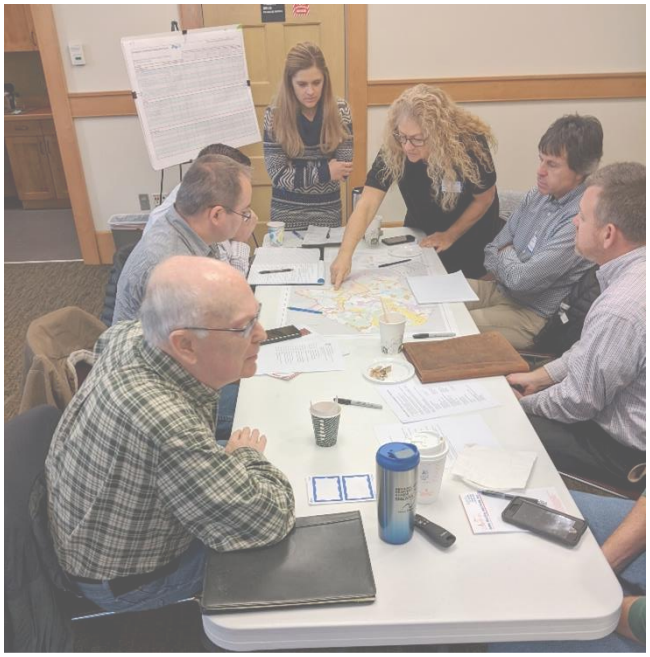
TOWN OF MIDDLETON



2020 HAZARD MITIGATION PLAN– MUNICIPAL VULNERABILITY PREPAREDNESS PLAN

Prepared by:

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EXECUTIVE SUMMARY

Hazard mitigation planning is a proactive process used to systematically identify policies, actions, and tools that can be used to reduce the dangers to life and property from natural hazard events. Climate adaptation planning recognizes that climate change will exacerbate the vulnerabilities and risks associated with natural hazards. The Town of Middleton completed a planning process focused on both hazard mitigation planning and climate adaptation, which provides a robust assessment and implementation plan to build the Town's resilience. The Town is now also eligible for hazard mitigation funding through the Federal Emergency Management Agency (FEMA) and climate adaptation funding through the Massachusetts Executive Office of Energy and Environmental Affairs' Municipal Vulnerability Preparedness (MVP) Grant Program.

Planning Process

The Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HMP-MVP Plan) planning process was completed through the following steps.

1) Convened a core team of municipal department heads who provided key input through meeting, online surveys, and interviews.
2) Created a set of hazard mitigation and climate adaptation goals.
3) Engaged the public through a Community Resilience Building Workshop and online public engagement techniques.
4) Established a list of critical facilities and assets.
5) Conducted a vulnerability and risk assessment of historic hazards and the potential impact of climate change.
6) Documented the Town's capacity to mitigate and respond to hazards.
7) Captured progress on the 2012 Hazard Mitigation Plan.
8) Developed an action and implementation strategy.
9) Sought public feedback on the final document.

Hazard Mitigation and Climate Adaptation Goals

The Town endorsed the following set of hazard mitigation and climate adaptation goals.

- Prevent and reduce the loss of life, injury, public health impacts and property damage resulting from all identified natural hazards and projected hazards under climate change.
- Build and enhance local mitigation capabilities to ensure individual safety, reduce damage to public and private property and ensure continuity of emergency services.
- Increase cooperation and coordination among private entities, Town officials and Boards, neighboring communities, State agencies and Federal agencies.
- Increase awareness of the benefits of hazard mitigation and climate resiliency measures through outreach and education.
- Identify and seek funding for measures to mitigate or eliminate each known significant hazard area and reduce the impacts of climate change.
- Ensure that future development meets federal, state, and local standards for preventing and reducing the impacts of natural hazards today and under climate change projections.
- Integrate hazard mitigation planning and climate change projections as an integral factor in all relevant municipal departments, committees and boards.

Vulnerability and Risk

Among the communities of Essex County, hazard mitigation and climate adaptation planning tend to focus on flooding because it is one of the most likely natural hazards to impact these communities. However, the Middleton HMP-MVP Plan assesses the potential impacts to the Town from a variety of natural disasters including:


Flooding


Drought, Extreme Heat, & Wildfires


Severe Thunderstorms, Wind, Tornadoes, & Hurricanes


Ice, Nor'easters, & Extreme Cold

The HMP-MVP Plan documents the location and exposure of over sixty critical facility and assets. Among them are emergency services, roads, utilities, social services, and natural resources.

Hazard Mitigation and Climate Adaptation Strategy

Through the planning process, several hazard mitigation and climate adaptation measures were identified as high priorