local source (e.g., aquifer) of drinking water, that are located in the current 100-year floodplain. Flooding could impact the wellheads by overwhelming the system and as greater quantities of water must be accommodated. It could also affect the water supplies by introducing greater amounts of runoff, which could introduce sediments, pollutants, waste, and other materials.[73] As a result, water supplies could become unsafe or need water treatment at the municipal and household scales.

[72] Current restrictions can be found here: http://www.mass.gov/eea/agencies/massdep/water/watersheds/municipal-water-use-restrictions.html

[73] U.S. Climate Change Science Program, "The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States," 2008.

Figure 19. Map of wellheads and floodplains



Source: MAPC

Adaptive Capacity

Water Supply Protection

While there are some state level protective measures in place, many of the MAGIC municipalities have adopted their own protective regulations. As identified in the Aquatic Habitat section, eight of the 13 towns have a local water resource protection regulation (Table 12). These regulations restrict or limit development in areas above and around water supplies. They create a buffer to allow for recharge and to protect the supplies from development, hazards, and pollutants.

Water Conservation

Many local water authorities in the MAGIC region currently promote water conservation measures and monitor the need for water restrictions. Having these measures in place now gives towns the capacity to make adjustments as needed and provides a system for making future changes in response to new conditions.

The towns of Acton, Boxborough, Concord, Lincoln, and Littleton provide rebates to residents who purchase water-conserving appliances. The rebates are promoted both as a water saving measure and a cost saving measure for residents. Several towns, including Acton, Boxborough, and Concord, provide tools that educate residents on conserving water. The towns with local water suppliers (eight of the 12) were found to have alert systems that notify residents when voluntary or mandatory water use restrictions are put in place.

A limitation of this capacity is the ability to apply it to the towns where water is supplied via private wells. The towns - Bolton, Boxborough, Carlisle, and Stow – do not have the same mechanisms available to them as the towns with water authorities do. They are limited by not having a local agency responsible for monitoring water levels, offering economic measures to affect usage (e.g., rebates, pricing), and enacting restrictions (e.g., water conservation by authority).

Stormwater Infrastructure

Assessment Summary

- The Stormwater Infrastructure system is assessed as moderately vulnerable
- Potentially high vulnerability areas are surface waterways used as part of stormwater systems and locations with significant impervious surface coverage
- Vulnerabilities are due to sensitivities to changes in precipitation, the amount of existing impervious surfaces, and impaired waterways
- Adaptive capacities present in the region include water conservation measures in towns with active MS4 permits, stormwater management plans, and promotion of low impact development techniques such as residential rainwater harvesting

Stormwater Infrastructure Vulnerability Assessment

Sensitivity

More frequent and intense precipitation events, including extreme floods, are likely to increase the amount and frequency of stormwater runoff in the MAGIC region. An increase in stormwater volume has the potential to overwhelm the capacity of stormwater management systems maintained by public and private entities. When capacities are exceeded, systems backup, causing flooding and sending contaminants back into local waterways. Similarly, more stormwater in combined stormwater and wastewater drainage systems could cause more sewer overflows into local water systems.

Increased precipitation could adversely impact the stormwater sewer networks and infrastructure in the MAGIC region. These networks are currently designed for historic conditions and in some cases networks have used rather conservative design parameters for past conditions. The region has already experienced system failures resulting in infrastructure damage and flooding. Therefore, private and public stormwater infrastructure and pipes, as well as the land use and transportation systems they intersect, will suffer as precipitation frequencies increase and volumes exceed what the systems were designed to accommodate. Similarly, older green infrastructure elements, such as bioretention facilities, may be adversely affected due to their design parameters and limitations. It is important to note that severe roadway and property flooding due to inadequate stormwater capture and treatment will create a "snowball effect" in which adverse impacts to other sectors follow, which is noted in other sections.

For MAGIC, there is not a central source for stormwater system mapping, so impervious surfaces are used as a guide to where stormwater could be expected. Impervious surfaces are those that water cannot permeate and which generate a surface runoff of stormwater. Examples include roads, buildings, and parking lots. The Environmental Protection Agency (EPA) has mapped where and how much of each MAGIC town is impervious. In particular, it has estimated how much of the impervious surfaces convey stormwater to local water sources like a stream or lake.[74] These only include areas that have been identified for stormwater controls according the MS4 for Massachusetts.

Approximately 7,600 acres, or nine percent, of the MAGIC region is identified as covered by directly connected impervious surfaces, meaning these surfaces are discharging stormwater to local water resources. Across the towns, the percentages of directly connected impervious surface coverages range from a high of 16 percent in Littleton to a low of three percent in Stow.

[74] EPA, "Methodology to Calculate Baseline Estimates of Impervious Area (IA) and Directly Connected Impervious Area (DCIA) for Massachusetts Communities," https://www3.epa.gov/region1/npdes/stormwater/ma/IA-DCIA-Calculation-Methodology.pdf, accessed February 17, 2017.

Table 14. Directly connected impervious surface coverages for MAGIC towns

	Area in Regulated Area (acres)	Area of Directly Connected Impervious Area (acres)	Percentage of Directly Connected Impervious Area
Acton	11,559	902	8%
Bedford	8,783	1,016	12%
Bolton	442	19	4%
Boxborough	5,336	230	4%
Carlisle	723	33	5%
Concord	9,213	657	7%
Hudson	6,182	913	15%
Lexington	10,586	1,510	14%
Lincoln	4,752	312	7%
Littleton	4,017	658	16%
Maynard	3,461	420	12%
Stow	7,378	212	3%
Sudbury	10,675	768	7%
Total	**83,106**	**7,649**	**9%**

Source: Comprehensive IC Statistics, Regulated MS4 in Massachusetts Communities, EPA

The impervious coverages provides information about how changes in stormwater volumes could impact municipalities. Those with higher coverages could potentially experience greater demands on their stormwater systems and possibly experience flooding in locations where the systems cannot keep up with the higher amount of rainfall. It is also a guide to identifying how local surface water resources might be impacted by the additional runoff and the contaminants that the runoff carries.

The state maintains a list of waters that characterizes the water's capacity to specific uses such as aquatic life, drinking water, and recreational uses. This list, referred to as the 303(d) List, provides an assessment of inventoried waters and identifies if the waters are impaired and if so, how it is impaired. Impaired waters in MAGIC are mapped, and descriptions of the degree of impairment are shown in Table 15**Error! Reference source not found.**.

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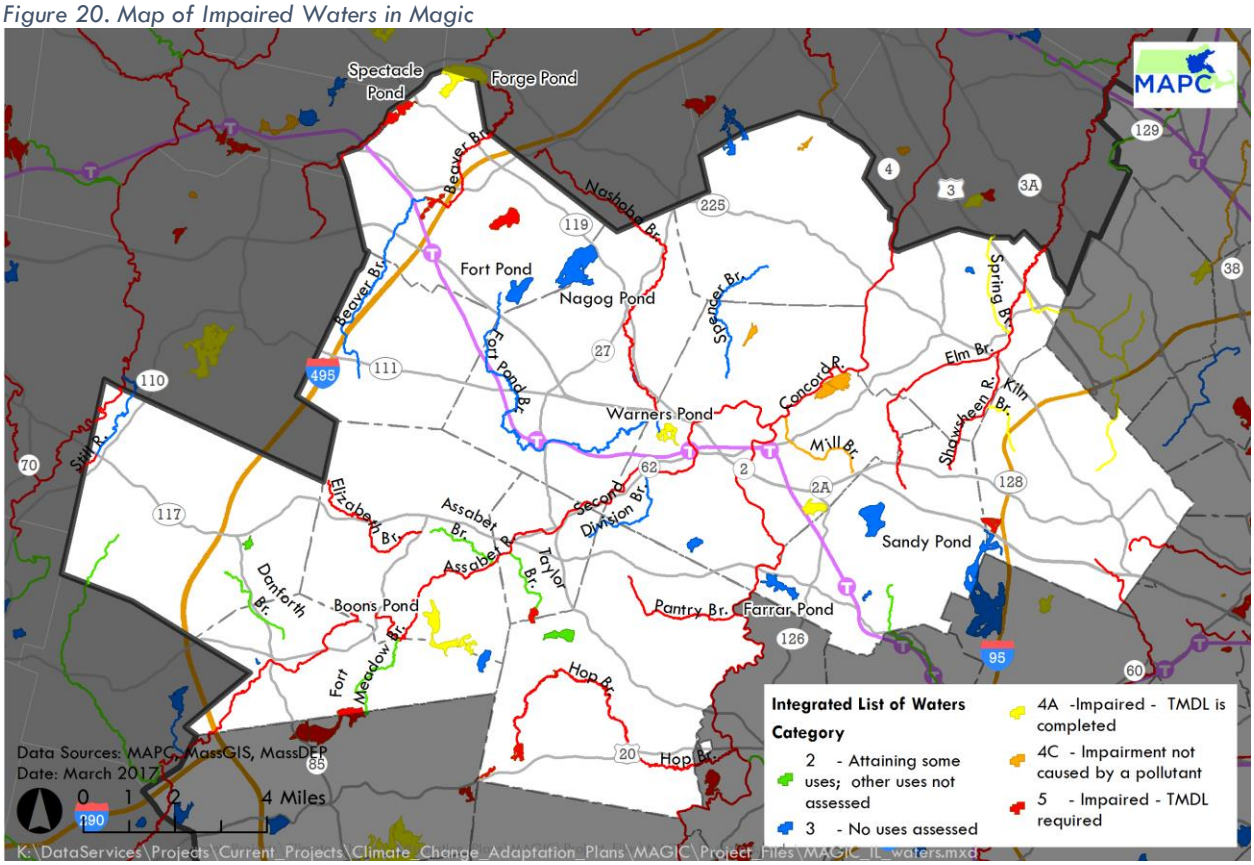
Figure 20. Map of Impaired Waters in Magic



Source: MAPC

The sections of rivers in the MAGIC region that are categorized as impaired are identified below.

Table 15. Rivers with Impaired Waters

MAGIC Rivers with Impaired Waters	
Assabet River	Nashoba Brook
Beaver Brook	Nashua River
Bennetts Brook	Pantry Brook
Concord River	Shawsheen River
Elizabeth Brook	Spring Brook
Elm Brook	Still River
Hop Brook	Sudbury River
Kiln Brook	Vine Brook
Mill Brook	

Source: MassGIS Data - MassDEP 2014 Integrated List of Waters (305(b)/303(d))

The majority of these rivers are impaired for one of more uses and require a total maximum daily load (TMDL) to control a specific pollutant affecting the waterway. The total length of the rivers with an identified impairment in MAGIC is 139 miles, which is approximately 75 percent of the total length of all rivers assessed in the region.

There are a number of water bodies in the MAGIC region that are also currently impaired. Each is impaired for one or more uses and approximately half of the assessed lakes require the development of a TMDL to control for a specific pollutant. The impaired lakes occupy an area of approximately 1,030 acres which accounts for 38 percent of the total assessed area of lakes in the MAGIC region.

Table 16. MAGIC Lakes with Impairment categories

Lake	Location	category
Butterfield Pond	Burlington/Lexington	5
Meadow Pond	Carlisle	4C
Batemans Pond	Concord	4C
Great Meadows Pond #3	Concord	4C
North Great Meadows	Concord	4C
Walden Pond	Concord	4A
Warners Pond	Concord	4A
Cambridge Reservoir, Upper Basin	Lincoln/Lexington	5
Long Pond	Littleton	5
Mill Pond	Littleton, North Basin	5
Mill Pond	Littleton, South Basin	5
Spectacle Pond	Littleton/Ayer	5
Puffers Pond	Maynard/Sudbury	5
Boons Pond	Stow/Hudson	4A
Carding Mill Pond	Sudbury	5
Stearns Mill Pond	Sudbury	5
Grist Mill Pond	Sudbury/Marlborough	5
Forge Pond	Westford/Littleton	4A

Source: MassGIS Data - MassDEP 2014 Integrated List of Waters (305(b)/303(d))

At this time, a consistent source of information is not available on the age, capacity or other characteristics (e.g., presences of combined sewer overflows (CSOs)) of the municipal stormwater systems. There is a project in the MAGIC region in 2017 that will gather this information as part of looking for regional opportunities for stormwater management. Information from that project should be used to update the vulnerability assessment for the region.

Adaptive Capacity

MS4 General Permit

Few towns have a stormwater management plans. A scan of the region's towns showed the Town of Acton adopted a management plan in 2003 and the Town of Littleton developed an Action Plan in 2014. Both plans were developed in response to requirements of the National Pollutant

Discharge Elimination System (NPDES) Small Municipal Separate Storm Sewer Systems (MS4) requirement.

Town	Primary Watershed	Secondary Watershed	Tertiary Watershed
Acton	Concord		
Bedford	Shawsheen	Concord	
Bolton	Concord	Nashua	
Boxborough	Concord	Merrimack	
Carlisle	Concord		
Concord	Concord	Shawsheen	
Hudson	Concord		
Lexington	Shawsheen	Charles	Boston Harbor (Mystic)
Lincoln	Charles	Concord	Shawsheen
Littleton	Merrimack	Concord	
Maynard	Concord		
Stow	Concord		
Sudbury	Concord		

Source: https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/final-2016-ma-sms4-gp.pdf

Stormwater Regulations

Most of the municipalities in the MAGIC region have a regulation for stormwater. Nine of the 13 were identified as having a stormwater bylaw that seeks to limit runoff from new and redevelopment projects and to eliminate illicit connections within the existing stormwater system. Subdivision rules and regulations were not explored in depth, but a preliminary review indicates that each town addresses stormwater controls in this process as well. Likely most of these regulations and controls reflect current or past conditions (e.g., projected stormwater volumes). However, they do represent current management efforts and provide a set of existing protections that can be enhanced to address projected future conditions.

Stormwater Utility

A stormwater utility, or management authority, allows municipalities to assess property owners a fee relative to the amount of runoff from their property to a public stormwater system. The fee works similar to fees charged by other utilities, like electric and sewer. Funds collected by a stormwater utility are dedicated to stormwater management like replacing aging infrastructure and enhancing maintenance practices. The utility can also provide incentives to reduce the amount of impervious surface on properties in order to encourage local recharge of rainwater and decrease the amount of runoff to the local stormwater system.

No towns in the MAGIC region have adopted a stormwater utility or fee[75] although the Town of Lexington has considered the option.

Rainwater Harvesting

A number of towns in MAGIC support rainwater harvesting. Rain can be captured on residential and commercial sites for re-use and rainwater harvesting, such as the use of rain barrels, make this possible.

- Acton Water District offered a rebate program in for residents who purchase rain barrels.
- Bolton encouraged residents to purchase them through neighboring towns at discounted rates (through support of a MA DEP grant program)
- Lincoln offers barrels at discounted rates during certain times of the year
- Sudbury promotes use but does not currently offer discounts

Low Impact Development

Nearly all of the towns in the MAGIC region promote Low Impact Development (LID) in new construction and redevelopment projects. LID is method for preserving natural resources and natural drainage so that water resources are addressed at the site level. Examples of how LID is promoted include:

- Bedford: In site plan submissions, applicants must ensure that their plans employ LID design
- Concord: The Engineering Department evaluates suitability of LID designs within municipal project designs, including transportation and open space projects
- Maynard: The Planning Board's Landscape Regulations require a project to embrace LID design and offers examples and types of LID measures.

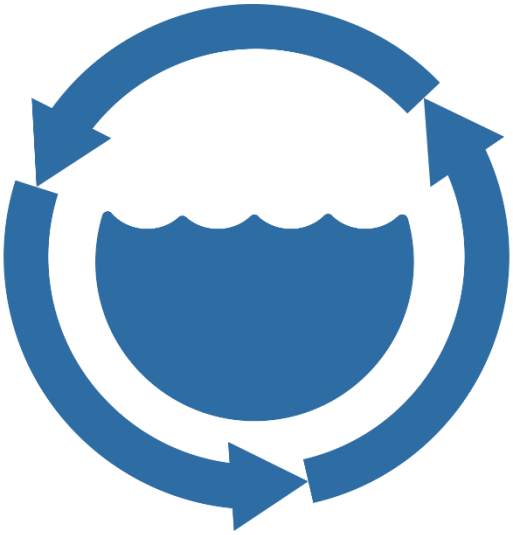
Acton, Carlisle, and Hudson were not found to currently promote LID as part of the development process.

[75] For more information about a Stormwater Utility: http://www.mapc.org/Stormwater_Financing

Wastewater Infrastructure

Assessment Summary

- The Wastewater Infrastructure system is assessed as moderate vulnerability with potentially high vulnerability for treatment plants and pump stations located in 100-year floodplains.
- Vulnerabilities are due to sensitivities to increased temperatures and potential flooding events in the proximity of waterways
- Adaptive capacities are unclear for the region (more information is necessary to document existing policies or practices). Vulnerability assessment needs additional information regarding adaptive capacities.



Water Infrastructure Vulnerability Assessment

Sensitivity

Wastewater infrastructure generally includes community wide systems and individual facilities that capture, treat, and dispose of sewage. For the purpose of this assessment, wastewater infrastructure will refer to municipally-operated pipes and treatment plants and septic systems that are installed and controlled by residential private property owners. The assessment does not address commercial or industrial wastewater systems, but may be updated in the future to include them.

Wastewater infrastructure faces challenges coming from both changes in temperature and changes in precipitation. From temperature, the municipal systems and individual septic tanks rely on a certain temperature conditions to treat sewage so that harmful elements change removed or remediated and so that cleaned effluent is what is released back into the environment.[76] While higher temperatures may better facilitate some processes, many biological treatments must stay within certain temperature range to work (107 – 113 degrees F).[77] In addition to possible treatment challenges, rising temperature, as well as changes in water quality, may increase processes needed to cool and treat discharges into local water bodies and waterways.[78]

Increases, and possible decreases, in precipitation will affect wastewater systems in multiple ways. For municipal treatment systems, more precipitation could exert a greater demand on pipes and treatment facilities as the volume of liquids increases. This would be most applicable to wastewater systems that also capture stormwater and those that have leakages that allow in outside waters. Treatment plants would face a risk from flooding. While coastal facilities may face a greater chance of this threat, treatment facilities that are in floodplains could be at risk. Lastly, septic systems rely on unsaturated soil between the leach field and the water table underground.[79] Under changing precipitation patterns, more intense rain or snow, the level of water table may rise. This would compromise processes meant to filter effluent from the septic tank and in certain cases, may result in flooding that would bring untreated sewage back to the surface. Although not yet noted in inland locations, studies of septic system impacts in coastal locations has also noted the potential for impacts to wellwater.[80] At least three of 12 MAGIC towns rely wholly or partially on wells for their drinking water.

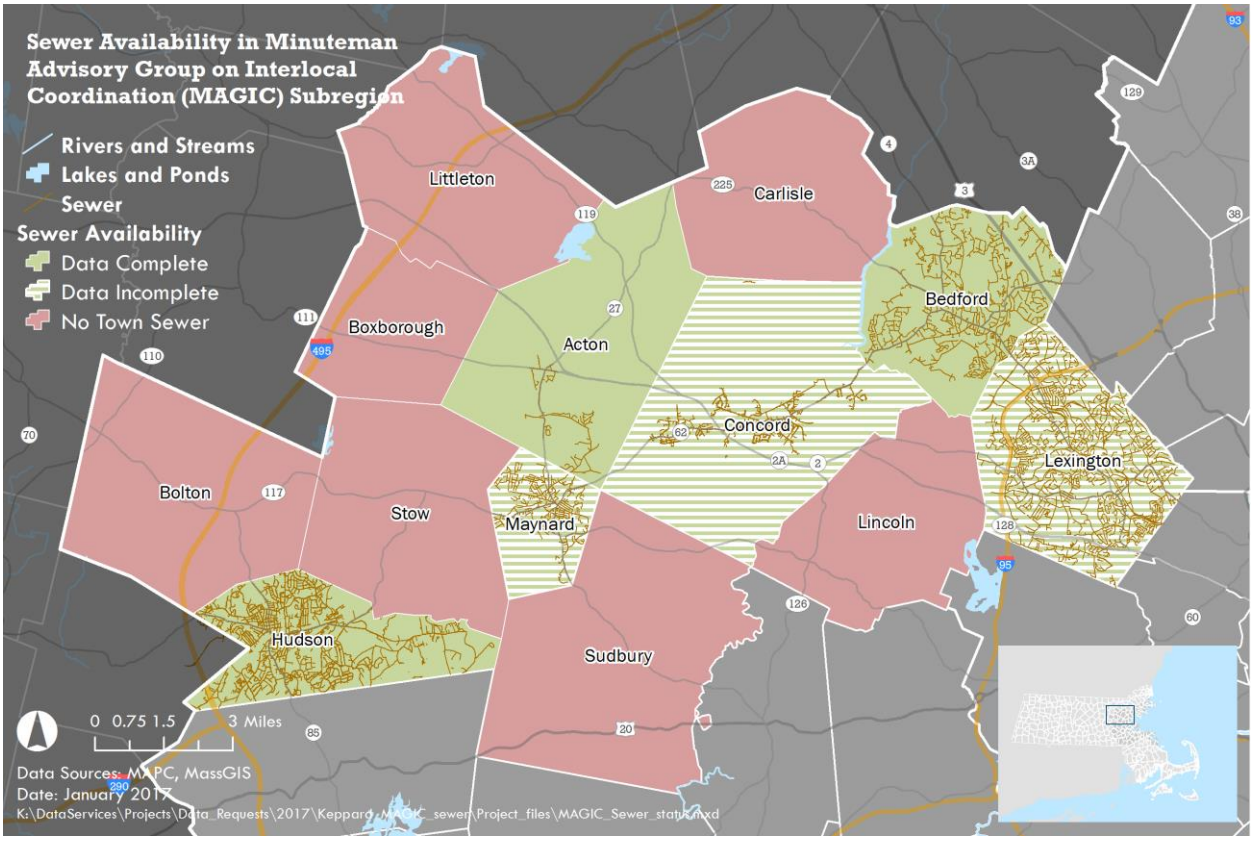
Municipal Wastewater Systems

Based on available geospatial data, six of the 13 MAGIC towns have a municipal wastewater system (Figure 21). In the towns that do have sewer service, the system vary from partial to nearly entire coverage of the municipality. Additionally, the systems are operated by the municipality,

[76] Water Environment Research Foundation, "Implications of Climate Change For Adaptation by Wastewater and Stormwater Agencies," December 2009
[77] Water Environment Research Foundation, "Implications of Climate Change For Adaptation by Wastewater and Stormwater Agencies," December 2009
[78] http://nca2014.globalchange.gov/report/sectors/water#narrative-page-16599 , accessed March 1, 2017
[79] EPA, "How Your Septic System Works," https://www.epa.gov/septic/how-your-septic-system-works, accessed March 1, 2017
[80] Jennifer A. Cooper, George W. Loomis, Jose A. Amador, "Hell and High Water: Diminished Septic System Performance in Coastal Regions Due to Climate Change," September 2016.

typically through their Department of Public Works or an individual Water and Sewer Department.

Figure 21. Sewer Availability in MAGIC



Source: MAPC

The systems, as well as other uses, require wastewater treatment facilities (WWTFs), which are located throughout the region. Using data from the MA Department of Environmental Protection (MassDEP), the WWTPs were inventoried for the region. The WWTFs include both municipal and non-municipal facilities. In MAGIC, Boxborough and Acton, nine and eight respectively, have the highest number of graded WWTFS while Carlisle and Lexington have the fewest with one each.

Table 17. Graded WWTF by Town

Town	Wastewater Treatment Facilities
Acton	8
Bedford	2
Boxborough	9
Carlisle	1
Concord	7
Lexington	1
Lincoln	3
Littleton	7
Maynard	2
Stow	4
Sudbury	4

Source: MassDEP Graded Wastewater Treatment Plants by Town

Of the graded WWTFs, the majority (approximately 90 percent) treat non-industrial waste and more than 60 percent are graded as 4M facilities indicating the facilities use moderately complex processes in their treatment of waste and require an operator with a higher degree of expertise and experience.[81]

Table 18. Facilities by Grade in the MAGIC region

Facility Grade	Number
0-M	1
1-M	1
2-M	2
3-M	6
4-M	32
5-C	4
6-C	1
6-M	1

Source: MassDEP Graded Wastewater Treatment Plants by Town

There is currently no mapping available for the region to show the location of the WWTFs. However, through hazard mitigation planning processes, towns in MAGIC have included WWTFs and related facilities as part of their critical infrastructure. Five towns have WWTFs or related facilities (e.g., pumping station) located in a mapped flood zone. Concord has the highest number of infrastructure elements (4 pumping stations) located in a currently mapped 100-yr flood zone.

[81] 257 CMR 2.00: Certification of Wastewater Treatment Plant Operators, http://www.mass.gov/eea/docs/dep/service/regulations/257cmr02.pdf

Table 19. Identified Critical Infrastructure in Flood Zones

Town	Flood Zone	CI Description	Number
Lexington	AE	Wastewater Treatment Facility	1
Hudson	AE	Wastewater Treatment Facility	1
Hudson	X	Wastewater Treatment Facility	1
Concord	AE	Sewer Pumping Station	4
Acton	X	Wastewater Treatment Facility	1

Source: Municipal Hazard Mitigation Plans, MAPC

It should be noted that in the cases of Lexington and Bedford, wastewater treatment is managed by the MWRA and wastewater is treated and released outside of the MAGIC region.

Septic Systems

Septic systems are used throughout the MAGIC region although there is no uniform source of data available to show specific or general location of the systems by town. Given this limitation, we estimate that between 17,500 and 21,000 housing units are on septic systems in the MAGIC region. The lower number represents the percentage of housing units reporting septic systems in the Boston Metropolitan Statistical Area (MSA) through the US Census American Housing Survey 2015 and the number of units in the towns that are not served by a sewer system.

The life expectancy of septic systems can vary depending on system elements (e.g., tank material), environmental conditions (e.g., soils), use, and maintenance. An average life expectancy is approximately 20-40 years. Assuming a recent installation or upgrade of a system, by 2050 at the latest, systems or elements of the system (e.g., septic tanks) for potentially 17,000 or more housing units will have to be addressed. These same housing units may also face changing and new maintenance demands sooner as the life expectancy estimates are under current conditions and not under changing conditions.

Adaptive Capacity

Innovative Systems and Treatment

Innovations in wastewater systems and treatment offer opportunities to address climate change effects. They can set enhance or set up new systems to adjust to new conditions, whether it be changes in temperature or precipitation. In the MAGIC region, the Town of Littleton, along with the Charles River Watershed Association, has explored the use of smart sewering. The smart sewering system, which would operate as a decentralized wastewater treatment system and potentially produce energy, considered limited new sewering in Littleton along with local wastewater treatment and recharge to the local environment. The system would more closely mimic natural hydrologic processes and be part of strategy to support more development in the town's center. Such a system could also assist individual homeowners with septic systems to updating their systems and create more resilient local wastewater treatment systems.

Septic Systems Best Practices/Smart Septic Systems

The US and the Commonwealth of Massachusetts provide guidance regarding installation, operations, and maintenance of septic systems. So, rather each owner needed to figure out each element of their septic system, these resources provide easily accessible guidance materials. For

example, EPA provides the SepticSmart Homeowners webpage[82] and the MA Department of Environmental Protection provides a comprehensive webpage regarding septic systems and Title V.[83,84] As part of the MA resource page, the use and approval of innovative technologies is detailed.[85] While it is not clear which, if any, approved innovative technologies address climate change effects, the recognition of alternatives approach and materials indicates a possible pathway for elements that would increase adaptive capacities.

[82] https://www.epa.gov/septic/septicsmart-homeowners, accessed March 1, 2017
[83] http://www.mass.gov/eea/agencies/massdep/water/wastewater/septic-systems-title-5.html
[84] Title 5 govern the proper siting, construction, upgrade, and maintenance of septic systems and the transport and disposal of sanitary sewage. Local Boards of Health are the primary regulatory authorities. http://www.mass.gov/eea/agencies/massdep/water/regulations/310-cmr-15-00-septic-systems-title-5.html
[85] http://www.mass.gov/eea/agencies/massdep/water/wastewater/summary-of-innovative-alternative-technologies-approved.html, accessed March 1, 2017

Land Use and Buildings

Assessment Summary

- The Built Environment system is assessed as moderately vulnerable with potential high vulnerability related to areas subject to more frequent or additional flooding. More information is needed regarding the potential for riverine flooding to make a preliminary assessment.
- Vulnerabilities are related to exposure and sensitivity buildings and critical infrastructure proximity to existing floodplains and age of structures – residential and commercial – are their ability to withstand flooding and additional energy demands for predicted temperature changes.
- Adaptive capacities in the region include regulatory measures that reduce the exposure of more recent and proposed buildings and properties to flooding, protection of undeveloped open spaces and conserved land to serve as buffer for flooding, and actions by multiple towns to encourage more energy efficient buildings and mitigation and management of stormwater on individual properties.

Built Environment Vulnerability Assessment

Sensitivity

Precipitation and Flooding

The predicted changes in precipitation are expected to increase the likelihood of flooding events. Buildings and properties located in current floodplains are most at risk given the proximity to rivers and streams. In MAGIC, there is no identified potential for risk from coastal flooding.

There are approximately 7,300 parcels in the MAGIC region that overlap with a Zone A, or the 1% flood zone. The towns of Acton and Concord have the most parcels (1,000 or more) overlapping with the 1% flood zone (100-year flood) while Boxborough, Carlisle, Lexington, Maynard, and Lincoln have the fewest, each with less than 300 parcels in the flood zone.

The cumulative land value for the parcels located in or intersecting with the 1% flood zone is estimated to be more than $2.5 billion based on available assessor's level parcel data for the MAGIC region.[86] Buildings on these parcels, which may or may be not located in the flood zone, have an additional estimated value of $3.2 billion. The town of Concord has the highest overall estimated cumulative value (land and building value) at $1.6 billion and the town of Bedford has the second highest at $843 million. Maynard and Carlisle have the highest overall estimated cumulative value with both below $150 million.

Table 20. Land Value and Building value of Parcels in the 1% Flood Zone

Town	Number of Parcels	Sum of Land Value	Sum of Building Value	Total Value
Acton	1,174	$ 300,098,890	$ 267,578,584	$ 575,225,790
Bedford	697	$ 315,590,972	$ 525,083,588	$ 843,284,672
Bolton	400	$ 58,380,380	$ 108,794,380	$ 167,174,780
Boxborough	254	$ 51,112,300	$ 105,795,897	$ 158,890,100
Carlisle	235	$ 79,740,281	$ 65,321,798	$ 147,145,781
Concord	1,090	$ 643,768,063	$ 998,479,093	$ 1,698,576,956
Hudson	777	$ 130,336,100	$ 226,990,900	$ 366,722,200
Lexington	230	$ 168,750,000	$ 195,854,000	$ 368,019,000
Lincoln	227	$ 137,481,367	$ 108,643,600	$ 248,549,967
Littleton	526	$ 94,312,309	$ 141,014,198	$ 240,223,909
Maynard	230	$ 68,085,235	$ 78,798,293	$ 148,817,735
Stow	611	$ 191,956,196	$ 159,759,996	$ 333,350,096
Sudbury	866	$ 303,884,135	$ 230,188,295	$ 536,738,235
Total	**7,317**	**$ 2,543,496,228**	**$ 3,212,302,622**	**$ 5,832,719,221**

Source: MAPC Analysis

[86] MAPC Assessor's Parcel Database

A variety of uses occur on these parcels that are located or intersect with the 1% flood zone (Table 21). Among them natural resources like wetlands and forests make up the majority of identified uses (nearly 80 percent in total). This likely reflects the protections that are in place to limit development in flood-prone locations. On developed parcels, the uses with the highest percentages are non-residential uses that include agricultural and commercials uses and residential uses with a medium density (housing on 1/4 - 1/2 acre lots).

Table 21. Land Uses in the 1% Flood Zone

Land Use Description	Protected (ac.)	Unprotected (ac.)	Total	% Total
Forested Wetland	2,252.6	2,822.2	5,074.7	37.2%
Forest	1,159.6	1,781.2	2,940.8	21.6%
Non-Forested Wetland	1,488.2	1,315.7	2,803.8	20.6%
Water	129.4	1,167.6	1,297.0	9.5%
Cropland	217.4	135.8	353.1	2.6%
Low Density Residential	10.9	153.8	164.7	1.2%
Open Land	43.1	93.7	136.7	1.0%
Pasture	38.2	85.2	123.4	0.9%
Commercial	5.8	116.4	122.2	0.9%
Industrial	0.6	97.8	98.4	0.7%
Medium Density Residential	4.0	93.3	97.3	0.7%
Golf Course	2.4	74.7	77.1	0.6%
Very Low Density Residential	5.2	56.0	61.3	0.4%
Participation Recreation	4.8	52.8	57.6	0.4%
Urban Public/Institutional	5.1	36.9	42.0	0.3%
Transportation	0.5	37.6	38.0	0.3%
Cranberry Bog	31.8	0.0	31.8	0.2%
Multi-Family Residential	0.0	28.1	28.1	0.2%
High Density Residential	0.1	16.0	16.1	0.1%
Brushland/Successional	7.8	8.1	15.9	0.1%
Powerline/Utility	6.0	9.5	15.6	0.1%
Nursery	2.1	9.3	11.4	0.1%
Mining	0.7	7.0	7.7	0.1%
Transitional	0.4	7.1	7.5	0.1%
Total	5,418.39	8,211.40	13,629.80	100%

Source: MAPC Analysis

Town staff identify critical infrastructure as part of the natural hazard mitigation planning process encouraged by Federal Emergency Management Agency (FEMA) and Massachusetts Emergency Management Agency (MEMA).[87] The critical infrastructure reflect town and stakeholder

[87] Critical infrastructure are identified by local officials under the guidance that they should include facilities important for disaster response and evacuation (such as emergency operations centers, fire stations, water pump stations, etc.) and facilities where additional assistance might be needed during an emergency (such as nursing homes, elderly housing, day care centers, etc.).

knowledge about structures, buildings, and services that are vital for municipal operations, social services, and emergency response.

In the MAGIC region, the town of Concord has the highest reported number of critical infrastructure (39) located in mapped floodzones.[88] Several other towns have around 12 critical infrastructure elements identified in flood zones. Most critical infrastructure are in a 1% floodzone and dams (55), bridges (16) and sewer pumping (10) stations are the top three critical infrastructure identified in flood zones.

Table 22. Critical Infrastructure in Mapped Floodzones in MAGIC region

Town	Flood Zone	Critical Infrastructure	Frequency
Acton	AE	Dam	9
	X	Dam	1
	X	Wastewater Treatment Facility	1
Bedford	AE	Sewer Pumping Station	4
	AE	Well	1
	AE	Dam	1
	X	Child Care	1
	X	Mortuary	1
	X	Sewer Pumping Station	2
	X	Well	2
Bolton	AE	Dam	1
	AE	Bridge	1
	X	Dam	2
Boxborough	AE	Dam	2
	X	Dam	1
Carlisle	AE	Dam	7
	X	Cistern Water Source	1
	X	Hazardous Materials	1
Concord	A	Dam	3
	AE	Bridge	8
	AE	Child Care	1
	AE	Court House	1
	AE	Dam	6
	AE	Fire Station	1
	AE	Hazardous Materials	1
	AE	Hotel	1
	AE	Medical Facility	2
	AE	Municipal Office	3
	AE	Police Station	1
	AE	Sewer Pumping Station	4
	AE	Water Pumping Station	1
	AE	Well	1
	X	Gas Distribution	1

[88] Based on MAPC analysis and most recent hazard mitigation plans for towns in the MAGIC region

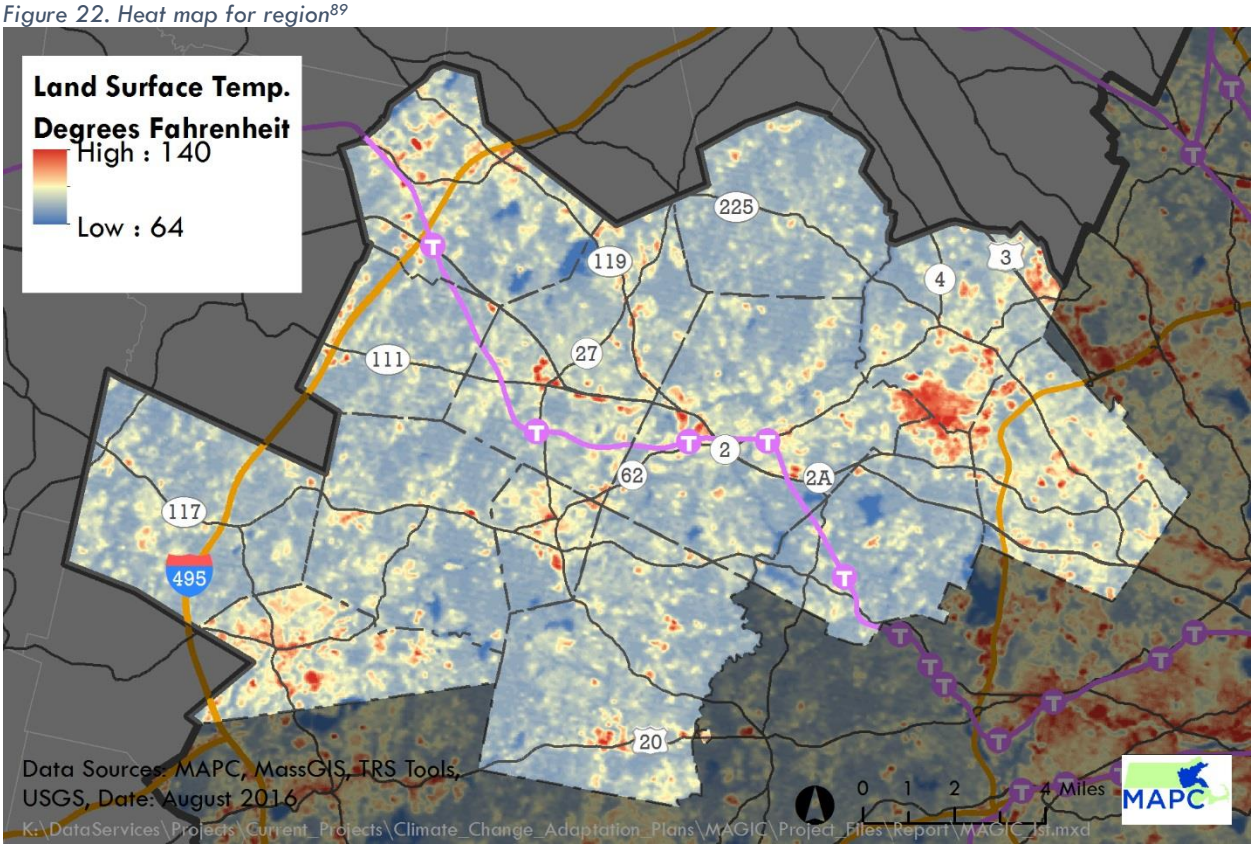
Town	Flood Zone	Critical Infrastructure	Frequency
	X	Medical Facility	1
	X	Pharmacy	1
	X	Water Pumping Station	1
Hudson	AE	Place of Assembly	1
	AE	Power Substation	1
	AE	Wastewater Treatment Facility	1
	AE	Well	2
	AE	Dam	4
	X	Wastewater Treatment Facility	1
	X	Water Supply	1
	X	Well	1
Lexington	A	Reservoir	1
	AE	Dam	1
	AE	Hazardous Materials	1
	AE	Wastewater Treatment Facility	1
	AE	Transformer	1
	X	Dam	1
	X	Hazardous Materials	3
	X	School	1
	X	Transformer	1
Lincoln	A	Dam	3
	A	Well	1
	AE	Dam	2
	X	Dam	1
	X	Well	1
Littleton	A	Group Home	1
	AE	Well	1
	AE	Dam	1
	X	Hazardous Materials	1
Maynard	AE	Bridge	3
	AE	Dam	2
	AE	Water Supply	1
	AE	Bridge	4
	AE	Dam	1
	D	Federal Office	1
Stow	A	Dam	2
	AE	Dam	4
	X	Water Pumping Station	1
Sudbury	AE	Public Water Supply	1
	X	Child Care	1

Source: MAPC

Temperature and Heat Island Effects

The heat island effect is anticipated to affect areas with higher concentrations of impervious surface such as buildings, parking lots, and roadways. These areas experience the effect due to their absorption of heat during the hottest part of the day which increases the temperature in the daytime and keeps nighttime temperatures higher as the heat is released from the materials.

Figure 22. Heat map for region[89]



Source: MAPC

Heat mapping for MAGIC shows the potential for heat islands in some specific areas rather than being widespread across the region (Figure 22).[90] Those areas that look like they could experience heat islands by exceeding the air temperature during a high heat day include:

- Littleton - In the northern and eastern portions of town, generally bounded by the Fitchburg Commuter Rail Line and Route 2
- Boxborough – in the portion of town that is located north of Route 2

[89] J. Walawender, M. Hajto, and P. Iwaniuk, "A new ArcGIS toolset for automated mapping of land surface temperature with the use of LANDSAT satellite data." *Proceedings of the IEEE International Geoscience and Remote Sensing Symposium*, (Munich, 2012): 4371-4374.

[90] Heat maps were created using satellite imagery shows the variation in land surface temperature across the MAPC region. The maps were created from two images taken in August of 2010, on a day when the Logan Airport weather station logged a high of 92 degrees. For more information, please visit: http://www.mapc.org/mapping-heat-surface-temperatures-mapc-region

- Acton – along the Route 2 and Route 2A corridors
- Lexington – in the center of town, along Worthen Road and Woburn Street
- Concord – in the vicinity of the Concord and West Concord commuter rail stations
- Bedford – in the vicinity of Route 4 and along Shawsheen Road
- Hudson – in the downtown, along Route 85, and the Intel property
- Stow – along Route 117
- Maynard – in the downtown and along Route 27
- Sudbury – along Route 20 and Union Avenue

The Laurence G. Hanscom Field shows up as a potential large heat island location in the region. Straddling the towns of Bedford, Concord, Lexington, and Lincoln, the Hanscom Field airport appears to be the largest contiguous area in the MAGIC region with the potential experience heat island effects. The airport is a public use facility and is used by adjacent Hanscom Air Force Base, which is a United States Air Force defense-research facility.

Extreme heat could affect the existing building stock in MAGIC. The heat is expected to place added thermal stress on building materials and increase demands for cooling. Newly constructed buildings may not be as sensitive to the increased stress and demand from extreme heat given recent changes to the state building code. They are also likely to have been built with central heating and air conditioning systems and built with more energy efficient materials.

Older structures may not offer the same heating and cooling options and may be less energy efficient. In MAGIC, it is estimated that approximately 62 percent of homes were built before 1980.[91] These buildings, if not updated, could have the need for additional cooling capacity as the most likely current cooling options are window units[92] or to not use air conditioning. In addition, energy demands needed for the new cooling options could exceed current electrical system capabilities. Heat may also contribute to accelerated deterioration of building materials like roofs.

Impervious surfaces contribute to heat island effects as well as stormwater and flooding issues. An impervious surface does not allow for water to permeate through it and typically characterize built environment elements such as buildings, sidewalks and roads, parking lots, and other surfaces made of concrete, brick, stone, and asphalt. In the MAGIC regions, the percentage of impervious

[91] Finding that in 1973, housing was less likely to have central air conditioning. For this report, 1980 was used as a point in time since ACS Housing Tenure by Year Built used 10-year groupings. The number here reflects housing reported to have been built before 1979. US Department of Housing and Urban Development, "Media Advisory: HUD Releases 2009 American Housing Survey," accessed August 19, 2017, http://portal.hud.gov/hudportal/HUD?src=/press/press_releases_media_advisories/2010/HUDNo.10-138

[92] "More than 20% of Massachusetts households do not use air conditioning, and those that do still predominantly rely on individual window/wall units for cooling." U.S. Energy Information Administration, "Household Energy Use in Massachusetts," accessed on August 19, 2016. https://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/ma.pdf

surface ranges from five percent to 21 percent; the towns of Hudson and Lexington has the highest coverage of impervious surfaces at 19 percent and 21 percent, respectively.

Table 23: Impervious acreage in MAGIC towns

Municipality	Impervious Acres per 100 People	% Impervious Surface	Impervious Surface Acres
Acton	8	14	1,791
Bedford	12	18	1,580
Bolton	16	6	783
Boxborough	12	9	587
Carlisle	12	6	586
Concord	9	9	1,518
Hudson	8	19	1,462
Lexington	7	21	2,240
Lincoln	14	9	869
Littleton	16	12	1,394
Maynard	6	18	613
Stow	11	6	714
Sudbury	9	10	1,572

Source: MAPC analysis of 2005 MassGIS land use data

Adaptive Capacity

The towns in the MAGIC region have many existing elements in place that support adaptive capacities in the built environment. These are the elements that currently serve as preventative measures that address issues such as flooding and development in wetland locations and elements that are working to increase energy efficiency and reduce greenhouse gas emissions.

Regulated Development in Floodplains

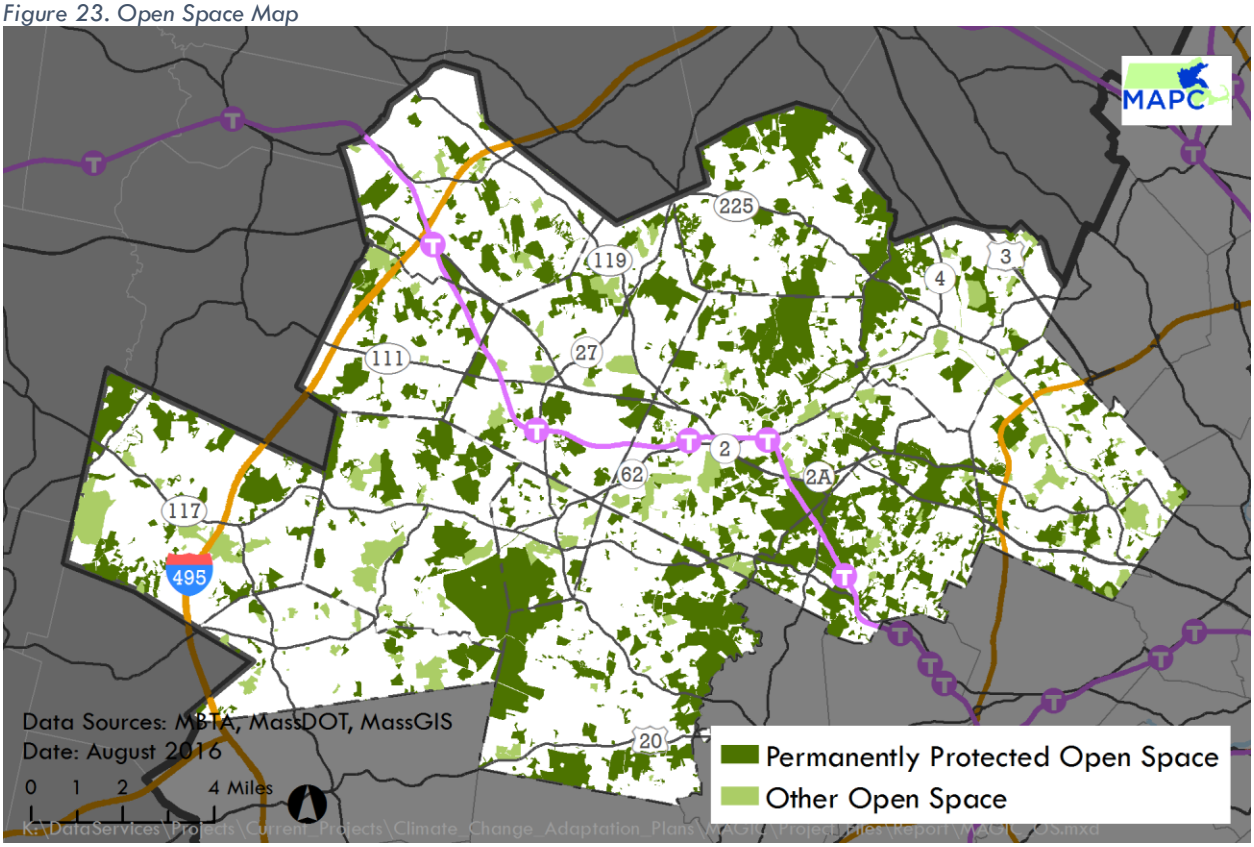
Each town in MAGIC has in place zoning provisions that prevent or limit new development and redevelopment in current flood zones. Each follows the state's building code which includes requirements for construction above Base Flood Elevation levels in order to prevent flooding of structures in a flood zone. No towns were found to have grants or incentives for flood proofing beyond regulations for development activities in a floodplain

Each town has some form of water resource protection zoning that prevents or limits development with areas that are identified as flood zones or that may be prone to flooding (see Drinking Water and Stormwater VA sections). As an example, the Town of Hudson has a Floodplain/Wetland District and a Watershed Protection District. The Floodplain/Wetland District is an overlay district which includes all areas designated as Zone A and AE (areas that would be inundated during a 100-year flood event) by FEMA. Within this district, new buildings cannot be erected, existing structures cannot be enlarged or moved, dumping and filling are not permitted, and land, buildings, or structures cannot be used for any purpose except those specified in the bylaw. These regulations limit the buildings and uses that could be exposed to flooding in the future.

Open Space Protection

The MAGIC towns have taken action to limit new development in undeveloped open spaces. As result, this has limited where impervious surfaces have been constructed and consequently where heat islands could exist in the region.

Figure 23. Open Space Map



Transfer Development Rights

Transfer of development rights (TDR), which reallocates development potential from one area to another, is a method that can preserve developments while encouraging development in appropriate locations. For example, this could include transferring development potential from parcels in a floodplain to a location outside the plain and at a higher elevation. The Town of Acton currently allows TDR in its current zoning bylaw and the Towns of Concord has a provision that allows for the greater development of a property when a portion is dedicated for public use. Both are limited in nature and involve business districts.

Stormwater Management and Techniques

As noted in the Water Infrastructure section, few towns in MAGIC were found to have stormwater management plans. There are examples of efforts in the towns to allow rainwater harvesting and to promote LID techniques. These efforts will increase the capacity of specific properties but do not yet promote adaptive capacity for the larger systems.

Energy Efficiency

There are a number of efforts in the MAGIC region to promote more energy efficiency. More will be provided in the Energy Infrastructure section, but these efforts make available tools for residents to see how they can make their buildings more energy efficient and use renewable energy like solar. Towns are also making progress through participation in the state's Green Communities program and taking advantage of funding opportunities to build clean energy solutions (e.g., grants awards from the Community Clean Energy Resiliency Initiative).

Green Roofs and Cool Roofs

Green roofs involve planting a vegetative layer on a building rooftop.[93] The use of vegetation such as plants and grasses has been shown to reduce temperatures when compared to conventional rooftops as well as assist in stormwater management and reduce energy demands. Cool roofs provide similar benefits, but rather than vegetation, these rooftops use materials that reflect light away from buildings reducing heat absorption. No municipalities in MAGIC were found to have green roofs or cool roofs programs or regulations.

[93] Environmental Protection Agency, "Heat Island Compendium", https://www.epa.gov/heat-islands/heat-island-compendium, accessed January 25, 2017.

Transportation Infrastructure

Assessment Summary

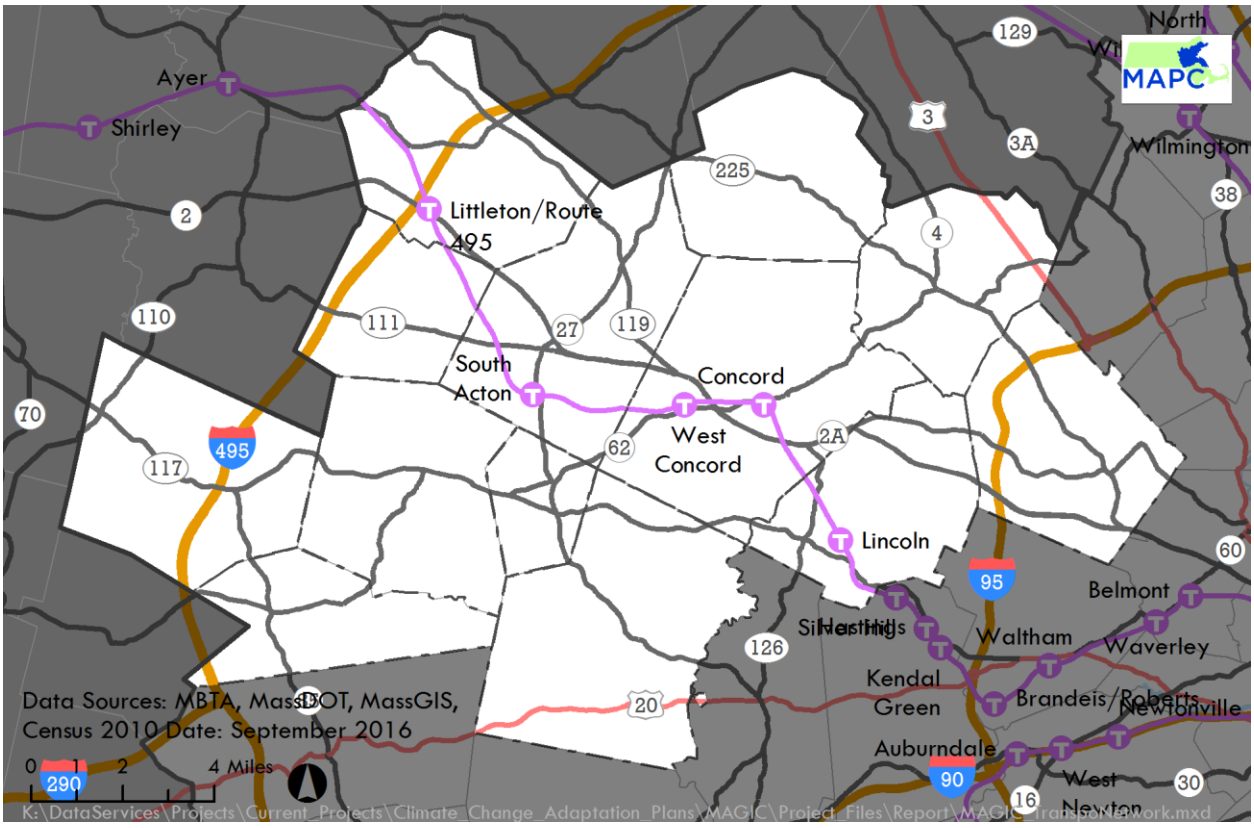
- The transportation system is assessed as moderately vulnerable with potential high vulnerability on roadways located in 1% flood zones and those in areas with more potential for heat island effects. More information is needed regarding the potential for riverine flooding to make a preliminary assessment.
- Vulnerabilities are related to exposure and sensitivity to flooding from additional and more frequent precipitation events and changes in the frequency of warming and cooling which can accelerate the deterioration of roadways, especially those that are locally controlled.
- Adaptive capacities in the region include municipal CIPs that allow local control over how and why investments are made into local transportation infrastructure, transit services that are part of a part of larger systems or have multiple forms of community support, and enhancement of bicycling and walking facilities.

Sensitivity

Roadways

Transportation infrastructure would likely experience an acceleration in deterioration of its facilities, like asphalt, from the combination of warmer temperatures and more precipitation and flooding. The higher temperatures and longer periods of heat would impact thermal expansion of metal structures and stress bridge infrastructure. This would also affect roadway materials by softening it and allowing it to expand which can lead to rutting and potholes.[94] While there may be decreased need to provide snow and ice removal, more rapid freezing and thawing cycles there impact could be more acute given damage to the roadway infrastructure that occurs during warmer months.

Figure 24. Map of major roadway and commuter rail transit infrastructure

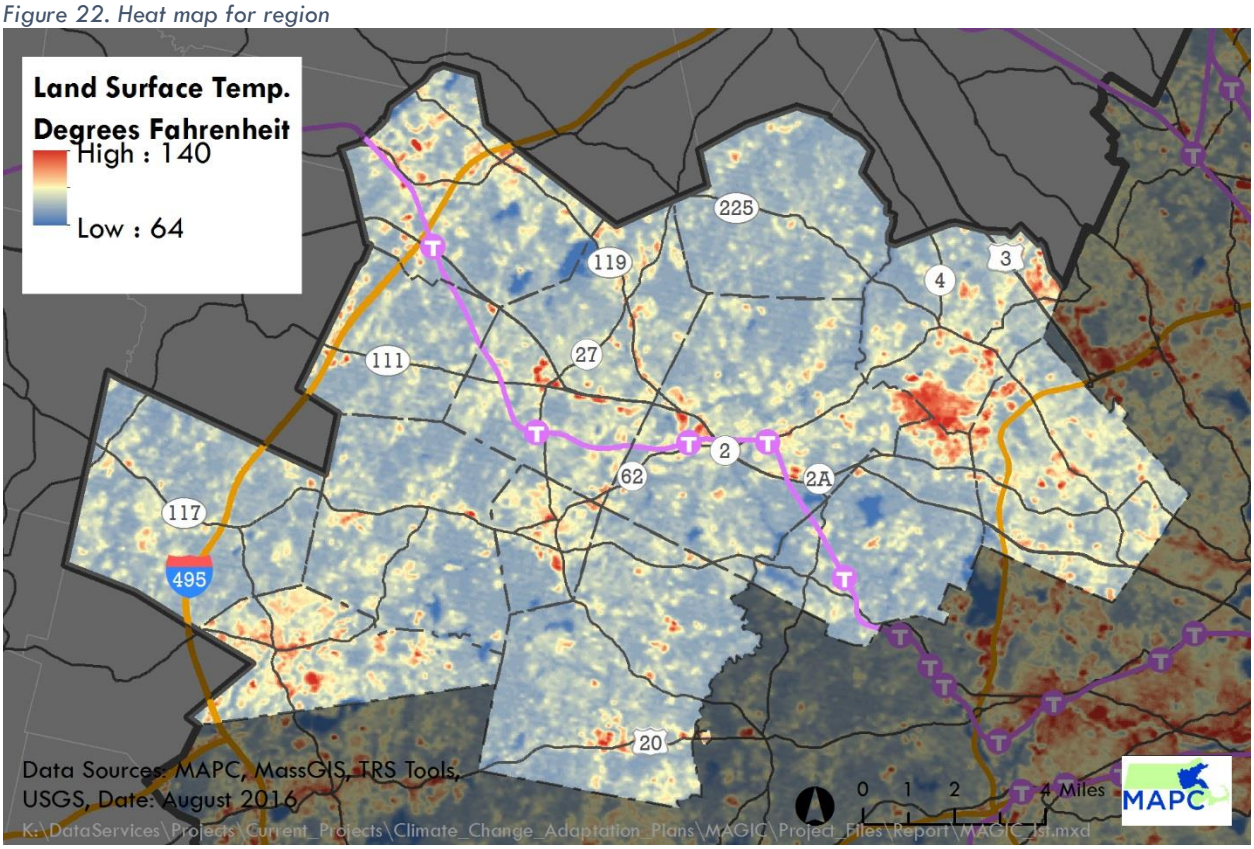


Source: MassDOT

Based heat mapping (see

[94] NRC (2008). The Potential Impacts of Climate Change on U.S. Transportation, Transportation Research Board Special Report 290. National Research Council (NRC).

Figure 22. Heat map for region



) in the previous section) and due to the potential for heat island effects, a number of roadways segments may have greater exposure to the effects of higher temperatures. These include sections of the following roadways which are primarily state-controlled assets:

- Route 2 and Route 2A corridors in Acton
- Route 4 in Bedford
- Route 85 in Hudson
- Route 117 in Stow
- Route 27 in Maynard
- Route 20 in Sudbury

Flooding has the potential to block roadways limited regular as well as emergency transportation access. There are approximately 16 miles of locally-controlled roadways in the MAGIC region that are located in the 1% flood zone area, which indicates that they could flood but is not an indicator that they do currently flood. The Towns of Acton and Stow have the highest number of local roads in the flood zone with approximately 4.3 miles and 8.9 miles, respectively. In addition to local roads, there is approximately one mile of state controlled roadway and 10 miles of non-municipally owned roadways (e.g., private ways, unaccepted streets) that intersect with a mapped floodzone.

Table 24. Roadways in Floodzones by Jurisdiction

Town	Jurisdiction[95]	Length (mi)
ACTON	Jurisdiction Unknown	1.29
	State	0.31
	Town	2.70
	Total	***4.30***
BOLTON	Jurisdiction Unknown	0.14
	State	0.14
	Town	0.86
	Total	***1.14***
BOXBOROUGH	Jurisdiction Unknown	0.24
	State	0.06
	Town	0.46
	Total	***0.77***
CARLISLE	Jurisdiction Unknown	0.09
	Town	0.42
	Total	***0.51***
CONCORD	Jurisdiction Unknown	4.17
	State	0.16
	Town	4.58
	Total	***8.90***
HUDSON	Jurisdiction Unknown	1.02
	State	0.05
	Town	1.73
	Total	***2.80***
LEXINGTON	Jurisdiction Unknown	1.73
	State	0.13
	Town	0.60
	Total	***2.46***
LINCOLN	Jurisdiction Unknown	0.21
	Town	0.69
	Total	***0.90***
LITTLETON	Jurisdiction Unknown	0.63
	State	0.15

95

Town	Jurisdiction[95]	Length (mi)
	Town	0.60
	Total	***1.38***
MAYNARD	Jurisdiction Unknown	0.28
	State	0.03
	Town	0.16
	Total	***0.47***
STOW	Jurisdiction Unknown	0.24
	State	0.05
	Town	0.71
	Total	***1.00***
SUDBURY	Jurisdiction Unknown	0.58
	State	0.00
	Town	3.29
	Total	***3.88***
Grand Total (mi)		***28.50***

Source: Massachusetts Department of Transportation Road Inventory, 2014

Public Transit

Public transit serving the MAGIC region could be affected by the changing conditions. Overheated rails can expand and lead to buckling of the tracks which in turn increases the risk of derailment.[96] The commuter rail line, which operates between Fitchburg and North Station in Boston, and includes several stops in the MAGIC region, would be required to operate under heat restrictions to reduce this risk. This change in operations would result in slower, and potentially fewer, trips during extreme heat days.

Existing on-road transit route could be impacted if roadway become damaged or blocked. Routes are potentially more at risk if they are occurring on roadway segments that are located in flood zones or flood prone locations, or if they are traveling regularly on roadways that have been maintained.

Adaptive Capacity

Capital Improvement Plans

The towns in MAGIC use capital improvements plans (CIPs) to track and determine what local roadways and other transportation facilities will require maintenance, rehabilitation, and reconstruction. Past practice has often been dictated by preparation and recovery from winter weather and winter precipitation events, especially snow and ice. There will no indication during

[96] Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation. FTA Report No. 0001 128 pp., Federal Transit Administration, Office of Research, Demonstration and Innovation, U.S. Department of Transportation

the process or through provided information that CIPs in the MAGIC region were including climate change effects such as the need to accommodate larger precipitation events or changing temperatures.

Public Transit

Public transit is available in many of the MAGIC towns. MBTA provides bus service in Lincoln, Lexington, Concord, and Bedford, with many of the lines connecting to commuter rail stations. Other regional transit authorities provide bus or shuttle service in MAGIC, including:

- Lowell Regional Transit Authority (LRTA), which covers Maynard but does not currently provide service
- MetroWest Regional Transit Authority (MWRTA), which covers Sudbury but does not currently provide service
- Montachusett Regional Transit Authority (MART), which covers Bolton, Boxborough, Littleton, and Stow and currently provides Council on Aging (COA) shuttle services and a commuter bus that connects to Boston

Each town provides COA shuttles for older adults, in some cases for one trip purpose (e.g., medical appointments) or for multiple purposes (e.g., medical, shopping, and programs). There are also private commuter bus services that connect from Concord and Sudbury to Boston.

Several of the towns have started their own local transit services. Lexington offers the Lexpress routes to connect to town destinations; Bedford offers local transit that has fixed route and on-demand service in town; and Acton offers the MinuteVan rail shuttle and the CrossTown Connect which operates in Acton, Boxborough, Littleton, and Maynard.

The MBTA Fitchburg Commuter rail infrastructure crosses through MAGIC with stops in Concord, Lincoln, Littleton, and Action. The line has recently been updated and new materials were used to reduce the potential for heat restrictions along the line.

Multiple municipalities in the region have plans or policies in place to support bicycle and pedestrian travel. Complete Streets policies to increase accommodation of transportation options. The towns of Bedford, Hudson, Maynard, and Stow have bicycle and pedestrian master plans; these same towns as well as Acton, Lexington, and Littleton have enacted Complete Streets policies. These efforts should lead to changes in the transportation systems that support facilities for non-motorists and potentially reduce GHG emissions from the region.

Active Transportation

Active transportation supported by investments such as pedestrian investments can lower GHG emissions and increase transportation choices for residents. The towns in MAGIC have developed plans and policies over the past several years to support active transportation like biking and walking. Four town have bicycle and pedestrian master plans (Bedford, Hudson, Maynard, and Stow) and all but five have adopted or have plans to adopt Complete Streets policies (Acton, Bedford, Hudson, Lexington, Littleton, Maynard, and Stow; Lincoln is in progress), which could help unlock up to $400,000 in addition funding for local multi-modal roadway enhancements.

Energy Infrastructure

Assessment Summary

- The energy infrastructure system is assessed to be low. This assessment is preliminary and of more information about current energy system information (e.g., usage in the towns, etc.) and energy providers is needed.
- Vulnerabilities are related to exposure and sensitivity of flooding energy infrastructure in or proximate to flood zones and the capacity of local utilities to respond to and address climate change effects that may increase energy demand or cause damage to the infrastructure.
- Adaptive capacities in the region include town activities to adopt changes that support production of and access to clean energy sources and adoption of measures like the stretch code that will increase the energy efficiency of new developments, and clean energy investments that support local energy generation in the event of disruptions the larger energy system.

Energy Infrastructure Vulnerability Assessment

Sensitivity

Increased temperatures will have an adverse impact on energy infrastructure in and serving the region. High temperatures will increase energy loads as demand increases for air conditioning, and refrigeration while demand likely also grows from equipment and services like a high-speed information and technology networks. Failures within the energy network could quickly cascade across other critical infrastructure sectors such as transportation, water service, etc. as transportation, water service, etc.

Energy service providers in the MAGIC region as follows:

Table 25. Energy providers for the MAGIC Region

Town	Electric Company	Gas Company
Acton	Eversource	National Grid
Bedford	Eversource	National Grid
Bolton	National Grid	Eversource
Boxborough	Littleton Municipal Electric/ Hudson Municipal Electric	National Grid
Carlisle	Eversource	National Grid
Concord	Concord Municipal Electric	National Grid
Hudson	Hudson Municipal Electric	Eversource
Lexington	Eversource	National Grid
Lincoln	Eversource	National Grid
Littleton	Littleton Municipal Electric	National Grid
Maynard	Eversource	Eversource
Stow	Hudson Municipal Electric	Eversource
Sudbury	Eversource	National Grid

Source: MAPC review of energy providers in the MAGIC region

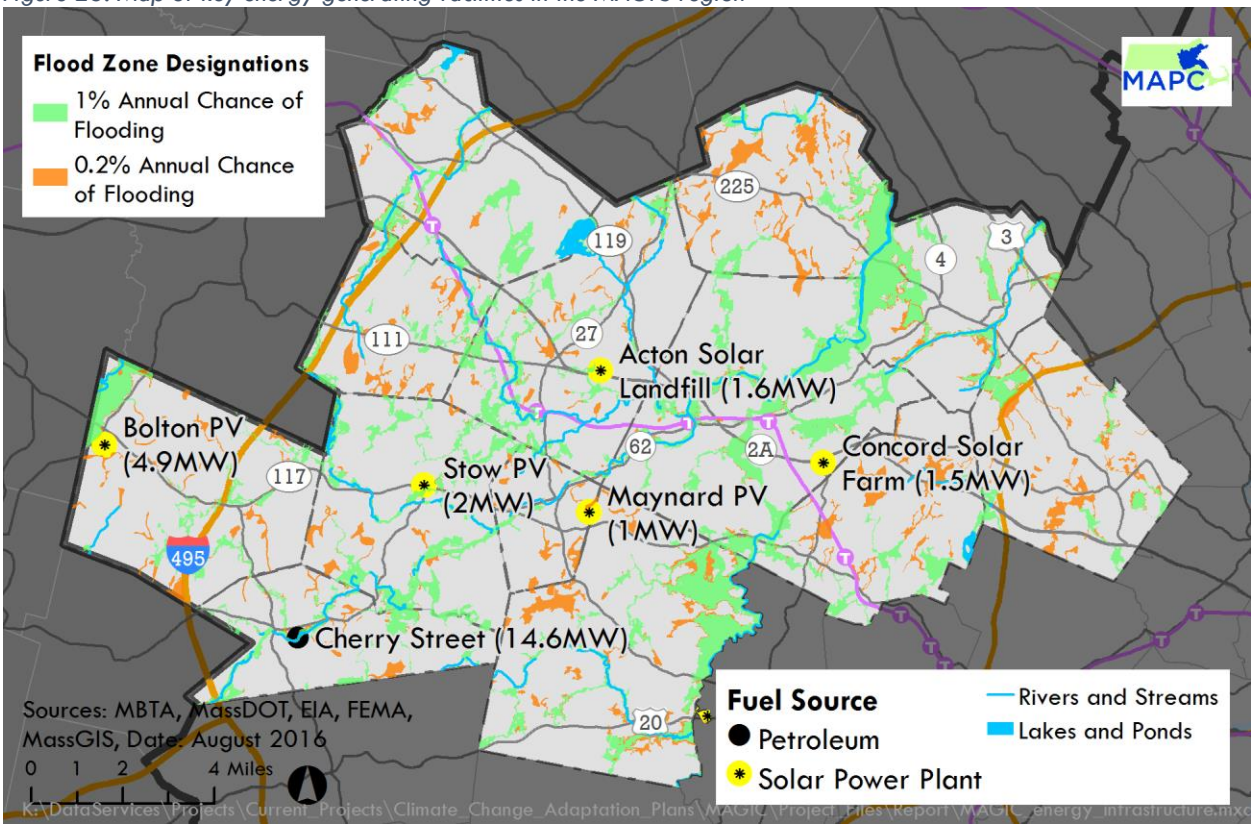
Energy infrastructure locations are strictly secured by all levels of government due to their designation by the U.S. Department of Homeland Security, primarily under the Homeland Security Act of 2002. However, the U.S. Energy Information Administration offers spatial analysis tools for released energy data which allows for some regional and local assessment of infrastructure.[97]

In MAGIC, there are six energy generating facilities located within the region (Figure 25). There are five solar power arrays and one petroleum-based power plant. Solar facilities in Acton, Stow, and Bolton are located near the 1% Annual Chance of Flooding zones, and Maynard's plant is near the 0.2% flood zone (areas of 500-year flood). The Cherry Street petroleum power plant in

[97] United States Energy Information Administration, "U.S. Energy Mapping System," accessed on August 19, 2016, https://www.eia.gov/state/maps.cfm,
United States Energy Information Administration, "Flood Vulnerability Assessment Map," accessed on August 19, 2016, https://www.eia.gov/special/floodhazard/

Hudson is adjacent to the Assabet River. These plants are relatively small, however, and likely provide only a small portion of the energy needs for the region.

Figure 25. Map of key energy generating facilities in the MAGIC region



Source: U.S. Energy Information Administration

Adaptive Capacity

Clean energy and local energy production support the reduction of GHGs and builds capacity of smaller geographies and places to meet their own energy demand. These resources can also take the form of energy efficiency initiatives and the promotion of conservation measures in order to reduce local energy needs.

Green Communities

Much of the clean energy work related to the built environment is occurring as part of the Green Communities program. Ten towns in MAGIC are currently Green Communities and another two are in the progress of getting certified. Hudson has not yet set in progress or become a green community.

All but two of the towns in MAGIC (Boxborough and Hudson) have adopted the Stretch Energy Code. The Stretch Energy Code provides a more energy efficient alternative to the standard energy provisions of the code that a municipality may adopt. It is based on provisions of the

International Energy Conservation Code 2009 (IECC 2009).[98] The stretch code helps reduce the energy demand from new buildings and can reduce GHG emissions.

Greenhouse Gases (GHG) Inventory

Towns can make contributions to overall efforts to reduce GHGs. An understanding of how and where to make these reductions can be supplied through local GHG inventory. The inventory involves looking at the multiple sectors that contribute GHG to the atmosphere and energy demands coming from local uses. Sometimes this work can involve just looking at governmental sources like municipal facilities and in other cases it can be for specific sectors or an entire municipality. A review of the MAGIC region did not identify municipal efforts to inventory GHG emissions.

Clean Energy Resiliency

The Community Clean Energy Resiliency Initiative is part of the Commonwealth's broader climate adaptation and mitigation efforts and is a grant program focused on municipal resilience that uses clean energy technology solutions to protect communities from interruptions in energy services due to severe climate events.[99] Two of the town have received TA awards which allowed the towns to explore recommend opportunities for resilient clean energy solutions.

The Town of Acton has received grants to look at incorporating solar PV with storage at the public safety building and the DPW and to determine the feasibility of adding inverters, controls and battery storage to two facilities (schools serving as shelters during emergencies) with existing PV arrays. The consulting team will look at the feasibility of incorporating CHP or renewable thermal generation where it might be applicable. The second project was done through Acton Boxborough Regional School District. The Town of Lincoln has a project with MAPC to explore the possibility of greater shared services, both in public safety resiliency and in community sheltering. MAPC seeks to gain technical assistance for the exploration of islanding capability, advanced switches, and/or battery storage in the planned solar installations at these critical facilities.

Residential Energy Efficiency Initiatives

All but two of the towns in the MAGIC are promoting residential energy efficiency initiatives. Boxborough and Maynard were not found to be currently promoting a similar initiative. Examples of this work are:

- Participation in Solarize Mass, which supports increased adoption of small-scale solar electricity systems[100] (Acton, Bedford, Bolton, Lexington, Lincoln, and Sudbury)
- Provision of community "Kill A Watt" that residents can borrow to determine the energy efficiency of appliances in their homes (Bedford and Carlisle)
- Resources and guides (energy audits, tools, etc.) to help residents in making energy efficiency improvements (Carlisle, Concord, Littleton, and Stow)

In many cases, the work is either being led by or supported by volunteer groups.

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[98] Executive Office of Public Safety and Security, "Stretch Energy Code – Information," accessed August 24, 2016, http://www.mass.gov/eopss/consumer-prot-and-bus-lic/license-type/csl/stretch-energy-code-information.html

[99] Executive Office of Energy and Environmental Affairs, "Community Clean Energy Resiliency Initiative," http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/resiliency/resiliency-initiative.html, accessed August 25, 2016

[100] Massachusetts Clean Energy Center, "Solarize Mass," http://www.masscec.com/get-clean-energy/residential/solarize-mass, accessed August 25, 2016

Human Health and Welfare

Assessment Summary

- The human health and welfare system is assessed as low vulnerability with potentially high vulnerability for older and aging residents, populations with existing chronic diseases, and the local public health infrastructure.
- Vulnerabilities are related to exposure and sensitivity of a growing population of older adults, populations that have chronic diseases like asthma and diabetes, and mental health disorders, and the capacity of local public health emergency preparedness to respond to an increase in emergency events like heat waves and outbreaks in vector borne diseases.
- Adaptive capacities in the region come from health behaviors that are better on average than the state and lower rates of poor health conditions relative to the state as well as some preliminary local public health efforts to consider the effects of climate change in their work.

Human Health and Welfare Vulnerability Assessment

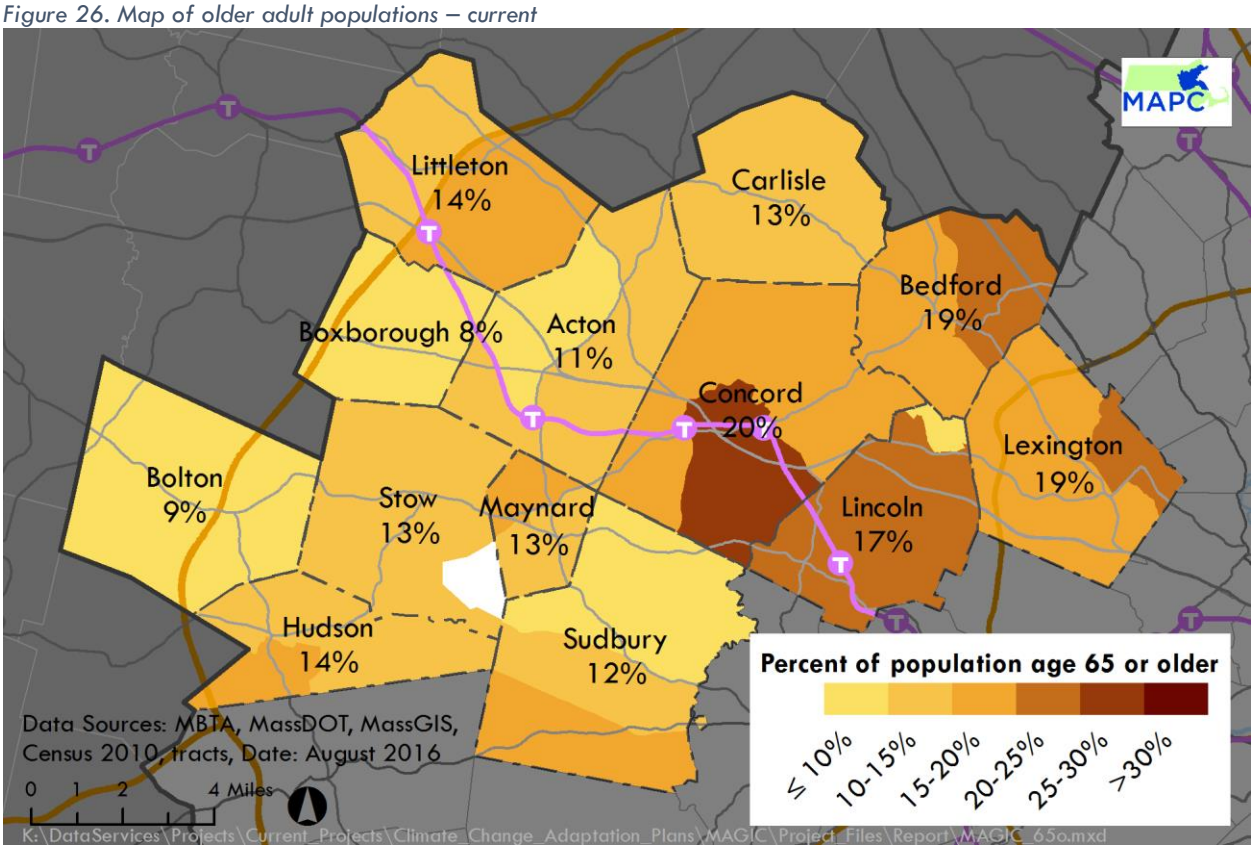
Sensitivity

Vulnerable Populations

The projection for more frequent and intense weather events means that precipitation may fall in shorter durations and with greater volumes and result more flooding. Flooding can be expected to disrupt transportation systems and potentially isolate people in their homes. Those at risk from reduced transportation options are those individuals who need daily medical care, assistance with meeting basic daily needs like preparing food, and being exposed to water-borne pollutants. Older adults, people with disabilities, and those with health needs that require regular access to medications or services (e.g., dialysis) are at particularly high risk when these disruptions occur.

In the near term, disruptions in services will have greater consequences for older populations. In MAGIC, most towns have at least 10 percent of the residents comprised of older adults (65 years and older) and in some cases, including the towns of Concord, Bedford, Lexington, and Lincoln, the percentages of older adults are close to 20 percent of population (Figure 26).

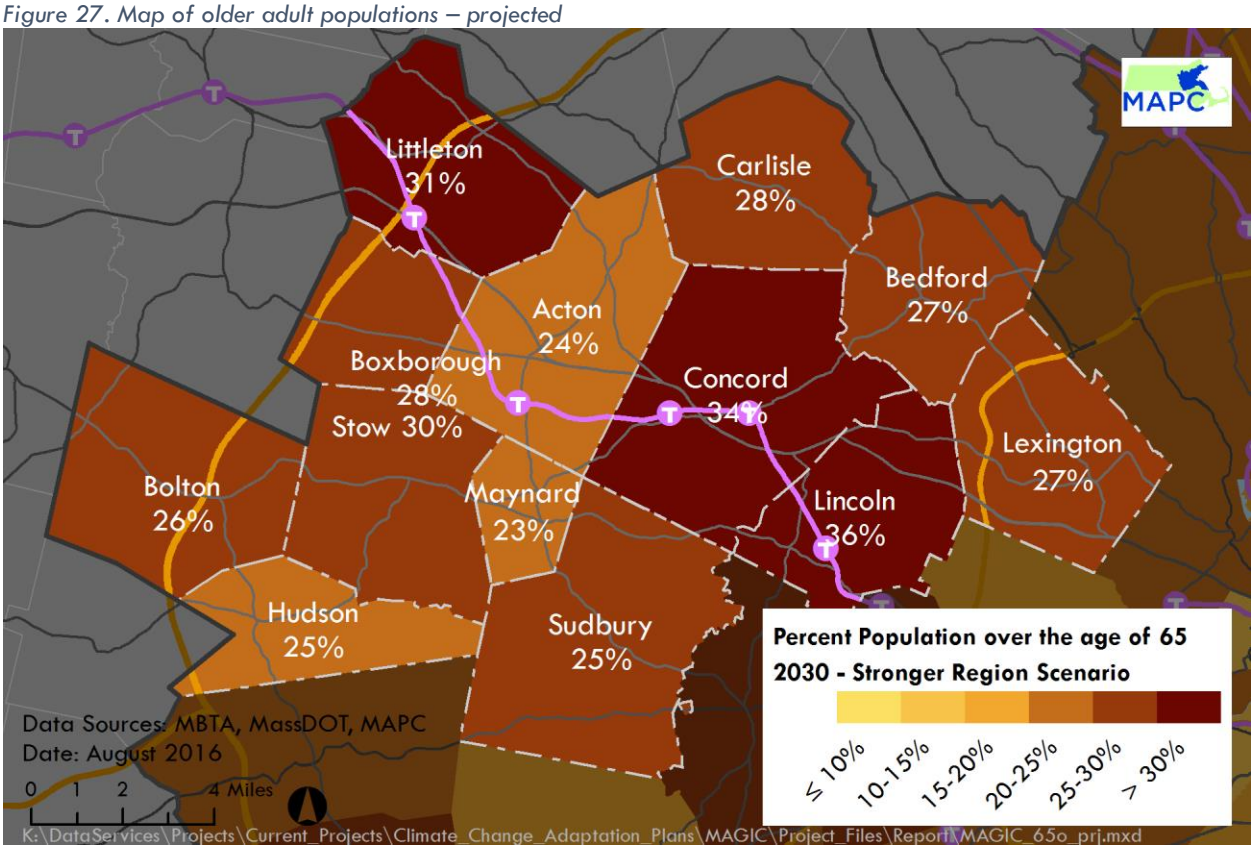
Figure 26. Map of older adult populations – current



Source: MAPC

In the future, the concern related to impacts on seniors could increase across the region according to existing projections. At least a quarter of each town's population will be over 65 and some will have approximately a third of their population 65 and older (e.g., Concord and Lincoln).

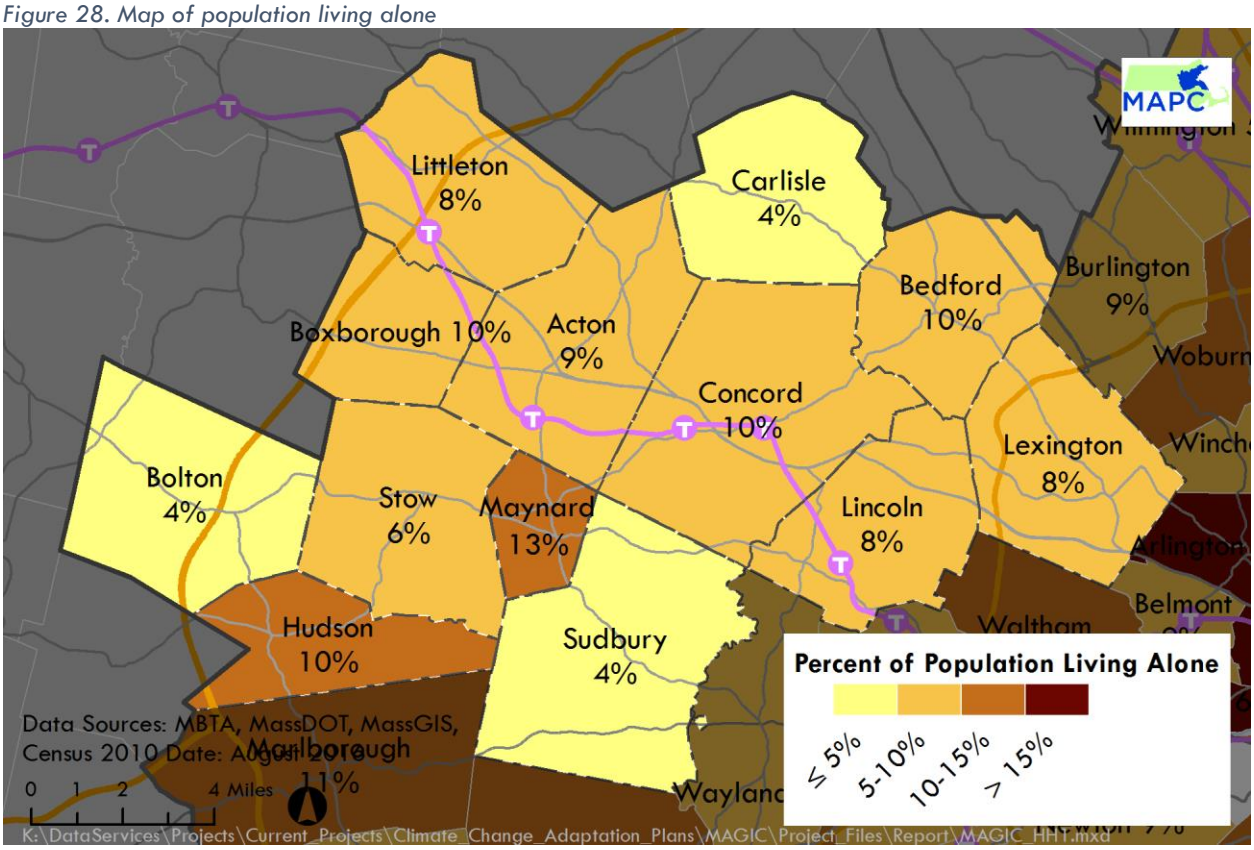
Figure 27. Map of older adult populations – projected



Source: MAPC Projections, Stronger Region Scenario

Often extreme storms are accompanied by disruptions in electrical systems. When this occurs, heating, air conditioning, and ventilation systems can be put at risk if there are not backup power systems. As result, residents may face difficulties in maintaining indoor temperatures and supplies that rely on refrigeration (e.g., perishable foods). Those most at risk from these disruptions include older residents as well as those that may be living alone, as they may not have other support systems and networks in place. Three towns in MAGIC (Maynard, Bedford, and Hudson) are estimated to have 10 percent of their populations living alone.

Figure 28. Map of population living alone



Source: Census 2010

Longer term impacts of reduced air circulation in combination with increased moisture can lead to more indoor mold and contaminants. Those who suffer from respiratory issues like asthma face challenges during these situations and others become susceptible to developing similar health issues. The asthma hospitalization rate in MAGIC is below that of the state; the highest rate in the region is in the area that includes the towns of Bolton, Stow, and Hudson (Table 21).[101]

[101] The region was separated into four area, or quadrants, due to limitations in reporting health data at small geographies (e.g., town with a limited number of cases in a particular time period). The four quadrants are identified below and additional information is presented in the Appendix.

West Quadrant	North Quadrant	South Quadrant	East Quadrant
Bolton, Hudson, and Stow	Littleton, Boxborough, and Acton	Maynard and Sudbury	Bedford, Lincoln, Concord, and Lexington

Table 26. Asthma Hospitalizations

Asthma Hospitalizations 2008-2012	Age Adjusted Rate per 100,000 (95% CI)
North Quadrant	54.04 (43.35, 64.74)
East Quadrant	66.67 (57.78, 75.56)
South Quadrant	49.23 (37.8, 60.67)
West Quadrant	89.71 (74.04, 105.38)
MAGIC Region	64.49 (58.89, 70.08)
Massachusetts	151.92 (150.56, 153.27)

Source: MDPH, MassCHIP

Prolonged exposure to high temperatures can cause heat-related illnesses, such as heat cramps, heat exhaustion, heat stroke, and death. Heat exhaustion is the most common heat-related illness and if untreated, it may progress to heat stroke.[102] Additionally, heat is expected to contribute to the exacerbation of chronic health conditions.[103] In particular, hyperthermia—elevated body temperature due to failed thermoregulation can be caused by heat stroke — is a contributing factor to cardiovascular, metabolic, and other causes of death.[104] As noted earlier, there are multiple, but not widespread, locations (e.g. town centers and roadway corridors) in the region where extreme heat in the form of heat islands could be expected.

Extreme heat has the potential to contribute to greater levels of ground level air pollution and allergens. Heat helps form by chemical reactions between NOx and volatile organic compounds (VOCs) in the presence of sunlight. Breathing ozone can irritate the respiratory system, reduce lung function and heighten sensitivity to allergens.[105] Likewise, increased temperatures in the presence of higher concentrations of CO_2 has been linked to earlier blooming of flowers (shrubs and trees), which in turn affects the timing, distribution, and composition of pollen and other allergens.[106]

Those at particularly high risk of adverse health effects from extreme heat exposure are older adults, children, those living alone, those with chronic illnesses, residents with lower incomes, and people without access to air conditioning.[107] In addition, people with chronic mental disorders or pre-existing medical conditions (e.g., cardiovascular disease, obesity, diabetes, neurologic or

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[102] Ibid

[103] J. Kravchenko, A. Abernethy, M. Fawzy, and H. Lyerly, "Minimization of heat wave morbidity and mortality," *American Journal of Preventive Medicine* 44 no. 3, (2013): 274–282.

[104] M. O'Neill and K. Ebi, "Temperature Extremes and Health: Impacts of Climate Variability and Change in the United States," *Journal of Occupational and Environmental Medicine* 51no. 1 (2009), 13–25.

[105] MassDEP, "Ground-Level Ozone," accessed on August 19, 2016, http://www.mass.gov/eea/agencies/massdep/air/quality/aq-ground-level-ozone.html

[106] USGCRP. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. A. Crimmins et al eds.* (Washington DC: U.S. Global Change Research Program, 2016)

[107] R. Basu, "High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008," *Environmental Health*, 8 no. 40 (2009).
G. Luber and M. McGeehin, "Climate change and extreme heat events." *American Journal of Preventive Medicine*, 35 no. 5 (2008b): 429–435.

psychiatric disease), and those participating in outdoor manual labor or sports in hot weather also are at increased risk for heat-related illness.[108]

Table 27. Diabetes Hospitalization

Diabetes Hospitalizations 2008-2012	Age Adjusted Rate per 100,000 (95% CI)
North Quadrant	57.95 (46.42, 69.48)
East Quadrant	45.46 (38.57, 52.35)
South Quadrant	87.4 (69.94, 104.86)
West Quadrant	83.66 (69.05, 98.28)
MAGIC Region	59.85 (54.56, 65.13)
Massachusetts	135.03 (133.81, 136.26)

Source: MPDH, MassCHIP

Table 28. Hypertension Hospitalization

Hypertension Hospitalizations 2008-2012	Age Adjusted Rate per 100,000 (95% CI)
North Quadrant	22.37 (15.4, 29.34)
East Quadrant	20.61 (16.23, 25)
South Quadrant	24.36 (16.24, 32.48)
West Quadrant	25.84 (17.74, 33.93)
MAGIC Region	22.18 (19.15, 25.22)
Massachusetts	45.49 (44.79, 46.19)

Source: MDPH, MassCHIP

The MAGIC region as a whole performs better than the state in most of these regards, but these populations are still present. In terms of chronic diseases, the region's residents have much lower rates than the state; among the region, the south and west quadrants, which include the towns of Bolton, Hudson, Stow, Maynard and Sudbury, had the highest rates of diabetes and hypertension hospitalizations.

[108] J. Holstein et al. "Were less disabled patients the most affected by 2003 heat wave in nursing homes in Paris, France?," *Journal of Public Health*, 27 no. 4 (2005): 359–365.

Vector Borne Diseases

With climate change, residents in Magic may be subject to greater exposure to disease vectors, such as Eastern equine encephalitis (EEE), West Nile virus (WNV), and Lyme disease. Massachusetts is predicted to have a general trend of warmer temperatures, which may lead to higher mosquito and tick numbers and greater activity. This may prolong transmission seasons for all vector-borne diseases, extending the risk of transmission outside of the traditional late spring through early fall timeframe.

In MAGIC, risk of vector-borne disease varies. The most recent available data for Middlesex County (which covers 12 of the 13 MAGIC towns) indicates that confirmed and probable new cases of Lyme disease has been rising over the past several years. This is reflected in the incidence rate which has also been rising and in 2015 was estimated at 71 new cases per 100,000 people. This trend follows a general trend of increasing Lyme disease incidence or ticks being reported with Lyme across the Northeast.[109]

Table 29. Lyme Disease Reporting for Middlesex County

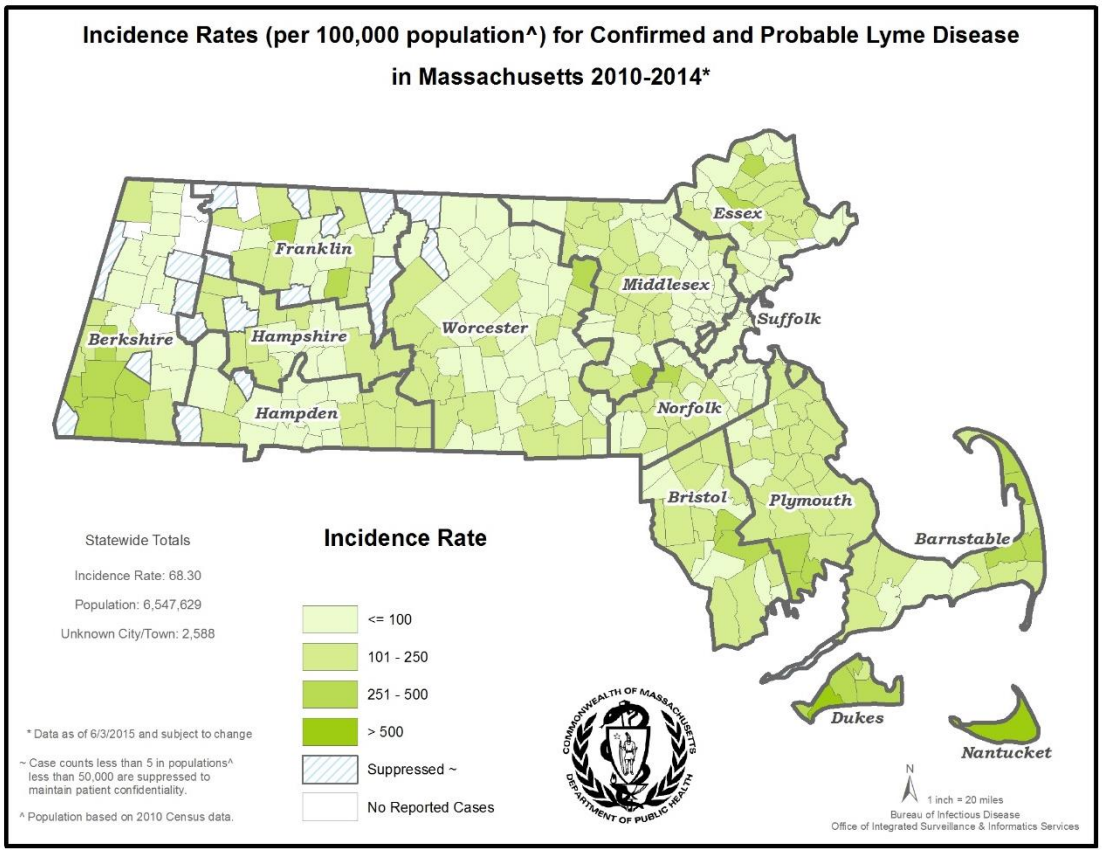
Year	Confirmed Cases (#)	Probable Cases (#)	Combined Incidence Rate for Confirmed and Probable Cases
2011	361	-	24
2012	485	289	51
2013	720	267	66
2014	748	320	71

Source: MPDH Arbovirus Surveillance

Data is not readily available at the town level for Lyme Disease. The map below does show Lyme Disease incidence rate over a five-year period. Based on the map, it appears town in MAGIC are in the middle to lower categories of incidence rates.

[109] Centers for Disease Control and Prevention, "Lyme Disease - Data and Statistics", accessed on August 19, 2016, http://www.cdc.gov/lyme/stats/

Figure 29. Map of Lyme Disease Incidence Rates per municipality, 2010-2014

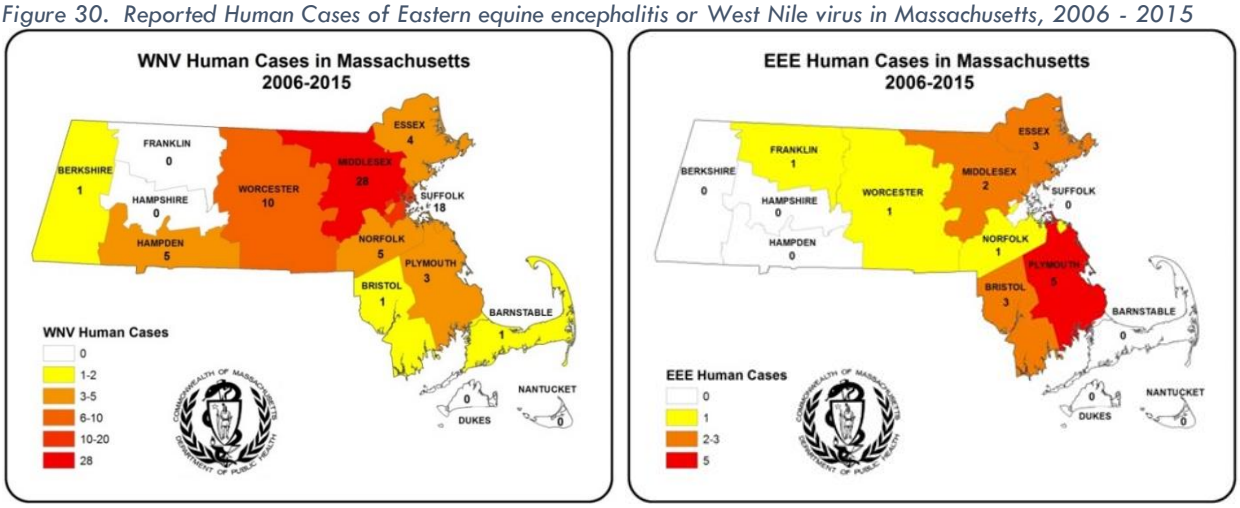


Source: MPDH Arbovirus Surveillance

State health surveillance data for mosquito-borne diseases over the past ten years shows that there have been more reported human cases of WNV than EEE.[110] Middlesex County, which includes all but one of the MAGIC towns, had the highest number of reported WNV Human cases in the state. For EEE, the southeastern region of the state has had the highest number of reported cases.

[110] Massachusetts Department of Public Health (MDPH), "Arbovirus Surveillance in Massachusetts, 2015," accessed on August 19, 2016, http://www.mass.gov/eohhs/gov/departments/dph/programs/id/epidemiology/researchers/public-health-cdc-arbovirus-surveillance.html

Figure 30. Reported Human Cases of Eastern equine encephalitis or West Nile virus in Massachusetts, 2006 - 2015



Source: MPDH Summary of Arbovirus Surveillance in Massachusetts 2015

Surveillance data for testing of mosquito reflects a similar trend. The data indicates that a majority of the towns in MAGIC have had at least one reported case of mosquito-borne disease in the past five years and that WNV accounted for most of the positive tests.[111] The data also show that no mosquito has tested positive for EEE since 2012 and that since 2013 there has been a drop in the number of mosquitos testing positive for WNV in MAGIC.

Table 30. Numbers of Mosquito Samples that Tested Positive for Eastern equine encephalitis (EEE) or West Nile virus (WNV)

Town	2015	Virus	2014	Virus	2013	Virus	2012	Virus	2011	Virus
Acton	-		-	-	1	WNV	1	EEE	2	WNV
Bedford	1	WNV	-	-	-	-	2	WNV	-	-
Bolton	-	-	-	-	-	-	-	-	-	-
Boxborough	-	-	-	-	1	WNV	1	WNV		
Carlisle	-	-	-	-	-	-	-	-	-	-
Concord	-	-	-	-	1	WNV	-	-	-	-
Hudson	-	-	-	-	-	-	2	WNV	1	WNV
Lexington	2	WNV	-	-	2	WNV	1	WNV	-	-
Lincoln	-	-	-	-	1	WNV	-	-	-	-
Littleton	-	-	-	-	-	-	-	-	-	-
Maynard	-	-	-	-	1	WNV	-	-	-	-
Stow	-	-	-	-	1	WNV	1	WNV	-	-
Sudbury	-	-	-	-	-	-	1	EEE	1	EEE

Source: MPDH Summary of Arbovirus Surveillance in Massachusetts

The vector-borne disease discussed above represent the diseases most relevant or of concern in Massachusetts and the MAGIC region. They do not, however, characterize all such diseases that might pose risk going into the future, such as the Zika Virus (mosquito-borne disease) and Powassan Virus (tick-borne disease).

[111] Arbovirus Surveillance in Massachusetts, 2015

Mental Health

There is a social and mental sensitivity to climate change effects. Extreme weather events have the potential to increase stress among residents and serve as a trigger for those with existing mental health conditions. Longer term events like heat waves and droughts also have the potential to exacerbate existing health conditions be affecting people's physiology and reduce the time people may need to recover from a traumatic event. The U.S. Global Change Research Program (USGCRP) Climate and Health Assessment highlights mental health impacts as a key finding and suggests that these impacts can also have consequences for social networks.[112]

The rate in MAGIC for those requiring hospitalization for mental health issues is lower than that of the state. The east quadrant – including the towns of Concord, Bedford, Lexington, and Lincoln – has the lowest rate, while the south quadrant (Maynard and Sudbury) have the highest rate in the region.

Table 31: Mental Health Hospitalizations

Mental Health Hospitalizations 2008-2012	Age Adjusted Rate per 100,000 (95% CI)
North Quadrant	714.96 (672.33, 757.58)
East Quadrant	561.34 (532.08, 590.61)
South Quadrant	717.84 (665.12, 770.56)
West Quadrant	644.13 (601.42, 686.85)
MAGIC Region	635.95 (616.54, 655.36)
Massachusetts	837.85 (834.74, 840.95)

Source: MDPH, MassCHIP

Adaptive Capacity

Health Status and Determinants

The MAGIC region demonstrates capacities across multiple dimensions to adapt to potential health impacts of climate change. The population of the region has healthier behaviors, like higher rates of physical activity and healthy eating, and experiences healthier outcomes when compared the state. There are some exceptions, but on the whole the region has a health profile that reflects fewer immediate health issues and a state of health that has the capacity to adapt to conditions in the short-term.

The population of the region reports higher average incomes than the rest of the state. Residents tend to be more highly educated and have more access to personal vehicles when compared to the state. These demographics characterize a population that is less likely to experience conditions that lead to health disparities. They have resources to purchase or access technologies

[112] Impacts of Climate Change on Human Health

that allow them to adapt. This includes the ability to have air conditioning and heating and emergency or back up power sources. It also allow them to make changes to their homes in order to reduce or mitigate impacts from extreme weather events and heat.

Social Capital

The MAGIC region show signs of having high social capital, which characterizes the strength and reliability of connections among people living in a particular area. Through feedback from the Working Group, the consensus was that towns in the region have a history of working together to solve shared issues as is demonstrated with the climate change planning project. They also noted a shared identity that commonly values the role of agriculture in the area and that they have an active network of non-profit organizations in the area, many of which address open space and conservation.

Local Public Health Infrastructure

The region has existing public health infrastructure that can address short term and long term health impacts. Each town has a Local Public Health Department, with a Health Director, Health Agent, or Public Health Nurse, and elected Board of Health. The towns in MAGIC were part of the emergency preparedness region (Region 4) that had the second highest response rate to a recent Massachusetts Department of Public Health (MDPH) survey regarding the capacity of local health departments to respond to the public health impacts of climate change.[113] Nearly half of the respondents from this region indicated that they were prioritizing preparations for climate change-related public health problems.

All but one of the health departments in MAGIC are part of the Massachusetts Public Health Emergency Preparedness Region 4A (the town of Bolton is part of Region 2). As part of a region, the towns work together and with other municipalities to meet the Public Health Emergency Preparedness goals set forth by the Centers for Disease Control and Prevention and the Massachusetts Department.[114] Region 4A has an active Medical Reserve Corps (MRC), which is comprised of volunteers who assist in responding to public health emergencies and other disasters. The MRC also helps with broader public health initiatives to improve well-being among residents.

Mosquito Control

Nearly all of the towns in the region are part of regional mosquito control programs. The programs assist the state and their member municipalities with larval and adult mosquito surveillance, deployment of tactics to control mosquitoes (e.g., larviciding), and public education, among other services. Acton, Boxborough, Hudson, Littleton, and Stow belong the Central Massachusetts Mosquito Control Project and Bedford, Concord, Lexington, Lincoln, Maynard, and

[113] MA DPH Bureau of Environmental Health, "Capacity to Address the Health Impacts of Climate Change in Massachusetts Findings from a Statewide Survey of Local Health Departments," (2014) http://www.mass.gov/eohhs/docs/dph/environmental/exposure/climate-change-report-2014.pdf

[114] Massachusetts Public Health Emergency Preparedness Region 4A, "About region 4A and the mission," accessed on August 19, 2016, http://www.region4a-ma.org/About

Sudbury are part of the East Middlesex Mosquito Control Project. Bolton and Carlisle were not identified as part of mosquito control district.

Each of the MAGIC towns address the need for sheltering in the case of emergencies. These plans are detailed in their Comprehensive Emergency Management Plans and with local emergency planning committees. Whereas sheltering is a formal activity that can last days, warming and cooling centers address short-terms during the days when there is extreme weather but no emergency event. The towns of Concord and Sudbury were identified as having offered cooling centers during summer months, and Stow was identified as having a warming center.

A couple of the towns were identified as providing outreach programs for vulnerable populations in the event of an emergency such as prolonged periods of heat or cold as might be expected with climate change. It was identified that Carlisle and Sudbury offered emergency call lists. In Carlisle, residents can enroll in the town's Emergency Notification System and those with special needs can register with the Fire Department so that they can be alerted directly. Sudbury maintains an emergency call list that residents can sign on to and receive contact during emergencies.

Mass in Motion

The Town of Hudson is part of MetroWest Moves (MWM), which the only Mass in Motion (MiM) coalition location in the MAGIC region. MWM addresses chronic disease prevention by working to support environments where residents have access to healthy, affordable food, places to be physically active, and tobacco-free environments.[115] While not directly addressing climate change, the coalition is working to create conditions where residents suffer less health issues and have better overall physical, social, and mental health behaviors.

Healthcare System

There are two hospitals in the MAGIC region: Emerson Hospital in Concord and the Edith Nourse Rogers Veterans Hospital in Bedford. Emerson hospital is a 179-bed facility that offers access to over 300 primary care doctors and specialists.[1] The hospital includes an emergency room and ambulatory services. The Veterans Hospital offers in-patient and out-patient care to veterans and their families in greater Boston. In addition to these hospitals, the following three hospitals with emergency department that are located in near the region:

- Marlborough Hospital (south of Hudson)
- Nashoba Valley Medical Center (north of Littleton)
- Lahey Medical Clinic (east of Lexington and Bedford)

[115] MetroWest Moves, "About the Initiative," accessed on August 19, 2016, http://metrowestmoves.org/about-the-initiative/

Outdoor Workers

Assessment Summary

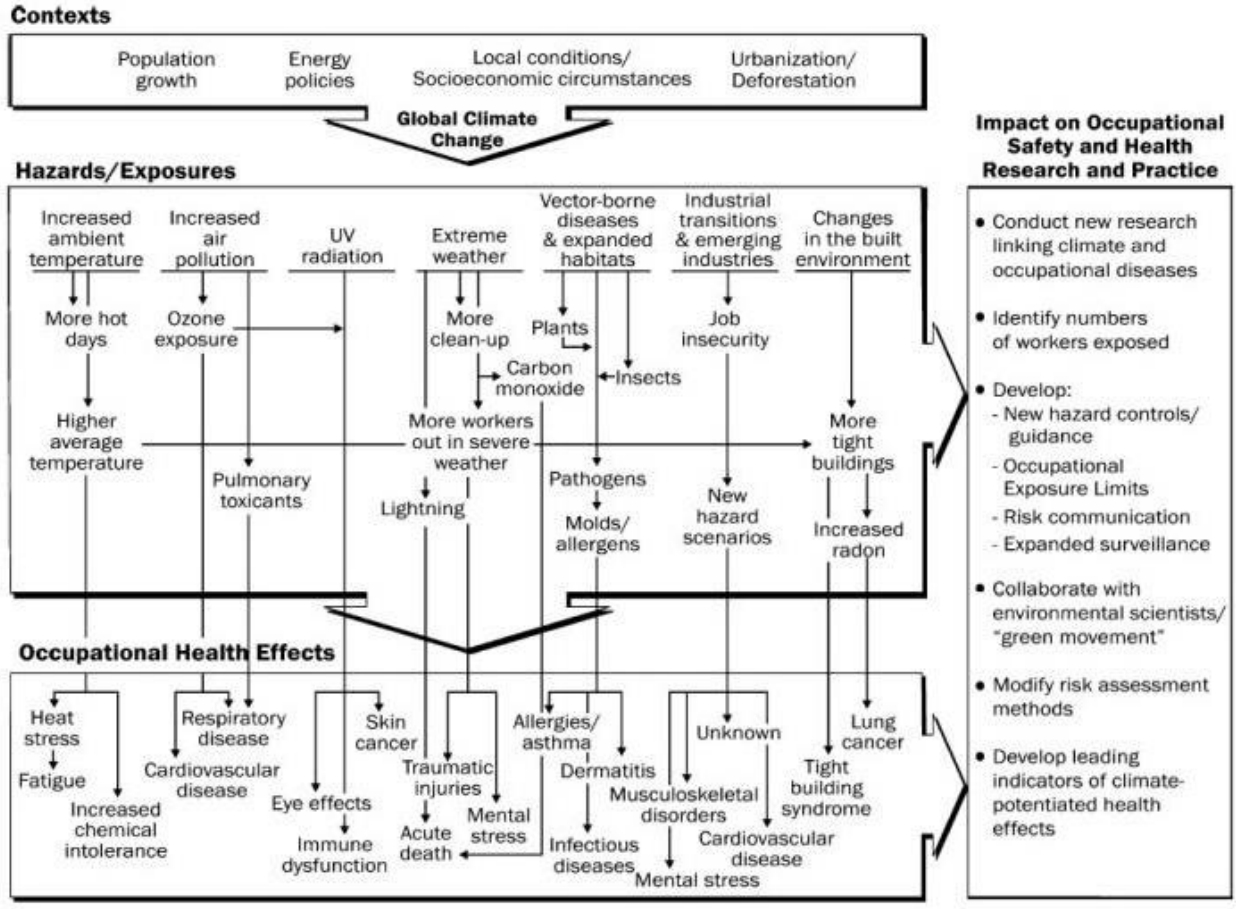
- The Outdoor Work population in the MAGIC region has been assessed as highly vulnerable.
- Vulnerabilities are related to exposure and sensitivity of outdoor workers to increased heat and heat related illnesses, to ticks, mosquitoes and other vectors carrying diseases, and to disruptions in work which may affect a lower income workforce that typically has limited benefit package.
- Adaptive capacities in the region come from high reported social capital and collective interest in proactive climate adaptation and the region's potential for increased participation in ate and federal programs, trainings, and publications to support workplace health and safety

Outdoor Workers Vulnerability Assessment

Sensitivity

Employees that engage in outdoor work are exposed to occupational and environmental hazards that are anticipated to worsen as climate changes intensify. High temperatures are already responsible for the most weather related deaths, and as heat waves become more frequent, related health conditions, hospitalizations, and deaths are anticipated to increase.[116] Vector-borne diseases are expected to spread as climates become more habitable for carrier insects. UV radiation, ozone exposure, and air pollution may lead increasingly to chronic health effects, including respiratory diseases, allergies, and skin cancer.[117] Due to the nature of their work, employees may be limited in what they are able to do to protect themselves from these climate-related risks. Employees in outdoor industries like agriculture may face compounding issues, as these positions are typically low-wage, seasonal jobs. If health issues arise for these workers, it may be particularly difficult to miss work to recover, or to cover medical expenses.

Figure 31. Conceptual framework of the relationship between climate change and occupational safety and health



Source: NIOSH

[116] Centers for Disease Control, "Climate Change and Extreme Heat Events,": Report, nd.
[117] IPCC, "Human Health: impacts, adaptation, and co-benefits," in *Climate Change 2014: Impacts Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects*, (Cambridge: Cambridge University Press, 2014) https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap11_FINAL.pdf

In MAGIC, over four percent of the workforce is employed in industries engaged primarily or in part in work outdoors, including construction, agriculture, landscaping and outdoor recreation. Construction makes up the largest proportion of outdoor workers in the region, roughly 3,500. There are just over 450 agricultural workers in the region that are engaged mostly in crop production. Available data is not detailed enough to isolate the number of landscaping, outdoor recreational workforce, or public sector workforce engaged in outdoor work.

Adaptive Capacity

Outdoor workplace hazards, like heat stress and vector-borne diseases, are only anticipated to increase with climate change, putting at greater risk the over four percent of employees in MAGIC that work outdoor. Characterized as a region with high social capital and significant investment in proactively addressing climate change issues, MAGIC likely has the capacity to institute measures to protect outdoor worker health; at this point, however, evidence available suggests little is being done to actively address outdoor worker health. As such the region has a low adaptive capacity to address outdoor worker health issues related to climate change.

On the state level, the Massachusetts Department of Public Health (MDPH) has started work to characterize climate health risks and related board of health activities. In their report, *Capacity to Address the Health Impacts of Climate Change in Massachusetts*, MDPH found through a survey of boards of health that between one third and one half had never fielded questions about climate-related health issues, including respiratory illness, outdoor air quality, or heat waves.

State and federal programs and educational resources are available to private and public sector employers that aim to increase workplace safety and decrease exposure to hazards.[118] Participation in these programs would suggest that MAGIC employers are better prepared to mitigate climate-related workplace health risks and increase the adaptive capacity of outdoor industries. Information on private sector participation in these programs is confidential, and as such it is not possible to assess the adaptive capacity of this sector. Data on programs for public sector employers shows that ten of the thirteen towns regionally are not participating in the MDOL Workplace Safety and Health Program.

Taking into consideration what we know of the regional will to address climate change issues, alongside evidence that shows limited participation in workforce safety and health programming, the adaptive capacity of the region is mid-level.

[118] Details on the state and federal programs and educational material can be found in the adaptation strategies portion of this report.

Agriculture

Assessment Summary

- The agricultural sector in the MAGIC region has been assessed as moderately vulnerable.
- Vulnerabilities are related to exposure and sensitivity of agricultural production and livestock management to changes in water availability and increasing temperature, to pest and disease pressure, and to disruption from new climate change driven weather patterns.
- Adaptive capacities in the region come from measures in place that ensure existing farmland is protected and a diversification of the region's farm operations which is and can be leveraged to meet changing climate conditions.

Agriculture Vulnerability Assessment

Sensitivity[119]

Heat and Precipitation

Increasing temperatures and variable precipitation have the potential to significantly alter the conditions under which agriculture will happen. Warmer spring and autumn weather may enable a longer growing season and greater crop production, but heat and precipitation patterns will also introduce concurrent threats.

The success of many biological interactions – plant emergence, pollination, blooming - depends on the synchronous response of diverse organisms to seasonal change.[120] Warmer weather has been shown to lead to early blooming and flowering in some species; and the pollinator insects for those plant species may or may not emerge in time to pollinate them.[121] Increased temperature is likely to disrupt the timing of significant biological events[122] in the life cycle of plants and animals negatively impacting ecological systems, and in agriculture, this may compromise crop production.

Plant and insect species migration and population growth, and new diseases will compromise crop productivity. Invasive plants outcompete and displace native vegetation, and as the climate of the Northeast becomes more humid and warm, new invasive species are likely to impact the regional ecology. Kudzu and privet, both invasive species are expected to gain a foothold in the Northeast by 2100.[123] Rising temperatures will also increase the disease and pest populations already in Massachusetts, and will lead to a greater diversity of disease and pests as conditions become more habitable. Milder winters will exacerbate these trends, and warmer temperatures will do less to interrupt pest life cycles. Stewart's wilt is a bacterial disease that can devastate sweet corn crops; cold winters can keep the disease in check, but the projections for generally warmer winters suggest there will be more outbreaks of Stewart's wilt in the future. [124]

Increasing precipitation creates favorable conditions for new insects and diseases. The spotted wing drosophila, a harmful insect became pervasive in Massachusetts and the Northeast generally only after Hurricane Irene in 2011. Sooty blotch, a fungal disease that affects apples has also become more prevalent in Massachusetts in recent years. Conventionally described as a summer disease common only in southern states, Massachusetts' warmer, more humid weather is now creating conditions favorable for this disease's proliferation.[125]

High temperatures can cause heat stress in livestock. For any type of livestock, this can directly and negatively impact health, performance, and fertility, and limit the production of meat, milk, or

[119] The need for more research and engagement with farmers is fully recognized and encouraged in order to investigate the specific vulnerability of the agricultural sector in MAGIC.
[120] Lengnick, L (2015). Resilient Agriculture. New Society Publishers
[121] Hegland, et. al. "*How does climate warming affect plant-pollinator interactions"?* Ecology Letters (2009). 12: 184-195. doi: 10.1111/j.1461-0248.2008.01269.x
[122] "Phenology" is the study of the timing of biological events.
[123] Bethany Bradley, David Wilcove, and Michael Oppenheimer, "Climate change increases risk of plant invasion in the Eastern United States," *Biological Invasions*, 12 (2010): 1855.
[124] Tufts, pest management paper, see food system plan folder
[125] Tufts, pest management paper, see food system plan folder

eggs.[126] A 2013 USDA Economic Research Service report estimated that as a result of climate-induced heat stress, dairy operations will suffer productivity losses between 0.6 and 1.35 percent. While in Massachusetts and the MAGIC region, dairy operations make up a small portion of farms, these estimates suggest the implications of increasing temperatures on the productivity of livestock operations generally.

Drought

Drought conditions threaten crop germination, maturation, and general success rates. Dry conditions require farm operations to irrigate more heavily, but even so, drought years can lead to lower yields or crop failure. 2016 saw the driest year in Massachusetts in more than a decade. By mid-August the entire state was under at least a drought advisor; and MAGIC towns were under a drought warning.[127] At the time, the region had received less than seven inches of rainfall, significantly less than the weekly one to two inches of water most crops require in mid-summer.[128] These conditions have prompted the state Department of Agriculture to evaluate the degree to which farmers have experienced crop loss, and whether the state would qualify for a federal disaster declaration, and the assistance and loans made available through it.[129] Climate forecasts anticipate significant changes in precipitation patterns that will bring more intense snow and rainstorms, as well as more and longer periods of no precipitation; the impacts of the 2016 Massachusetts drought on agricultural crops demonstrate the challenges farms might face as drought conditions recur more frequently.

Adaptive Capacity

Pests, diseases, and drought have always impacted agricultural production, and such issues are only anticipated to become more challenging with climate changes. Drought conditions in the 2016 growing season in MAGIC and the impacts on crops exemplify the regional challenges. MAGIC values its agricultural heritage, and from the evidence available about the range of measures it has in place suggests agriculture has a high adaptive capacity.

Farmland Protection

Farmland protection is essential to ensuring resiliency in agriculture, and MAGIC towns are active in a range of preservation efforts. Nearly 8,000 acres in the region are currently being cultivated, and thousands more acres are could be considered for agricultural uses. More than 600 acres are in permanent protection through an Agricultural Preservation Restrictions (APR) or Conservation Restrictions (CR).[130] Ten MAGIC towns have adopted the Community Preservation

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[126] USDA, *Climate Change and Agriculture in the United States: Effects and Adaptation*, (Agricultural Research Service, 2013)

[127] The drought intensity scale from least to most severe is as follows: Normal, Advisory, Watch, Warning, Emergency. EOEEA, "Drought Warning, Watch, Advisory Issued for Portions of Commonwealth," accessed on August 19, 2016, http://www.mass.gov/eea/pr-2016/drought-warning-watch-advisory-issued.html

[128] Northeast Regional Climate Center, "About State and Regional Maps," accessed on August 19, 2016, http://www.nrcc.cornell.edu/regional/monthly/monthly.html
UMass Amherst, "2016 Drought Information and Resources," last modified July 15, 2016, https://ag.umass.edu/news/2016-drought-information-resources

[129] NRCC, "Northeast Drought Update," accessed on August 19, 2016, http://www.nrcc.cornell.edu/regional/drought/drought.html

[130] MassGIS Open Space GIS Data, last modified March 3, 2016.

Act, which allows them to prioritize preserving open space for agriculture and recreation when there are opportunities to do so. [131]

Local farmland preservation efforts are supported through state policies and programs and local entities. State policies in place in Massachusetts help prevent the loss of farmland and increasing its permanent protection. These include Executive Order 193, which prevents state and federal funds administered by the state from being used to encourage agricultural land conversion, when there are alternatives; the Agricultural Preservation Restriction Program (APR); the Community Preservation Act (CPA) incentive program for protecting farmland; among others.[132] Eight municipalities convene agricultural commissions, that advocate for farmers and farmland preservation and help shape municipal agricultural policy.[133] The Concord Food Collaborative serves to educate and advocate for food systems and farming in Concord and surrounding towns.[134]

Farm Operation Diversification

The diversification of MAGIC's farm operations lends to their resiliency. The region's farms engage in a range of farming activities, including cultivating hay, vegetables, and nursery production, and raising livestock.[135] Where farm operations cultivate several types of crops, they are better positioned to recover from damage or loss to some crops caused by plant disease or pest infestations.

Several of MAGIC's farms operate multiple enterprises including farm stands or agricultural tourism and recreational enterprises, including pick-your-own activities, seasonal events for the public, or recreational and hiking.[136] Where farms have multiple enterprises and income streams it reduces their financial risks related to the unpredictable nature of farming. Further, where farm enterprises are not seasonally dependent, they can be a source of year-round income.

Farms may adopt other practices to increase resiliency - including cultivating crops or raising livestock that are anticipated to be more adaptive to changing conditions, and water management and conservation practices. However, data on these practices in MAGIC were not identified for this report.

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[131] Towns with and Open Space CPA area Acton, Carlisle, Concord, Hudson, Lexington, Littleton, Maynard, Stow, and Sudbury.

[132] American Farmland Trust, Conservation Law Foundation, Northeast Sustainable Agriculture Working Group, "New England Food Policy: Building a Sustainable Food System," 2014, http://www.clf.org/wp-content/uploads/2016/03/1.New_England_Food_Policy_FULL.pdf

[133] Agricultural Commissions with Right to Farm Bylaws are in place in Bolton, Boxborough, Carlisle, Concord, Lincoln, Littleton, Stow, and Sudbury. Massachusetts Association of Agricultural Commissions, "About AgComs: MA AgComs," accessed on August 19, 2016, http://www.massagcom.org/AgComs.php

[134] Concord Food Collaborative, "About," accessed on August 19, 2016, http://concordfood.ning.com/page/about-collaborative

[135] USDA, *2007 Census of Agriculture, Congressional District Profile, "Massachusetts 5th District"* http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Congressional_District_Profiles/cd2505.pdf.

[136] Mass Department of Agricultural Resources, The MassGrown Map

Local Economy: Health Care

Assessment Summary

- The health care sector in the region has been assessed as moderately vulnerable.
- Vulnerabilities are related to exposure and sensitivity of the sector to experience increases in demands for emergency and outpatient services, disruptions in service from extreme weather events, and lack of evidence regarding planning for climate change risks.
- Adaptive capacities in the region come from participation in a Health and Medical Coordinating Coalition which ensures integrated planning and capacity-building across five core disciplines: acute care hospitals, community health centers and large ambulatory care organizations, emergency medical services, local public health, and long term care.

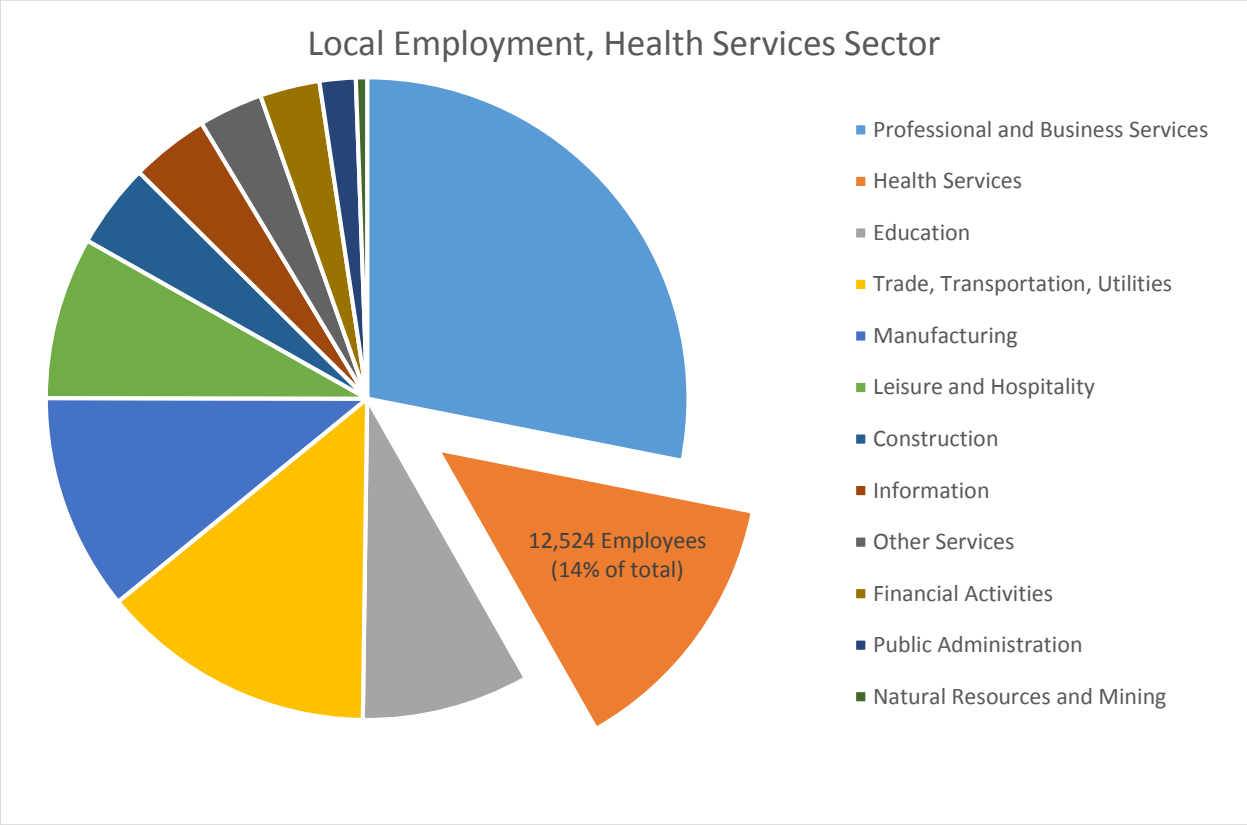
Local Economy: Health Care Vulnerability Assessment

Sensitivity[137]

Health Care and the Local Economy

Hospital and community health care facilities are significant to MAGIC's local economy. In total, the health care services sector employs over 12,000 individuals, representing nearly 14 percent of local jobs. The sector is comprised of a few large health care facilities, the Edith Nourse Rogers Memorial Veterans Hospital in Bedford and Emerson Hospital in Concord, and range of smaller family, elder, and specialty health care centers and providers. Where MAGIC's proximity to Boston makes available to residents a wide variety of specialized health care facilities, the local health care facilities in MAGIC offer convenient access to important services for area residents.

Figure 32. Health care services sector employment as part of MAGIC economy



Source: Bureau of Labor Statistics, Employment and Wages Report (ES-202)

[137] Note on limitations: The project did not investigate the vulnerability of the health care services sector in MAGIC, and further research and engagement with health care facilities would be required in order to do so. As such, the following section assesses generally the sensitivity, adaptive capacity and overall vulnerability of the health care services sector to anticipated climate change impacts. Based on general information available, the health care services sector is likely to be moderately sensitive to climate changes.

Health Care Facilities and Infrastructure

Severe storms and other extreme weather events may negatively impact the infrastructure and operations of health care facilities. On hot days, blackouts can happen from the greater demand placed on the electrical grid to run cooling and air conditioning systems. Hospitals typically have redundant energy systems, but many do not have their cooling systems on their emergency power generation systems. Typically, nursing homes and assisted living facilities are not equipped with emergency cooling systems during power outages. Older health care facilities may have been built without consideration of flood plains. While flood plain maps help guide where critical facilities like hospitals should be sited, older facilities may be built in areas more likely to flood. Further, anticipated increases in precipitation are not represented in the FEMA flood plain maps, and as such may not depict health care facilities as being in flood prone areas. Whether flooding presents risks to physical infrastructure or not, flooding in the surrounding areas can impede patient and health care staff access to facilities. While droughts have not caused significant disruptions to health care services to date, large health care providers, and hospitals in particular may put significant strain on local water systems. Hospitals are typically among the top 10 consumers of potable water.[138]

Healthcare System Capacities

As detailed in the Health and Welfare section, increasing temperatures, variable precipitation patterns, and more extreme weather are anticipated to cause direct and negative impacts to human health and potentially disrupt that people rely on to access the resources and services need daily and in the case of emergencies. Health care needs are anticipated to increase, including heat-related illnesses, vector borne and water-borne diseases and exacerbated mental health concerns, although the scale of the increase is not known at this time. In cases of gradual or sharp increased demand for health care services, health care systems will need to increase their capacity and delivery of health care services. As MAGIC's older population grows, health care systems will need to plan to meet the needs of this population, and other populations that have significant health care needs or are susceptible to health risks.

Further, in disastrous climate events, where the demand for health care services exceeds capacity in affected areas, MAGIC may need to be ready to provide services to those affected.

- Neither hospital is located in a flood plain. Although, Emerson is in the vicinity of the 500-year floodplain of the Sudbury River
- Emerson is located in an area that could have higher surface temperatures and may experience localized heat island effects. VA hospital also located in place that may experience higher surface temperatures than surrounding locations.

[138] United States Department of Health and Human Services, *Primary Protection: Enhancing Health Care Resilience for a Changing Climate,* by Robin Guenther and John Balbus, (2014), https://toolkit.climate.gov/sites/default/files/SCRHCFI%20Best%20Practices%20Report%20final2%202014%20Web.pdf

Adaptive Capacity

While this project did not investigate how MAGIC hospitals and health care facilities are preparing for climate change resiliency, towns have some measures in place that increase the adaptive capacity of the sector. In a recent survey of local boards of health found that in the region that includes MAGIC towns, nearly half of local boards of health are prioritizing public health problems related to climate change, and likewise, nearly one third of respondents were confident in the staff expertise to assess the impacts of climate change on public health.[139] This is a higher level of planning activity and confidence in staff expertise than in other regions in Massachusetts.

In MAGIC towns, preventative programs including mosquito control programs and chronic disease prevention programs, like Hudson's Mass in Motion program reduce the occurrence of disease and negative health outcomes, and as such alleviate the burden on local health care systems. MAGIC towns also coordinate emergency and public health response efforts through participation in the Massachusetts Public Health Emergency Preparedness programs and coordination of volunteer Medical Reserve Corps; these efforts similarly reduce the burden on local health care systems and increase the capacity to address local medical and health care needs in emergency situations.

Such complementary municipal programs increase the adaptive capacity of the health care services sector in MAGIC, by reducing the need for these services and distributing the responsibility to meet health care needs. The degree to which this alleviates the burden on the local health care services sector, however, is not clear and was not evaluated as part of this project.

Though there is no evidence of such an assessment for MAGIC's Emerson and Veterans Hospitals, the resiliency of healthcare facilities and operations can be facilitated by conducting a Climate Risk Assessment that determines an emergency plan in the event of extreme weather risks.

Health and Medical Coordinating Coalitions

Health and Medical Coordinating Coalition (HMCC)[140] are being developed in Massachusetts to promote cross-disciplinary planning and support public health and medical response. They will replace emergency preparedness regions (e.g., Region 4A that covered most of the MAGIC region). The HMCC's will continue to build emergency preparedness capacity among key partners, including those from acute care hospitals, ambulatory care organizations, and emergency medical services, so that a network approach can be used to deal with emergencies and disasters.

The towns in MAGIC fall mostly within HMCC 4AB (Bolton is in Region 2) following their previous inclusion in the emergency preparedness regions. The HMCC is a functional linkage between municipalities and health care organizations. Having the linkage in place increases the adaptive

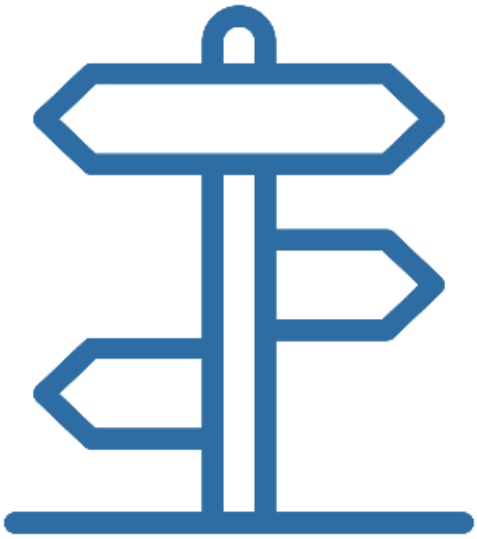
[139] Capacity to Address the Health Impacts of Climate Change in MA http://www.mass.gov/eohhs/docs/dph/environmental/exposure/climate-change-report-2014.pdf
[140] http://www.mass.gov/eohhs/gov/departments/dph/programs/emergency-prep/health-medical-coord-coalitions.html

capacity of this sector as response and recovery functions are already being defined and made operational.

Local Economy: Tourism

Assessment Summary

- The tourism sector in the region has been assessed as moderately vulnerable.
- Vulnerabilities are related to exposure and sensitivity of the sector weather and ecological changes that make the tourism industry more susceptible to seasonal changes and disruptions, challenges for local businesses that are dependent on natural resources.
- Adaptive capacities in the region come from the sector's ability to diversify and shift activities and of history of local and regional efforts to preserve ecological resources and support local economic development that highlights natural and historical assets.



Local Economy: Tourism Vulnerability Assessment

Sensitivity

The rural character, charming New England towns, nationally important historical sites, agricultural tourism, museums and outdoor recreation draw visitors to MAGIC towns. Several towns' chambers of commerce advertise the museums, trails, farms, parks, and historical grounds in the area that tourists and residents can visit.

MAGIC's tourism industry is comprised in large part of businesses involved in arts, entertainment, recreation, accommodation, and food services activities. In MAGIC, nearly 7,500, or eight percent of local employees work in tourism-related businesses. Some of the major employers include membership clubs and major hotels and resorts (e.g., DoubleTree and Starwood Hotels, The International Golf Club), but the sector is made up in great majority by smaller enterprises, including smaller restaurants and inns, and various sports, arts, and cultural organizations and clubs.

Ecological changes resulting from increased temperatures and more intense precipitation and drought patterns, are likely to interfere with the recreation-based tourism and tourism-support sectors of the economy. In the near term, high heat days can make outdoor activities untenable, and in the longer term it may have the effect of decreasing mid-summer tourism.[141]

Rising temperatures are prompting plant and animal species to shift, and where tourists are often drawn to MAGIC for its natural assets, such changes will impact the attractiveness of the Region to tourists. For instance, New England's "leaf-peeping" season and maple syrup industry are currently threatened by warming temperatures, which is an important factor for the region. The mix of deciduous trees that produce the vivid colors (maple and beech trees, primarily) that draw tourists to the countryside each fall will likely be displaced by the oak-hickory community of the Mid-Atlantic States.[142] Sugar maples are the crux of the maple syrup and sugar industry that portions of MAGIC are also known for.[143] Similarly, fruit-bearing trees (e.g. apple, pear) cultivated by farms in the region draw MAGIC residents and those living in surrounding cities and towns for fruit picking and other agri-tourism activities. Climate change is expected to shift the timing of agricultural production and potentially reduce availability, which in turn could affect both what is available for sale and how many tourists are drawn to the region.[144]

Climate change might also disrupt water recreation, where flooding or drought alters water body levels, or where increased heat triggers harmful algal growth. Where water resources are limited as an effect of more intense and sporadic precipitation and drought, and demands for water resources increase as regional populations grow, the tourism sector may be constricted in its water

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[141] University of Cambridge, *Climate Change: Implications for Tourism*, (2014), https://europeanclimate.org/wp-content/uploads/2014/06/Tourism_Briefing_Web_EN.pdf/

[142] United States Department of Agriculture, *Changing Climate, Changing Forests: the Impacts of Climate Change on Forests of the Northeastern United States and Eastern Canada*, by Rustad et al, (U.S. Forest Service, 2011) http://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs99.pdf, 18.

[143] United States Department of Agriculture, Future Forests of the Northern United States, Stephen Shifley and Keith Moser, eds., (U.S. Forest Service, 2016), 235.

[144] Climate Central, "Climate Change Is Coming For Your Maple Syrup", accessed July 8, 2016, http://www.climatecentral.org/news/climate-change-maple-syrup-20178

use.[145] Further, precipitation changes and warmer winters may change the viability of winter sports, if winter snowfall lessens and the season shortens

The tourism sector in MAGIC is comprised of a range of types of businesses, but the region's expansive natural areas and outdoor recreation are integral features that attract visitors. Changes to natural systems have wide-ranging implications for several systems in MAGIC, and for the tourism sector, these changes could impact outdoor recreation, and related businesses, such as hotels and restaurants that benefit from the influx of visitors to the region. The factors are too complex to predict exactly how ecological changes will prompt innovation in the tourism industry, or influence tourists' decisions to visit the region, and studies that attempt to project tourist behavior or industry adaptation are inconclusive. Still, given the importance of its ecological assets in the region, MAGIC's tourism sector is likely to be impacted by climate changes that alter or threaten these assets, and the region's tourism sector is likely to be at least moderately sensitive to climate changes.

Adaptive Capacity

Available evidence suggests the region's tourism sector has a moderate to high capacity to adapt and innovate as climate changes impact the industry.

Diversity of Local Economy Landscape

The sector is comprised of many types of businesses, and they engage in a diversity of activities; where environmental changes impact certain activities, some businesses will likely have the capacity to be agile and expand those activities that are not as susceptible to environmental changes. Regional open space features are integral to tourism attractions, but few businesses rely on the natural landscape for the core business activities and services. The sector's restaurants, museums, historical sites, hotels, and bed and breakfasts first offer their primary services and goods – dining, art and cultural activities, accommodations. Fitness and recreation facilities – including sports clubs and leagues, and fitness facilities – that engage in more outdoor activities may experience greater climate change impacts.

Local Government and Non-Profit Organization Activities

There are significant regional efforts to protect the natural resources that draw visitors to the region. The region has made substantial commitments to protecting open lands, and monitoring threats to its forest and watershed ecosystems. Nearly one third of the land in MAGIC (39,650 acres) is in permanent protection by national, state, municipal entities, as well as the Sudbury Valley Trustees and private property owners. The Sudbury Valley Trustees coordinates the West Suburban Conservation Council that convenes 36 towns to collaborate on regional conservation and land stewardship efforts.[146] Eleven of MAGIC's towns have developed open space plans that guide protection and management of open spaces. Ten MAGIC towns have invasive plant and insect species monitoring programs, and most of these towns are part of the tri-watershed SuAsCo Cooperative Invasive Species Management Area (CISMA) program that covers monitoring of 377

[145] Climate Change: Implications for Tourism
[146] Sudbury Valley Trustees, "West Suburban Conservation Council," accessed on August 19, 2016, http://www.svtweb.org/about/collaborations/wscc

acres in 37 municipalities including and beyond the MAGIC region.[147] The watershed organization, OARS along with U.S. Geologic Survey monitor the streamflow of rivers and brooks in most towns. The range of efforts in place to evaluate the health of the regional ecosystem equips the region to proactively prevent, minimize, and address threats to its natural assets.

Economic Development Committees in most towns seek to encourage community and business development that align with the town character and residents' desire central business districts to be comprised of smaller, independent businesses.[148] Boxborough and Hudson have incorporated economic development goals into their master plans, and Littleton and Bolton have efforts underway to develop economic development plans. The economic development goals of towns prioritize residents' interests for primarily village-like developments that conform with or enhance the small community character. Where towns encourage business development that builds on their assets, they become more attractive for both residents and tourists.

Chambers of Commerce and Business Associations

MAGIC institutions and town governments support businesses and economic development contributing to the resiliency of the tourism sector. The Bedford, Concord, Lexington and Middlesex West chambers of commerce serve the region and have business membership from eight MAGIC towns.[149] Several chambers of commerce market and promote regional tourism, highlighting area attractions and promoting their membership businesses. The town of Concord and OARS produce recreational maps for biking, hiking, boating, and picnicking, making its protected lands accessible and navigable for residents and visitors.[150] Business organizations can be allies in addressing industry issues, and as climate changes impact tourism and other sectors they may be activated to encourage business dynamism. Further, promoting outdoor recreation can reinforce the appreciation of natural assets to residents and tourists, and this can be an avenue through which consumers are educated about ecological threats, and compelled to support preservation efforts.

[147] CISMA SuAsCo website
[148] Littleton and Bolton resident economic development surveys: TK links
[149] Towns served by chambers of commerce in MAGIC are Acton, *Bedford, Boxborough, Carlisle, Concord, Lexington, Littleton, and Stow.*
[150] Town of Concord, "Town of Concord Trails Map," accessed on August 19, 2016, http://www.concordma.gov/pages/ConcordMA_NaturalResources/2015%20Trail%20Map.pdf
OARS, "River Recreation Map for the Assabet & Sudbury," accessed on August 19, 2016, http://www.oars3rivers.org/river_map/map/1

Local Government

Assessment Summary

- Local governments are responsible for the welfare and resiliency of their communities. The preceding vulnerability assessments detail the way climate changes will impact different MAGIC systems, sectors, and populations. To support resiliency of these sectors local governments in MAGIC will need to take a lead in communicating climate risks and coordinating efforts between partners. With issues of climate change far greater than what municipalities are able to handle alone, preparation, response, and mitigation efforts will need to utilize state and federal assistance.
- Because climate change will impact all parts of municipalities, governments are as affected by climate change as the collective sectors of the community. The degree to which governments work well and coordinate on various levels to address local needs influences a town's capacity for adaptation. As such, the following section identifies the elements that contribute to local governments in MAGIC to address climate change impacts that increase the adaptive capacity of towns and the region.

Local Government Assessment

Local Government and Climate Change Planning in the MAGIC region

Support available from the state and the resources in place within MAGIC equip communities well to respond to the new demands for municipal response that will come with climate changes.

In the current national and statewide context there is general consensus by scientists and government that climate change is happening and that broad measures are required now to assure that its impacts are minimized or avoided. The recently release National Climate Assessment provides the most comprehensive summary of climate impacts in the United States.[151] Massachusetts completed its statewide climate adaptation plan in 2011.[152] Recently the state also developed the Massachusetts Wildlife Climate Action Tool[153], which assesses climate risks to Massachusetts natural resources, and the State's Department of Public Health completed an assessment of local boards' of health capacity to respond to public health needs that come with climate change[154].These efforts frame climate risks and make recommendation to communities to evaluate impacts and adaptation strategies on a local level.

Several municipalities in Massachusetts are developing or have also completed climate adaptation plans[155] that lay out strategies for municipal action. In their creation, these plans are spurring development of a range of approaches to assessing municipal vulnerability and growing the body of regionally-specific climate impact data. MAGIC communities benefit from the preceding research and approaches to municipal climate adaptation planning. The region's collaborative efforts in climate change planning are also benefitting future efforts in Massachusetts.

Green Communities and Local Committees Addressing Climate Action

Within the region, a number of governmental, civic and organizational groups develop and implement strategies that address issues related to climate change. Twelve towns in the region are designated as Green Communities,[156] or are in the process of applying for this designation. With this designation, communities become eligible for state grants for energy reduction or efficiency efforts in municipal and school buildings, renewable energy initiatives, adopting latest building codes, among others.

MAGIC's Green Community towns also convene sustainability, clean energy and climate committees, most of which were formed to advance the towns' Green Community-related energy projects and goals, and some of which also focus on broader areas including sustainability, waste reduction, and climate change. The structure of these committees vary, and where most committees are appointed by the town and report to the board of selectmen on their recommendations, some are civic groups that do not have a formal advising role to the town. These groups provide a

[151] http://nca2014.globalchange.gov/
[152] http://nca2014.globalchange.gov/
[153] https://climateactiontool.org/
[154] http://www.mass.gov/eohhs/docs/dph/environmental/exposure/climate-change-report-2014.pdf
[155] Massachusetts municipalities that have completed or are in the process of developing climate adaptation plans include: Scituate, Duxbury, Cambridge, Quincy and others.
[156] http://www.mass.gov/eea/energy-utilities-clean-tech/green-communities/gc-grant-program/

forum for defining local issues, and in many cases groups inform policy and programs on the town level. For groups that focus predominantly on energy initiatives, integral to climate change mitigation, if groups expanded their focus, they could also serve as forums for advising on town climate adaptation initiatives.

MAGIC Regional Climate Change Working Group

A regional climate change working group was formed through the support of the MAGIC Sub regional Council, and it has representation from all towns in MAGIC – including conservation commission and public works staff; area conservation groups; state agencies – including the Departments of Energy Resources, Environmental Protection; and regional experts in climate change related fields. This group has been active in evaluating the anticipated climate change risks and developing the climate change plan. This group increases the capacity of MAGIC's towns to evaluate and coordinate across municipal boundaries and address common climate issues regionally. Notably, this group has strong energy and environmental representation, but lacks participation from public health, and business. Participation by public works representatives has also been minimal. These representatives should be included in future work of the climate change working group.

Emergency Response Capabilities

MAGIC towns' emergency response systems will become more important as extreme weather events are anticipated to become more frequent. All towns participate in emergency planning in several ways. The Massachusetts Emergency Management Agency (MEMA) coordinates a statewide emergency management program, and engages a range of partners, including municipal emergency management directors. Several MAGIC towns also maintain a hazard mitigation plan[157] that seeks to reduce loss of life, injuries, and property damage that result from natural disasters such as floods and storms. A handful of towns' plans have recently expired, and require updating. MAGIC towns also have emergency management departments or committees that coordinate with town officials; fire, police, and board of health departments; industries; and community organizations on emergency preparedness and response efforts.

Community Organizations

Community organizations contribute to the adaptive capacity of the region as well. OARS, a non-profit organization that works to preserve the ecology of the Assabet, Sudbury, and Concord Rivers and their tributaries is an advocate for local governmental action to encourage environmental adaptation and resiliency, and in particular with regard to stormwater management practices.[158] Sudbury Valley Trustees (SVT) is a regional land trust that conserves land surrounding the local watershed of the Assabet, Sudbury and Concord Rivers; the West Suburban Conservation Council, coordinated by the SVT includes climate adaptation in its priority issues as they relate to habitat preservation. Within ten MAGIC towns,[159] community members

[157] Carlisle, Concord, Hudson, Lexington, Lincoln, Littleton, Maynard, and Sudbury have current Hazard Mitigation Plans, or are in the process of updating them.
[158] http://www.oars3rivers.org/threats/climate%20change
[159] Acton, Bedford, Carlisle, Concord, Hudson, Lexington, Lincoln, Littleton, Maynard, Sudbury

coordinate groups that seek to build local capacity for slowing climate change and building community resiliency and adaptation efforts.

Potential Vulnerabilities Requiring Additional Research

The following systems, sectors, and populations were identified during the process, but due to the lack of specific data, timing, and resource limitations assessments were not initiated. These areas are identified here for future assessment and to identify qualitative and quantitative needs.

- Local Economy: Service Industries
- Cultural and Historical Resources

Moreover, a number of the preliminary assessment findings are cognizant of needing additional data and information in order to complete a full assessment. These systems, sectors, and populations, such as Energy Infrastructure and the Healthcare Sector, will benefit from additional quantitative and qualitative content to have a higher quality assessment finding.

MAGIC Climate Change Resilience Plan

Adaptation and Mitigation Strategies

ADAPTATION AND MITIGATION STRATEGIES

Introduction

The MAGIC region will face new risks in the coming decades due to climate change. As described in the previous section, the 13 towns of the MAGIC will experience weather events and related impacts more frequently and more intensely than they have in the past. Flooding will occur more frequently only to be matched by longer periods of drought. Entire years will be warmer on average than previous years and extreme and prolonged heat may be a regular occurrence in summer months.

Climate change mitigation and adaptation strategies serve as the response to these new conditions that will confront the region. Mitigation strategies will seek minimize or eliminate the impacts of climate change on the MAGIC region and larger geographies. Adaptation strategies recognize that certain aspects of climate change are already set given past GHG emissions and that the future level of emission are uncertain, and seeks to strengthen the region's ability to adjust to the new conditions.

The mitigation and adaptation strategies are informed by four assumptions and approaches: 1) MAGIC has existing strengths, 2) mitigation, adaptation and emergency preparedness are interconnected, 3) apply a 'no regrets' approach, and 4) apply an "adaptive management" approach. These are described in greater detail here:

MAGIC has Existing Strengths.

The MAGIC region has strengths that inform a shared agenda for climate action by individual towns and by the region. As identified by the project working group, these strengths include:

1. **The region is proactive**. This propensity to act is demonstrated by MAGIC Climate Change project and other projects where towns in the region have adopted local policy changes to address changing conditions such as transportation and agriculture.
2. **The region is committed to conservation**. This is evident in town participation in the state's Green Communities program, development of multiuse rail trails, and the protection of undeveloped open spaces and wetlands.
3. **The region values its agriculture**. Several farms operate in the region, and there are efforts to preserve farmland and keep it active. Agriculture is important to the local economy and heritage, and it informs a regional identity.
4. **The region has a dynamic network** of non-profits and institutions, including a community college, vocational and tech schools, and conservation groups.
5. **The region supports collaboration.** In discussing and acting on current and future regional matters, there is a culture and practice of collaboration between elected officials, municipal staff, residents, community groups, and private sector representatives.

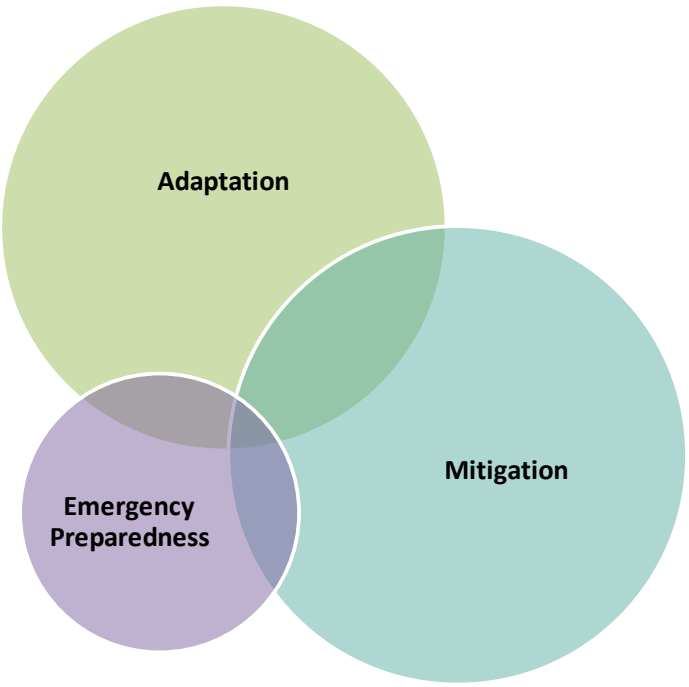
Maintaining these strengths as guideposts for action will be essential in an uncertain future. They will serve as reminders of existing adaptive capacities and provide direction regarding new capabilities that are needed to respond to a changing climate.

Mitigation, Adaptation, and Emergency Preparedness are Interconnected.

Responses to climate change include mitigation and adaptation strategies as well as support for emergency preparedness (Figure 33).[160] Of the three, emergency preparedness planning is generally in place already in each MAGIC municipality. However, emergency preparedness is a process that requires continuous updating and the strategies used are likely to change as a result of climate change.

These three elements are also interconnected, as action in one dimension can help address the causes or outcomes that another is also trying to tackle. For example, mitigation activities address the causes of climate change (e.g., GHG emissions), and in reducing the magnitude of impacts, efforts may, in turn, affect what adaptation actions are needed or the extent that of emergency preparedness and planning activities are necessary. An instance of this would be clean energy investments that reduce GHG emissions through solar. If done under certain circumstances, the solar could be connected to a microgrid[161] that would enable a set of homes of a neighborhoods to maintain electricity during outages and reduce the demand on emergency responders and utility companies.

Figure 33. Conceptual Representation of the Interconnections of Mitigation, Adaptation, and Emergency Preparedness



Each dimension – adaptation, mitigation, and emergency preparedness - provide valuable perspectives and tools that are needed to holistically address the causes of and potential impacts.

[160] Emergency preparedness typically encompasses four sets of actions: preparation, response, recovery, and mitigation.
[161] Department of Energy, "How Microgrids Work", https://energy.gov/articles/how-microgrids-work, accessed April 5, 2017

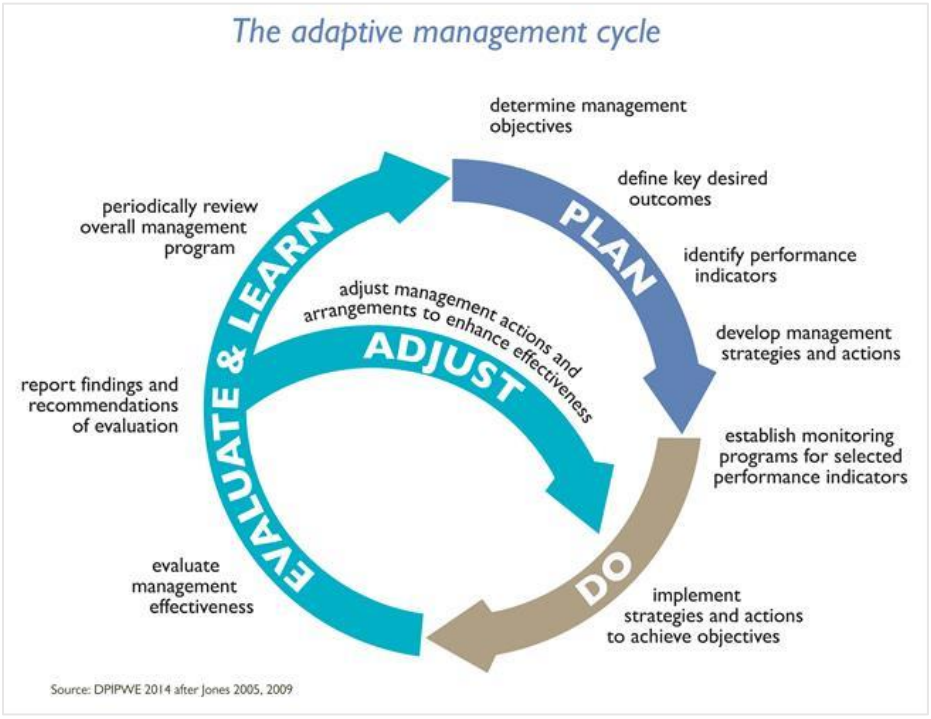
Use a "No Regrets" Approach

The strategies embrace a no regrets approach. They include action items that should be considered even in the absence of climate change and that are anticipated to generate economic, environmental, and social benefits. They include evidence-based and best practices for environmental protection, public health and safety, sustainable economic growth, and a reduction in disparities. An example is the use of green infrastructure and low impact development (LID) techniques that reduce stormwater runoff, provide additional green space, reduce cooling cost due to less impervious ground cover, and recharge water in the local ecosystem. This change would provide benefits to the region even if climate change was not occurring as it would expose more residents to green space, reduce demands on municipal stormwater drainage systems, and support the needs of local ecosystem.

Adopt an Adaptive Management Framework

The strategies embrace the concept of Adaptive Management. This concept is used to address issues that involve uncertainty. It relies on iterative processes that use continuous monitoring and assessment to understand what actions are working, which are not, and how these actions could potentially come into conflict with one another. It operates best when new information (e.g., projections, estimates, etc.) can be integrated quickly so that new approaches can be better evaluated and modified in order to maximize impact under changing climate conditions.

Figure 34. Adaptive Management Framework



Source: Parks and Wildlife Service, Tasmania

An adaptive management operating approach is likely to face many challenges in a municipal framework. The concept requires decision-making to be agile and capable of working quickly in the face of evolving information. Massachusetts town governments and residents frequently do not like, or cannot operate, in such a manner. Therefore, a general proposal is to identify how

adaptive management concepts can be tested and used to make enhancements in municipal decision-making in order to best address climate action.

PRIORITIES IDENTIFIED FOR THE MAGIC REGION

Residents and stakeholders in MAGIC provided their feedback on what action strategies should be part of the Climate Resiliency Plan[162]. The strategies that received 50 percent or more of the responses were:

- Increase the number of **clean energy** projects (e.g., wind and solar energy, low or no emission transportation options, etc.)
- Protect and restore **natural resources** that protect properties from climate impacts (e.g., wetlands, forested and open spaces).
- Use **green infrastructure** (e.g., natural landscapes and stormwater management) to retain and absorb flood waters.
- Expand access to **public transportation** options and schedules, as a means to encourage less car use and reduce greenhouse gases
- **Regulation and zoning reform** that takes climate impacts into account (e.g., increased setback areas to protect wetlands).
- **Agricultural preservation** to ensure regional food security and protect open spaces.
- **State action and funding** for climate resiliency planning and project implementation.

Working Group members were also asked to identify their top strategies and sectors to be addressed. They reviewed an initial list of strategies, many of which are listed in the following section, and asked to identify those they would prioritize. In order, the top 10 strategies are:

- Continue Transition to Renewable and Resilient Energy Systems
- Emergency Preparedness
- Maintain and Protect Critical Infrastructure
- Water Infrastructure
- Transportation Infrastructure
- Agricultural Land Conservation and Farm Resilience
- Use Low Impact Development Techniques
- Institute Water Conservation Practices
- Develop Climate Resilient and Restorative Building Practices
- Identify a Municipal Climate Lead

[162] See *Adaptation Strategies Survey Results* in Appendix.

Starting Points for the Region

The overlap in priority strategies across groups indicate support for a set of actions that sustain or introduce climate change-related strategies in the MAGIC region. Therefore, we recommend that MAGIC and the individual towns take the following actions to advance climate action in the region:

Recommended Action	Desired Outcome
E. Designate Municipal Climate Leads and Establish a MAGIC Climate Sub-Committee	A network of municipal stewards that lead local climate resiliency efforts and hold towns responsible in their decision-making as it relates to local and regional action to prepare for climate change. In addition, a formal body, recognized by MAGIC, that acts as peer exchange network and an advisory group for regional advocacy on state and federal legislation that affect climate change resiliency.
F. Engage in Regional Green and Clean Infrastructure Planning	A 13-town action plan for preservation and protection of natural resources, with a specific focus on open space and water resources and clean energy infrastructure. The plan would serve as a recommended investment plan for land protection and clean energy investments at the local level in service of regional climate change resiliency.
G. Prioritize Active Transportation Investments	Adoption of standard active transportation policy and performance targets for the region that produce reduction in GHG emissions and increase redundancy of existing personal motor vehicle infrastructure.
H. Build and Bolster Community-Level Climate Resiliency	Residents, regardless of income, background, or ability, have the capacity to meet their needs and assist neighbors prior, during, and after climate change-induced weather events. Although this work with begin through community organizations, its purpose would be to enhance informal neighbor-to-neighbor social connections that can be activated in the event of anticipated climate change impacts.

Layering on New Strategies

The information above reflects municipal, resident, and stakeholder perspectives on where action should begin in response to the changing climate. The strategies presented in the following include more detail about the identified strategies as well as other options related to identified vulnerabilities. The purpose of the additional options is to identify actions that should also receive consideration and that provide alternatives should municipalities need to pivot from one strategy to another in response to evolving climate conditions.

GUIDE TO THE MITIGATION AND ADAPTATION STRATEGIES

The mitigation and adaptation strategies are based on recommendations from the State's Adaptation Plan, MAPC's Regional Climate Change Adaptation Strategy (RCCAS) and input provided to date from the Working Group and local stakeholders. The strategies address vulnerabilities assessed to date and are grouped into the following seven categories:

- Prepare Local Government and Monitor the Local Economy
- Monitor and apply Local Predictions for Climate Changes
- Protect Natural Resources and Maximize Use of Ecosystem Services
- Increase Use of Clean Energy and Green Building Measures
- Enforce and Enhance Regulatory Measures Affecting the Built Environment
- Maintain and Protect Critical Infrastructure
- Safeguard Health and Human Resources

Each strategy includes a background and describes the purpose of the strategy; information on the strategy's regional relevance, and practical actions for implementing the strategies. As climate planning continues in the MAGIC region, process and output indicators will be added to assist with monitoring and tracking progress on the action items over time.

1 Prepare the Local Government and Monitor the Local Economy

1.1 Designate a Municipal Climate Lead

A single climate change preparedness "point person" can ensure that there is consistent management, monitoring, and oversight of a municipality's climate preparedness efforts. This climate lead can be an existing municipal staff member or if resources allow, a new position that employs a staff person who has expertise in climate change planning and implementation. Alternatively, a volunteer member on a municipal board or committee could take on this role due to their experience and capacity, especially in light on limited or no resources.

In addition to facilitating municipal climate change work, the Climate Lead would direct a communications program about climate change with residents, businesses, and property owner as the main audiences. The program's purpose would be to disseminate information about municipal climate resiliency work and new findings relative to local decision-making and empower communities within the town to take action.

Regional Applicability

The MAGIC Climate Change Working group reflects the willingness of towns to send representatives on their behalf to participate in climate change planning. Some of the working group members are municipal staff and others are volunteers who generously offer their time to participate. There is the opportunity for these individuals to transition to the role of a local climate lead or to influence their municipality to identify a lead who will advance the strategies.

Actions

- Review existing committees, such as municipal energy committees, as well as municipal staff to determine a potential Climate Lead responsible for coordinating climate resiliency efforts.
- Designate or appoint a municipal-level climate change coordinator that has a defined set of responsibilities. These could include:
- Update information related to climate predictions, projected impacts, vulnerabilities and progress on advance adaptation and mitigation strategies;
- Organize and set meetings across departments that will provide climate-related updates and serve to advance adaptation and mitigation strategies;
- Access to and relationship with the municipal leadership to be able to advise on implementation plans and budgeting resources for actions that increase local and regional resiliency;
- Ability to understand and communicate about climate adaptation and community vulnerabilities to a municipal and community audiences;
- Report periodically to the Select Board (suggested: every 6 months).
- Develop local or regional task forces or committees comprised of key municipal officials and local stakeholders to address climate preparedness.
- Use existing resources that provide guidance on how municipalities can work within existing programs when planning for climate change (e.g., *Preparing for Climate Change: A Guidebook for Local, Regional, and State Government*, developed by King County, Washington).
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1.2 Fund municipal climate resiliency efforts

One of the biggest challenges that towns in the region will face is the availability of resources to advance adaptation and mitigation strategies, especially those requiring new operating or capital expenditures. Municipalities should explore how to incorporate changes as part of ongoing activities like roadway reconstruction project and identify innovative ways to finance approaches that reduce the risks from climate change.

An example of innovative funding approach is to have a distinct budget for climate change adaption and mitigation channeled through a third party agency. Another approach would be to target CPA dollars towards open space and affordable housing projects that offer climate change adaptation co-benefits (e.g., green infrastructure in the form of parks, energy efficient housing units, etc.)

Another source is 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[163] to promote comprehensive climate change preparedness initiatives across the Commonwealth. This grant will be administered by the Department of Energy Resources (DOER).

Regional Applicability

At a minimum, the towns and residents in MAGIC are making an investment in climate change planning through in-kind and volunteer time. Likely they are also making such investments in the municipal actions that serve to as adaptive capacities such as open space planning and water resource protections. It will be important to capture these investments as a way to assess past progress and identify where additional resources, if any, can be directed to help other strategies get implemented. This will require more coordination with town leadership and communicate strategically with residents to inform decision-making at town meetings.

Actions

- Document current actions that demonstrate operational and capital investments that address climate change and increase resiliency.
- Review upcoming investments such as capital projects and planning and design projects for opportunities to integrate climate mitigation and adaptation strategies.
- Initiate local discussions about how and where to make changes in the municipal budget for climate mitigation and adaptation strategy implementation.
- Identify potential sources of outside funding to support climate mitigation and adaptation strategies, such as the proposed program that is part of Executive Order 569 that was signed by Governor Baker.[164]

[163] http://www.mass.gov/governor/pressoffice/pressreleases/2014/0114-climate-change-preparedness-investment.html
[164] http://www.mass.gov/eea/docs/executive-order-climate-change-strategy.pdf

1.3 Promote economic resiliency

Local small business owners are less likely to have the resources to prepare for and rebound from adverse climate events. Government can provide financial assistance and information and work to protect critical assets that businesses rely on. Financial assistance could be in the form of technical assistance, grants, or low interest loans for retrofitting buildings. Municipalities should collaborate with the private sector on identifying and protecting assets subject to climate change impacts and important for business operations such as critical infrastructure (energy, communications), transportation networks, public safety facilities, and cultural assets.

Regional Applicability

Small business make up a majority of the businesses in the region. Often these businesses, and their owners, are focused on short-term action and long-term business planning. They are likely not paying much attention to potential climate change effects. Awareness of climate change impacts can be increased through outreach via Economic Development Corporations and business associations.

MAGIC is home to a limited number of health care facilities, and health care demand at these facilities may increase with climate change and demographic shifts. Municipalities, HMCCs and similar coalitions can engage healthcare institutions on assessing and addressing their climate risks.

Actions

- Require key systems (electrical, HVAC, communications) in new buildings or renovations to be located on floors above flood zone levels to avoid internal service outages.
- Work with local business and trade organizations to identify funding sources to assist property owners with flood and storm proofing critical systems.
- To increase resiliency, health care institutions should conduct Climate Risk Assessments that identify anticipated extreme weather risks and determine an emergency plan. An assessment can identify opportunities for reducing energy consumption; producing energy on site through combined heat and power systems, or solar or wind power; reducing potable water use; and developing independent sewage systems. Where a surge in demand for services is anticipated, health care facilities can stockpile medical supplies and food to enable serving more patients for a longer period, and they can support planning for critical programs and services to be located in low risk areas within health care facilities.
- Encourage and increase participation in state workplace safety programs in order to reduce existing and potential future workplace climate change related vulnerabilities. An example is the Massachusetts' Department of Labor's (MDOL) On-Site Consultation Program which is free and assists private-sector employers in increasing safety, reducing health hazards, and training employers and employees to encourage compliance with OSHA regulations.[165]
- Promote awareness and use of educational materials that address workplace safety issues, especially those that may become of more concern due to climate change. Examples include the Federal Centers for Disease Control and Prevention (CDC) National Institute for

[165] http://www.mass.gov/lwd/labor-standards/massachusetts-workplace-safety-and-health-program/wshp-brochure-web.pdf

Occupational Safety and Health (NIOSH) 2-page Spanish and English “FastFact” fact sheets on Heat stress, Sun Exposure, and Ticks and Mosquitoes.

1.4 Emergency preparedness

Local governments and municipalities will need to provide emergency and disaster response when actual weather events associated with climate change occur. Hurricane Sandy was a grim reminder of the important role that municipalities in the MAPC region need to fill in order to ensure that communities are prepared and can respond to weather emergencies.

One of the key goals of emergency planning, as described in the UNISDR *Making Cities Resilient Report*[166], 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' *Climate Change Adaptation Report*[167], support is consequently requested and provided by the next higher level of government.

Regional Applicability

The towns in MAGIC already have a number of avenues for communicating with emergency preparedness partners about potential climate change impacts. Similarly, community partners have these and other relationships, such as volunteer corps, that can be leveraged to communicate about what impacts are expected and determine what response strategies may work best.

Actions

- Ensure towns offer local emergency notification systems and are enrolled in local and state sponsored emergency notification systems. Develop supporting communication plans for use of social media (e.g., Facebook, twitter) to compliment emergency notification system and increase exposure to emergency notices.
- Consider key audiences and communication channels, taking advantage of existing communication pieces from the town (e.g., newsletter, local access television, reverse 911, etc.). Use existing resources such as the George Mason Center for Climate Change Communication and the Yale Program on Climate Change Communication[168]Municipal Budget and Resources Allocation.
- Review and, as needed, update existing emergency preparedness capacities through activities such as regular training and exercise opportunities, reviewing and refreshing equipment at cache sites, and planning collaboratively with regional and state partners.
- Review and update local Comprehensive Emergency Management Plan (CEMP) to account for how emergency situations and response activities could be affected as a result of climate change impacts (e.g., flood roadways, heat island effects, etc.). In particular, review the

[166] https://www.unisdr.org/we/inform/publications/28240.
[167] http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html.
[168] https://www.climatechangecommunication.org/. and http://climatecommunication.yale.edu/.

number of people and that can be accommodate at shelters and the duration that the shelter can be in operation. This will help address immediate area population needs as well as the potential sheltering needs of residents evacuated from coastal areas.

- Promote the use of micro-grids and renewable energy at vital service stations such as hospitals and public safety buildings.
- Promote the use of solar energy at pump stations for emergency service vehicles.

1.5 Advocate for climate policy in the Commonwealth and the U.S.

Federal and state actions impact climate change planning and the allocation of resources to implement climate change mitigation and adaptation measures. Decisions made in federal and state government significantly influence the degree to which municipal governments are able to proactively address climate change and promote local resiliency.

Massachusetts has been a leader in progressive climate change legislation and has committed to prioritizing climate change resiliency going forward. However, the state and country face major obstructions to maintaining these efforts, as the current trends in the Federal Administration indicate a disregard for evidence of climate changes and for participation in national and international commitments to addressing climate change. With the rescission of Federal support, funding, research, data, and other resources to increase climate change, resiliency is under threat.

MAGIC is uniquely positioned for collective advocacy to prevent, and even reverse, these changes. Its regional climate resiliency planning is a model, having engaged the largest group of contiguous municipalities in Massachusetts to-date, and the region has a history of collaboration, engagement, and advocacy capacity.

Regional Applicability

The MAGIC region has formal relationships, like those through the MAGIC Subregional Council, as well as organized constituencies such as watershed groups and climate action networks that are well positioned to call for changes that would assist municipalities in responding to climate change. MAGIC can draw attention to municipal needs on behalf of the interests of inland communities as well as coastal communities in Massachusetts. In particular, MAGIC can push for actions that will help municipalities that rely on vehicular travel so that they have the information and capacities needed to serve residents who may be isolated if local roadways become inoperable due to flooding or other extreme weather conditions.

Actions

- Convene representatives from the 13-town MAGIC group in order to review potential state legislative action that would support climate change mitigation and adaptation action by municipalities. The group should look to identify up to two priorities that would benefit MAGIC municipalities and other Massachusetts inland communities, as well as coastal communities. MAGIC can be a leading voice for their region and for those cities and towns who do not currently have the capacity for collective advocacy.
- Collaborate and coordinate with regional, statewide, and multi-state coalitions to prioritize, shape, and support federal legislation that addresses climate change. Potential collaborating entities could include the Metro Mayors' Coalition and The Southeast Florida Regional Climate Change Compact that are advancing conversations for multi-state advocacy.
- Advocate for state investment to make necessary upgrades to state-owned and –operated infrastructure critical to local operations, in order to make Massachusetts and its communities more resilient to climate change.
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1.6 Disseminate municipally-tested and proven best practices for climate resiliency

Climate change adaptation is best served by practice, not plans. It is activity similar to how a rowing team may improve the coordination of their strokes and the speed of their boat. Improvement occurs as teammates share observations and apply changes to see if, and how, they work. Climate change resiliency for municipalities will benefit from a comparable approach: apply climate responsive actions now so that they can be tested and what is learned can be shared and used for improvement.

MAGIC is at the leading edge of climate resiliency planning, especially at a multi-municipal scale. The region is in a unique position to model climate resiliency and share what it finds with others in the Commonwealth and even beyond. In one aspect, the towns can model local action on certain issues – like clean energy investments or water resources management – and assess how the work has succeeded or faced challenges. In another aspect, MAGIC can be regional laboratory where successful practices and lessons learned are regularly shared at subregional meetings or climate change conventions. In both cases, this information can be disseminated across the state for others to use and for MAGIC member municipalities to receive peer guidance on future actions.

Regional Applicability

MAGIC has regularly tackled issues regionally and is a leader in municipal practices. Examples of other regional work include the MAGIC Comprehensive Agricultural Planning Program and MAGIC Suburban Mobility Transit Study, and the towns in MAGIC have lead the way on local practices in clean energy, affordable housing, and historical protection. This work has served as models for other municipalities in the MAPC region as well as the state.

Climate change resiliency continues this trend and expands on it. As one of, if not the first, multi-municipal climate change planning projects, MAGIC is leading the way on climate change in the state. As a first mover, MAGIC can model what climate action looks like regionally and locally. What is different here is that to do so, MAGIC towns will need to create a hub where actions can be tracked and assessed. This requires intention in the way that other project likely did not require. However, other projects were not responded to issue so large and so ignorant to local political boundaries.

Actions

- Inventory the actions that each MAGIC town has taken or will take to increase local climate change resiliency. Work could be coordinated through the MAGIC subregional council or another organization serving the 13 MAGIC towns.
- Organize the identified actions into a tracking table that identifies for each municipality the following (at a minimum): Town, Specific Action, Category (e.g., Transportation, Housing, etc.), Date of Implementation.
- Set a re-occurring time frame for assessing implementation status and impact. A two to three year time frame is recommended for the assessments.
- Develop a web-based clearinghouse for documenting implementation actions and findings from the assessments.
- Identify presentation opportunities (e.g., conference, workshop) for municipal and community partners to share work. Look for both state and national opportunities for presentation.

2 Monitor and Apply Local Predictions for Climate Changes

2.1 Operationalize climate change data use and updates

The past several years have seen the downscaling, or localizing, of climate change information. Starting with global predictions, national and state level predictions have become available. Likewise, municipal level predictions have become available in the Boston Metro region through climate change studies and planning efforts from the Cities of Boston and Cambridge and mapping efforts by the Massachusetts Department of Transportation (MassDOT).

The available Boston Metro region predictions have allowed for a more local characterization of impacts for the MAGIC region. That said, they are not yet the best characterizations for the region. The towns in MAGIC may be in a coastal region but they do not face the same immediate impacts that municipalities who have shorelines may face. There is different topography and hydrography in the inland region occupied by the MAGIC towns. Therefore, it will be important going forward to monitor for climate change predictions that address the MAGIC region and the individual towns that comprise the region.

Regional Applicability

As with other planning and implementation efforts, town staff and citizens prefer to use locally-applicable information. This information is more context sensitive (e.g., given certain topical features or built environment elements) and helps with community decision-making, especially when it comes to capital investments.

At present, localized information on climate change is limited. The MAGIC region will benefit from more local climate data and it will require a monitoring effort in order to determine when this information becomes available and updated over time.

Actions

- Identify a municipal department or board or committee to be responsible for monitoring the availability of updated climate change data.
- Initiate regular communications between the MAGIC Regional Council and the Executive Office of Energy Affairs, the Executive Office of Public Safety, and the Massachusetts Department of Transportation regarding the availability of local climate data and predictions (e.g., riverine modeling for impacts to state transportation facilities).
- Share updated data and predictions with all municipal departments so that information can be included in ongoing planning and implementation efforts (e.g., open space planning, capital improvement plans, etc.).
- Maintain current data on municipal critical infrastructure and assets that are important for assessing climate risk and making systems more resilient.

3 Protect Natural Resources and Maximize Use of Ecosystem Services

3.1 Adopt a Regional Green Infrastructure Approach

"Green infrastructure" describes a range of practices that mimic natural processes and use natural resources for organizing development and mitigating potential environmental needs and impacts of development. Green infrastructure practices use natural assets like soil, vegetation, water resources, and green spaces to help with issues such as water collection and recharge, habitat connectivity, and cooling. While mainly relying on natural resources, green infrastructure can integrate with traditional, or 'gray', infrastructure elements, especially in locations with existing development and impervious surfaces. Table 1 compares gray and green infrastructure features and functions.

Table 32. Gray versus Green Infrastructure

Conventional (Gray) Infrastructure	Green Infrastructure
Single 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

Green infrastructure can address multiple climate change issues, including mitigating precipitation impacts to stormwater systems and reducing heat island effects. Habitat protection efforts across municipal borders offer a demonstration of the host of additional benefits from a green infrastructure approach, including reduced ecosystem fragmentation as well as cleaner air and water, flood mitigation, groundwater recharge, and passive recreational spaces for people.

Regional Applicability

Regional water resources protection and monitoring is a common practice across most of the towns in the region. However, there does not yet appear to be multi-municipal or regional green infrastructure planning initiative in MAGIC. Such a regional plan could offer an organizing principle for local planning related to natural resources as well as recreational opportunities. It could also help MAGIC identify how local and state action are needed to preserve terrestrial or aquatic resources that straddle multiple municipalities.

There are plans that could inform such efforts, including stormwater management plans, open space plans, and hazard mitigation plans. Additionally, the new NPDES General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4) for Massachusetts will go into effect in the near future and there are regulatory requirements for that may be satisfied through the use green infrastructure at the regional scale.

Actions

- Hold a regional meeting to share municipally-focused natural resource related plans and initiatives. The meeting should focus on available plans, such as recently updated open space and recreation plans, as well as other materials to identify where there are opportunities to establish regional infrastructure elements (including the use of state and federally protected lands) and what actions are needed to protect these spaces.
- Establish a regional fund that can serve as a match for outside funding and as source for purchasing or protecting land (local, state, or federal) that is essential to the regional green infrastructure network.
- Integrate green infrastructure plans into other local and regional planning efforts, such as master plans and transportation plans.
- Add provisions for green infrastructure into Hazard Mitigation Plans under development.

3.2 Use Low Impact Development Techniques in Local Development

Low Impact Development (LID) is a site planning process that identifies critical natural resource areas for preservation and restoration. LID ensures that maintenance of natural drainage flow paths, minimization of land clearance, building clustering, and impervious surface reduction are incorporated into the project design. LID includes a specific set of strategies that treat stormwater management at the site level, ensuring that water is managed locally rather than engineering the discharge of water away from its source. Three examples of LID[169] are:

1. Bioretention: Bioretention is a practice of using 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), into the groundwater, with some of the water taken up by the plants.
2. Raingardens: Raingardens are a type of small-scale Bioretention Cell. These are frequently on residential lots; include simple overland outlets/overflows; and require simple soil amendments, rather than specialized media often required of larger bioretention cells.
3. Vegetated Swales: Vegetated swales are open, shallow channels that slow stormwater 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.

Other examples of LID practices include permeable pavement, green roofs, and rainfall capture and harvesting.

As the climate changes, individual properties will have to take actions to manage precipitation, especially as it becomes less predictable, The LID method should assist the properties in building their resilience and making better use of the precipitation that falls on their sites.

Regional Applicability

Multiple towns in MAGIC have LID or a version LID regulations in place. How these regulations are applied is unclear as is how many properties have used LID techniques in their construction. Given this, there is the opportunity to increase and document use of the existing regulations, change the regulations to encourage broader use, and expand the regulations to towns who do not yet have them. Additionally, the new NPDES General Permit for Stormwater Discharges From Small

[169] "Low Impact Development (LID) Toolkit," Metropolitan Area Planning Council, accessed August 23, 2016

Municipal Separate Storm Sewer Systems (MS4) for Massachusetts goes into effect July 1, 2018, and there are regulatory requirements for that may also be satisfied through such planning.

Actions

- The MAGIC Stormwater Partnership project is helping MAGIC communities prepare for MS4 compliance, and the planning process will identify and rank potential stormwater recharge retrofit sites on town parcels and roadway rights-of-way. Municipalities should evaluate how they can implement LID retrofits on identified sites through municipal projects.
- Identify opportunities for LID implementation as part of green infrastructure planning
- Require white, green, blue or photovoltaic roofs on large developments.
- Review and revise municipal requirements in order to reduce the percent of impervious cover, e.g., required road widths, number of parking spaces, street tree planting, etc.
- Provide incentives for developers to use LID practices. Incentives could include: expedited project review and approval, relief from specific development standards (e.g. density, lot size, etc.), or property tax reduction for a given period.
- Identify and implement incentives for private property owners to retrofit properties using LID techniques, such as rainwater harvesting and reuse. Programs could be modeled after energy efficiency programs already used by many MAGIC towns.
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Resource

- MAPC's Low Impact Development Toolkit provides practical fact sheets on LID methods including rain gardens, bioretention, pervious pavement, and green roofs. It also includes model bylaw language and an LID codes checklist.
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3.3 Plan for a stormwater utility

New requirements of the MS4 Permit will introduce new costs, and a significant increase in municipal stormwater management budgets. There is a more urgent need for communities to develop new, dedicated revenue sources to implement sustainable stormwater management and comply with new requirements. And, as precipitation amounts increase, greater burdens will be placed on stormwater systems to absorb larger volumes and prevent more runoff pollution from entering waterways. The combination of these factors – management requirements, fiscal requirements, increasing burden on systems – illustrate the need for a long-term funding source and incentives for improved stormwater management.

A stormwater fee, (a.k.a. drainage fee) collected via a utility structure holds potential for generating reliable stormwater management revenue. A municipally-based stormwater utility would generate dedicated funds for stormwater management and improvements, and support municipal green infrastructure and LID efforts. It could also incentivize reductions in impervious surfaces which would increase the amount of local recharge and if done strategically, could remove surfaces that contribute to heat islands.

Regional Applicability

Most of the towns in MAGIC will have to conduct more stormwater management activities due to the new MS4 regulation.[170] No towns at present have a stormwater utility or drainage fee in place. Since stormwater is a shared issue, the utility structure presents an opportunity for regional action. Towns could pursue the utility and fee structure individually; however, a regional approach could be used as it has in many other places in the US.

Actions

- Develop or update stormwater master plans in each town.
- Plan for and adopt municipal stormwater utilities in each MAGIC town.
- * During the MAGIC Stormwater Partnership project, MAPC will update its stormwater utility assessment methodology and prepare a preliminary analysis of stormwater rate alternatives tailored for each community using MAPC's parcel-based GIS analysis of impervious surfaces and alternative fee structures.
- Identify and implement municipal collaborations that use utility resources to invest in regional projects.
- Build from municipal collaboration projects to explore establishment of regional stormwater utility. Look to similar examples in the U.S. as models for MAGIC regional utility.
- Hold discussions with chambers of commerce, business associations, community-based organizations, and residents to present and gather feedback on the establishment of stormwater utility for the towns and the MAGIC region.

[170]Region 1: EPA New England, "Massachusetts Small MS4 General Permit", https://www3.epa.gov/region1/npdes/stormwater/MS4_MA.html, accessed April 8, 2017

Resource

- MAPC's Stormwater Financing/Utility Starter Kit is designed to help municipalities analyze existing and anticipated budgets and design appropriate billing and revenue structures for stormwater utility programs.

3.4 Institute water conservation practices

Periods of low precipitation in Massachusetts (typically, mid-summer and fall), can significantly impact watersheds and surrounding ecosystems and diminish groundwater recharge. New and expanded development compounds this issue, increasing water demand and impervious surface coverage, which contributes to low-flow conditions and pollution in waterbodies. Water conservation is an important strategy for reducing impacts from low-precipitation and drought.

The Sustainable Water Management Initiative[171] (SWMI) promotes water conservation as a critical measure for mitigating water withdrawal impacts. The SWMI Framework lays out a set of eight standard conditions that all Water Management Act (WMA) permittees in the Commonwealth will be required to comply with. Of these, conditions four to seven have a direct bearing on water conservation. Additionally, requiring users of *private* irrigation wells, as well as users of public water supply to comply with water conservation restrictions is also a useful, indirect mitigation measure. These should be put in place now rather than waiting for the 2018 WMA permits in the Concord basin.

Regional Applicability

Each town with a municipal water system had water use restrictions in place 2016, as they have in most years in recent history. In 2016, some instituted complete bans on non-essential outdoor water use. In light of these immediate experiences, the towns can take a proactive approach in managing water resources and actively encouraging water conversation year round. The conservation would not only help with residential uses but would also make a key contribution to supporting the resiliency of local natural resources.

Actions

- Explore and, where possible, enact year round watering restrictions in municipalities with either public water supplies or private wells. Examples could include restrictions that limit irrigation to two days per week outside the hours of 9 am to 5 pm, and clear guidelines for restriction mandates or tiers such as “no sprinklers” and “total ban.”
- Explore, and where possible, enact new financial structures for water use such as 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.
- Provide educational templates such as flyers, press releases, notifications to be added to water bills, website postings, and outdoor sandwich board 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. The public needs to be educated about the fact that water is a shared resource, and what actions they can take to use water responsibly. As part of the MAGIC Stormwater Partnership, MAPC will establish an online library of education and outreach resources and other useful resources available to the Partnership towns.
- Explore Net Blue bylaws to achieve no net increase in water use with future development.

[171] SWMI was a three-year, multi-stakeholder process to update the implementation of the Water Management Act (WMA).

3.5 Ecological and habitat restoration

Habitat restoration projects provide a range of valuable ecosystem services, including the generation and preservation of soils and soil carbon, cycling and movement of nutrients, partial stabilization of climate by removing carbon from the atmosphere, 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.

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 at Harvard University Graduate School of Design promotes this concept which she describes as providing a landscape" network strategy." The idea is that landscape is infrastructure, 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.

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 about the importance of properly designed stream crossings to prevent flooding and maintain riverine habitat continuity. 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.

Regional Applicability

Habitat fragmentation is a constant risk. Private development often focus on immediate and proximate impacts to natural resources. As a region that is continuing to experience commercial and residential growth, MAGIC can begin to look to a larger systems to prevent and hopefully restore necessary linkages in the environment. These linkages such as contiguous forested lands or unobstructed waterways will increase the ability of current and future species to thrive as conditions change. Additionally, through mechanism such as density bonuses and transfer of development rights, the towns can direct development into appropriate locations and use potential proceeds (e.g., additional tax revenue) to restore lands that have been abandoned or are underutilized.

Actions

- Hold a session for municipal officials regarding ecological restoration.
- Include ecological restoration as a priority in open space and master planning processes.
- Work with DER to provide technical assistance regarding the prioritization and implementation of restoration projects.
- Explore potential for use of native species and introduction of species that may be better suited to grow under predicted future climate conditions. Avoid introduction or facilitation of growth of invasive species.

- Re-vegetate/stabilize riparian corridors with native plants.
- Redesign and/or remove impediments to flow, sediment supply, and habitat migration potential such as dams and undersized culverts.
- Use Stream Crossing Standards in the Massachusetts Stream Crossing Handbook to evaluate existing culverts that need to be replaced as well in the construction of new culverts.
- Adopt open space residential design and/or other mechanisms to protect and restore habitat and natural groundwater recharge.

3.6 Tree planting initiatives

The addition of trees is very effective at reducing heat magnification, especially in areas with significant amounts of impervious cover and that are lacking in vegetation. This strategy can also assist by being proactive in testing new types of tree species – those that reflect the predicted climate to come. As current tree populations change, tree planting can help foresters and municipal officials find options that can meet new conditions and potentially assist with terrestrial species adaptation. Lastly, these planting can remove carbon from the atmosphere, reduce air conditioning needs, and reduce negative air quality impacts to people and wildlife.

Regional Applicability

Tree planting programs already exist in the MAGIC region. Likely these look to introduce species that are already present or that are known to not impact things like utilities or stormwater management. These programs could begin to integrate a climate lens and investigate new species. The planting of these new species would allow a better understanding of potential benefits and consequences in proactive fashion.

Actions

- Share climate change predictions with municipal foresters and arborists so that tree species selection and maintenance is resilient to climate disruptions. If there is no municipal foresters and arborists, identify a lead in another department or seek contract with outside party to fulfill the role.
- Develop an inventory of tree species that would accommodate future climate conditions and detail their requirements.
- Review new tree species relationship to existing animal species and potential for reducing of exacerbating climate change impacts (e.g., trees that may produce more pollen and add to local allergens).
- Require an increase in the percentage of tree cover in all new developments, especially over parking lots and roadways.

4 Increase Use of Clean Energy and Green Building Measures

4.1 Continue transition to renewable and resilient energy systems

Renewable energy technologies, such as solar panels or wind turbines, work by harvesting naturally available forms of energy and converting them into electric energy. Use of renewable energy mitigates climate change by helping to reduce GHG emissions. In addition, renewable energy can increase local resilience by increasing the amount of energy that is sourced and produced locally. The energy use of buildings can be significantly reduced and the heat island effect diminished by using white roofing, or installing green or blue (water-holding) roofs. Solar panels may also be part of the design, and all buildings can to be solar-ready structurally.

Local resiliency can be increased more through the use of new technologies such as microgrids. This type of power grid is self-contained with the ability to generate and store its own energy. When a larger system goes down, the microgrid could remain available for critical facilities like hospitals and shelters in order to aid in emergency response and recovery efforts. While the microgrid concept holds much promise, it too should be getting its supply through clean energy systems (e.g., solar) in order to avoid contributing to greenhouse gas emissions and reducing local air quality (e.g., use of diesel generators).

Regional Applicability

MAGIC has been making progress in assessing opportunities for energy efficiency improvements and implementing changes in the built environment. Many MAGIC towns have gained Green Community designations, and have received state funding for energy efficiency and renewable energy projects. Progress should continue in this regard and towns – individually or as groups – should pursue more advanced plans or policies like net zero, microgrids, and battery storage. A factor in this will be the mix of current energy providers: where some towns have municipal light plants, others having service from regional utility companies.

Actions

- Maintain municipal Green Community designations in the region in order to leverage state support and funding for energy efficiency and renewable energy measures.
- Develop municipal energy and GHG emissions baselines to inform short- and long-term clean energy planning.
- Develop more local and regional renewable energy generation for shared or on-site consumption.
- Adopt net zero plans or policies at the municipal level
- Build 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.
- Facilitate widespread adoption of residential solar photovoltaic, but not at the expense of tree cover.
- Support the uptake of renewable technologies not yet common in the region including renewable thermal technologies, microgrids, district energy, and battery storage.

4.2 Establish weatherization and green building measures

It is critical to retrofit existing buildings with proper weatherization, energy conservation, and efficiency upgrades. Given the age of existing buildings, weatherization measures would improve the ability of buildings to 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 economic benefits by reducing energy usage and related expenses.

New developments present an opportunity to equip structures to meet future needs and reduce overall exposure to climate change effects in the built environment. There are a number of standards that can be used or referenced (e.g., LEED by USGBC, EnergyStar, etc.) to guide local green building practices. While these standards may have a modest impact on construction, they have the potential for reducing an economic, social, and municipal costs in the long term under climate change scenarios.

Regional Applicability

A few towns in MAGIC have promoted a green building standard or provided weatherization support. There is space to increase the number of towns promoting these changes especially in regard to the number of older buildings that may face exposure to flood and increased high heat days. Greater use of these changes would assist residents in reducing energy loads by shifting to more efficient cooling systems, increasing efficiency of homes, and potentially build resiliency in the event of disruptions.

Actions

- Municipalities will work with property owners to retrofit existing. Prioritize efforts by looking for homes most risk, such as location relative to floodplain, year built (e.g., pre-1970), household income (e.g., 30% area median income), and age of resident (e.g., older residents).
- Work with state agency partners and legislators to develop technical assistance and grant/loan programs for water damage and mold abatement at private residences (e.g. Solarize MA).
- Support green building standards and 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.

4.3 Develop and institute building practices that are climate resilient and restorative

Climate resilient building design can leverage and apply existing and new design approaches. Some existing measures go beyond what might be currently included in green building guidance or certification. As examples, the table below compares a list of the United States Green Building Council's (USGBC) site selection ("sustainable site") categories with items specific to climate adaptation.

Table 33. 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

Going further, there are likely to be new techniques that increase building resiliency and may assist in restoring past impacts to natural systems. For example, builders may want to experiment with new techniques to address flooding risks or the collection of rainwater. Towns should consider where and how they might like to accommodate, or even incentivize, such experimentation. Similarly, redevelopment or reconstruction of properties can provide a chance to restore aspects of the natural environment that have been interrupted or degraded. Towns can use such instances to encourage restoration, such as wetlands or habitat corridor, in order to increase adaptive capacity of the resources.

Regional Applicability

MAGIC has been a leader in many regards. Building on its work with the Green Communities program and in open space protection, the region could identify where and how it wants to encourage development that has resiliency as one of its core principles. This could take the form of one town taking on the challenge or several towns working collectively for outside resources to support new forms of building.

Actions

- Hold forum on climate resilient design.
- Identify how natural systems have been fragmented and key locations for restoration.
- Incentivize experimentation with new building approaches.
- Provide information on municipal building department websites that promotes climate resilient designs. Sources for design examples include the City of Boston's Article 37 Green Building

and Climate Resiliency Guidelines and the City of Hoboken's (NJ) Resilient Building Design Guidelines.

- Require evaluation of green building and landscape design as part of all medium and large project reviews, at a minimum.
- Consider a Net Zero bylaw (see Cambridge's Net Zero Ordinance).
- Offer resiliency audits in flood-prone areas, covering flood walls, backflow prevention and raised electrical and essential equipment.

5 Enforce and Enhance Regulatory Measures Affecting the Built Environment

5.1 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. For the purposes of this section, the term floodprone will be used to capture all areas exposed to flooding, not just the areas regulated under FEMA. This is because the FEMA Floodplain Insurance Rate Map (FIRM) does not take climate change impacts into account within inland riverine systems and past experience has shown that flooding occurs not just in flood plains.

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. It is also based on FEMA's 100-year flood delineation which is likely to be an underestimate given anticipated precipitation changes.

Regional Applicability

Wetland and floodplain regulations are common in most MAGIC municipalities. This demonstrates an understanding of potential impacts and the need for local policy and action. It is not clear how well regulations are enforced or whether they are consistently applied across municipalities. It is also not clear when the regulations were last updated and whether any consider potential climate change effects, e.g. changing floodplains.

Actions

- Explore local policy changes to increase, or possibly mandate, protective buffers to the following resources:
- Land Outside the FEMA 100-year Floodplain, e.g., ,use the 500-year floodplain
- Isolated Vegetated Wetlands
- Vernal Pools
- Intermittent Streams
- Landward Migration of Wetlands
- Strengthen local wetlands bylaw restrictions in buffer zones to restore original 100' no-build buffer of resource areas under the Wetlands Protection Act. Work with partners and towns to map areas outside the FIRM that reflects changing conditions and to ensure flood protection.

5.2 Transfer of Development Rights (TDR)

Transfer of Development Rights (TDR) includes a similar principle of preserving natural areas for flood protection by increasing development in other designated areas. The method for doing so identifying specific "sending areas" (preservation areas) and "receiving areas" (development districts), 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 and increasing 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.

Regional Applicability

TDR is a known application in the MAGIC region (e.g., included in section of Town of Concord zoning ordinance) although it is not currently applied in the towns. In coastal situations, an approach referred to as rolling easements is being considered to accommodate inland migration of wetlands. Similarly, TDR could be used inland to help accommodate changes in wetlands and floodplains while helping property owners maintain equity in their land and its development or redevelopment potential. It could also serve as another tool for redirecting development to locations that are less sensitive to climate change and that could reduce transportation-related GHG emissions.

Actions

- Evaluate outcomes and lessons learned from TDR application in MAGIC.
- Identify what areas could potential serve as sending and receiving zones in individual towns.
- Explore potential for a regional TDR application that would take advantage of efficiencies of scale and recognize larger system impacts from climate change.
- Enact TDRs.
- Consider Net Zero policy where possible on energy use.

5.3 Implement climate responsive land use policies and regulations

Policy and regulations form the basis for the measures that ensure development occurs in a manner consistent with local plans and for basic community protections. As the climate changes, existing polities and regulations regarding development can be updated to reduce community impacts from new development and protect existing development. The model of smart growth can be used as the foundation from which to build local land use policies and regulations like zoning that will create a more resilient community. Recent examples from extreme inland storm events has shown that a lack of preparedness and development in higher risk areas can cause personal and economic harm.

There are innovative changes that can be implemented to protect social and physical assets in a community. A number of these measures have previously been identified, such as local policies to promote green infrastructure and energy and water conservation measures. Additional, protective regulatory measures include:

- Inclusion of climate change and predicted impacts in local plans including master plans, open space and recreation plans, and housing production plans.
- Identify opportunities to reduce vehicle trips through zoning that encourages more compact, walkable developments.
- Incentivize existing property owners to make changes like reducing impervious surfaces, similar to incentives used to promote the use of solar panels.
- Plan for community gathering facilities that can serve as mustering points and that support community cohesion and resilience.
- Adjust wetland and stormwater bylaws to increase protection and resilience.
-

Regional Applicability

The MAGIC region has shown a willingness to consider future conditions and determine how best to act in response. The region has also shown creativity in implementing past solutions such as the development of suburban TMA that include both public and private sector transit services. It will likely require taking a risk, but there is precedent for the region to consider new approaches – regulatory and by incentive – to alter how and where development occur in the region.

Actions

- Review of local regulations and zoning to make required cross-sectional changes to eliminate prohibitions of climate resiliency measures.
- Explore model zoning that would promote reductions in impervious surfaces on already developed properties.
- Explore model zoning to reduce parking requirements and the use of impervious surfaces for off-street parking lots.

5.4 Flood proofing

Flood proofing measures for buildings and structures in floodplains is critical. It protects physical assets as well as residents, local economic assets, and the natural environment by reducing potential exposures. Unfortunately, there are 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
- Consistency between the Massachusetts Building Code and the Massachusetts Wetlands Protection Act regulations and permit approvals.
-

However, the state building code does not account for increased flooding frequency and intensity caused by climate change. Therefore, municipalities could consider more actively promoting building design standards in existing flood zone areas and even in adjacent areas that are identified through future modeling of impacts. 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.

Regional Applicability

In each MAGIC town, there are many properties with high financial values that are located in the 1% floodplain. It is not clear at this time whether flooding risk is going to change for these properties and the exact extent to which buildings and other fixed assets would be impacted. Although these unknowns exist, it can be anticipated that there will be impacts given past experiences with flooding and given the age of many of the buildings in region. Consideration and use of more protective zoning could reduce exposure in the region as new development and redevelopment occurs.

Actions

- Incentivize the elevation of the lowest floor (including basement mechanical and utility equipment, and ductwork) one - two feet above the Base Flood Elevation (BFE), which should reduce exposure and may improve the flood insurance rating for the building. Although the state building code can prevent municipalities from regulating this change, local incentives can encourage property owners to elevate in other flood prone areas outside the floodplain and in flooding areas that are not mapped.
- 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).
- Promote the elevation of utilities and sanitary facilities, including heating, air conditioning, electrical, water supply, and sanitary sewage services, in new and redeveloped sites above

the base flood elevation and be completely enclosed within the building's watertight walls. Or, make utilities 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.

5.5 Agricultural land conservation and farm resilience

Farm acreage loss[172] continues to pose a major threat to local food production and the agricultural economy. As farmers age and plan for the future of their farm operations, the MAGIC region, like most of Massachusetts, is faced with the need to preserve local farmland and enable new farmers to gain access to these lands. Moreover, 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, 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.

Farmers will need to employ adaptive farming techniques as climate conditions introduce new and dramatic challenges in the field. Anticipating more and new insects and disease, and greater water shortages, a range of techniques can help increase agricultural resiliency, including crop diversification, integrated pest management (IPM), no till soil management, increasing soil organic content, and drip irrigation.[173] UMass Extension is the primary statewide entity providing technical assistance to farms in Massachusetts. It conducts extensive agricultural research, monitors conditions, and promotes best practices in farming. Its research and education efforts include addressing climate change threats to agricultural production, and developing early warning systems and promoting adaptive farming practices. The services UMass Extension offers are important for MAGIC's farms to remain informed about potential issues affecting the state's farms, and to receive the technical assistance and other support to remain adaptive.

Regional Applicability

The MAGIC region highly values its agricultural identity and the farming uses that can be found in the region. It reflects the history of the region and is a reflection of how the communities in the region support local food production and access. In addition to loss of farmland, climate change will stress farms in how they produce current crops and in how they make transitions to new crops that can grow under changed weather patterns. Adaptation actions will be critical to make sure farms uses in the region can prosper, and even expand, going in to the future.

While MAGIC farms are mostly under 50 acres, and are relatively minimal emitters, farms that employ energy reduction measures and produce renewable energy can contribute to efforts to reduce the contributions of agriculture to climate changes. Massachusetts' Department of Agricultural Resources (MDAR) manages two programs, the Agricultural Energy Grant Program and the Agricultural Energy Special Project Grant Program that support projects for renewable energy or energy reduction. Anaerobic digester, solar photovoltaic, and green building construction are examples of projects funded through these programs.

[172] 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.
[173] K:\SG Land Use\Planning Projects & Information\DLTA 2016\MAGIC Climate Project 2015\Task 2 - Data Collection and Analysis\Economy\ IPCC_AR5__Implications_for_Agriculture__Briefing__WEB_EN

Actions

- Amend bylaws and ordinances to provide zoning relief for accessory land uses that provide diversified revenue for farms. Make sure that any new regulation of accessory uses does not overstep the MGLc. 40A, §3, agricultural zoning exemption. Consider permitting accessory uses as of right instead of by special permit, or if some measure of review is needed, create and utilize a modified site plan review process that is tailored to agricultural land uses.
- Implement an agricultural overlay district that requires any development within the district be clustered in order to preserve prime agricultural soils.
- Identify and promote farmers' use of resources, technical assistance, and funding provided by the Massachusetts Department of Agricultural Resources, UMass Extension, USDA branches, and other agricultural agencies to support adaptive farming practices for climate resilient livestock, produce and other operations.

6 Maintain and Protect Critical Infrastructure

6.1 Water infrastructure

Protection of drinking water sources and infrastructure from changes in precipitation and increased heat are critical measures for a community's overall health. Drinking water availability is likely to become less reliable due to increased frequency of droughts and loss of aquifer recharge due to development and increasing intensity of rainfall events. The periods between precipitation events change and potentially reduce water availability. Wells and water sources can be compromised due increased flooding and the potential introduction of toxic materials carried by floodwaters.

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.174

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. IWM looks 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.

Regional Applicability

Most of the MAGIC towns have local control over the water resources. They do not need to wait for larger systems or authorities to consider and make changes. Given this, there is potential for these systems to refine their water management practices in the current in order to prepare for future impacts. Moreover, given the close working relationship among the towns, this work could occur collectively in order to develop a regional systems strategy that reflects a long-term integrated water management (IWM) approach.

Actions

- Monitor and regulate existing systems (e.g., ecological monitoring and protection, pollution control, monitoring population growth).
- Maintain, rehabilitate, re-engineer, and relocate existing systems for climate adaptation (e.g., dams, pumps, tide gauges, streams/beds, and wetlands).
- Systematize and promote water conservation measures (e.g., low flow showers, toilets, weather smart irrigation, etc) among residential, commercial, and institutional uses, providing

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

incentives (e.g., provide equipment for free, reduce permit fees, etc.) to accelerate adoption of the measures.

- 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., biotechnology, and wastewater reuse and recycling).
- Develop protective flood walls around key infrastructure and treatment facilities, prioritizing those that are unable to be relocated.
- Develop and maintain interconnections with other towns in case of emergency water needs.
- Ensure uninterrupted power supply to water and wastewater treatment facilities and pump stations.

6.2 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.[175] 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 transportation facilities are evaluated for repair, reconstruction, and re-design, their proximity to flood prone area should be carefully reviewed. If the facility is within an area that could be impacted by flooding, 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.

Regional Applicability

Transportation assets and services are a priority for MAGIC. While most of the residents in the region typically rely on personal vehicles, the region has been taking action to increase multi-modal options and active transportation. This work is beginning to meet current needs such as travel options for older adults and those seeking more physical activity and if continued will help reduce GHG emissions generated by those in region.

Actions

- Adopt and implement Complete Streets policies in order to increase non-motorized transportation facilities and options that are essential to reducing GHG emissions and promoting healthier behaviors.
- Include performance measures in local circulation plans and transportation elements of capital improvement plans that are tied to mitigation and adaptation of climate change impacts.
- Encourage behavioral changes in mode choice through prioritization of funding to support transit services (e.g., shuttles) and construction of pedestrian and cycling facilities (e.g., shared use paths, cycletracks, Leading Pedestrian Intervals). Use pilot projects to demonstrate project's changes and impact on non-motorized transport.
- Promote compact and transit-oriented development patterns through the development of travel demand forecasts, population projections, and a regional vision.

[175] 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.

- Ensure that state stream crossing standards are applied to all bridge and culvert repairs and proactively at vulnerable stream crossings.

7 Safeguard Health and Human Resources

7.1 Protect vulnerable populations

Warmer temperatures and more instances of life-threatening heat waves will put certain populations at greater risk for disability and death. The heat will tax cardiovascular systems and, in combination with changes in air quality, it will directly impact the respiratory health of residents. Population that could be especially affected are the elderly, children, and those with pre-existing chronic health issues such as asthma and heart disease.

Protracted heat waves and flooding will likely also have large economic consequences that affect health and wellbeing. This comes not just from the initial events, but from the prolonged disruptions – economic, transportation, communication - that may follow a climate event. These tolls will be more difficult to bear for those already struggling economically and with fewer resources to for recovery. Loss of property is only one such effect of major climate threats. These population include those who are small businesses, low income workers, live on fixed budgets, and depend on outdoor work like farming and landscaping.

Regional Applicability

MAGIC is an aging region and will have more residents who are 65 and older in the coming decades. These older residents are a highly vulnerable population for the region. MAGIC also values and supports agricultural uses in addition to other outdoor workers like those in landscaping, public works crews, construction and segments of the tourism economy. Lastly, the towns in the region are aware of other populations that may more vulnerable to impacts – disabled residents, residents who have low incomes and who are cost-burdened – and can take actions to include these populations in climate resiliency efforts.

Actions

- Identify and develop relationships with partners (e.g., independent living, community health network area) that serve vulnerable populations in order to share information about potential climate impacts.
- Ensure that emergency preparedness materials are translated into languages that represent populations that do not speak English as a first language in the region.
- Enable vulnerable residents to evacuate when needed, as well as employing specific procedures to handle communications with vulnerable populations during a disaster.
- Ensuring that new and redeveloped affordable housing includes resilient design elements, especially in regard to heat. Elements should include elevated utility panels and equipment in flood-prone areas, 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.
- Create financial and technical assistance programs to help older and low-income households acquire, install and run high-efficiency air conditioning units.
- Develop plans for cooling centers and locations in each municipality that will be operational during extreme heat events and periods of lost electrical services during storms.
- Access to prescription medication and to medical equipment during emergencies.

7.2 Build and bolster community resilience

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.

Regional Applicability

The MAGIC region has demonstrated its ability to collaborate and to make collective process on key issues such as agricultural preservation and growth and suburban transit. Climate change is another area to leverage the community social capital in the region. Work on this strategy builds on an existing asset and would provide a human component to the other work that may be occurring to create more resilient natural and built environments.

Actions

- Strengthen and build ties with business and trade organizations as part of outreach and education about the risks of climate change. Co-generate materials about actions that can prevent and respond to these risks such as disruptions in electrical services, flooding, vector-borne diseases, and extreme heat events.
- Use existing projects and programs to build community connectedness related to natural hazard preparedness and response. Use formal and informal meetings to create more connections among residents and link to capacities that may be needed during extreme heat and weather events, such as checking on an elderly neighbor and participation in MRCs or Community Emergency Response Teams (CERTs).
- Establish partnerships with community, faith-based, and culturally-focused organizations as well as properties that house or serve populations with limited incomes or limited mobility. Through these partnerships build and foster capacity of organizations and people to network with one another so that informal community networks are strengthened.

7.3 Ensure access to food

Monitoring efforts will need to address the quality and safety of food production and distribution. Food supplies should be monitored for potential disease outbreaks, especially to identify the occurrence of new diseases and disease patterns. 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.

It will also be critical to understand where there may be current and potential future gaps regarding access to food. For those that rely on vehicles to access food, disruptions that may last several days or more may lead to having less food that may be needed on a daily basis. These individuals, especially those that may not have the ability to store food, will be at risk for poor nutrition. This has been especially noted for those that are older and may not drive and people disabilities who rely on being driven or a service in order to access supermarkets and convenience stores.

Regional Applicability

A mostly suburban region, residents in MAGIC typically need to drive to meet daily needs for food, medicine and shopping. Given its reliance on transportation infrastructure and services, parts of the region could be cut off from food access due to flooded or blocked roadways. Where electricity is cut off, refrigeration of perishable food would be significantly limited, in residences, at local food businesses and hunger relief organizations. Diminished capacity to safely store foods could also lead to residential or supply chain food safety issues.

Actions

- Encourage backup power systems in supermarkets and stores selling food and at community food pantries. Renewable energy microgrids could serve as a solution for backup energy.
- Emergency response strategies should include identifying roadways vulnerable to flooding, and alternative routes for vehicles servicing food stores and hunger relief organizations.
- 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.
- 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.
- Support and maintain local sustainable food systems. These systems would 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.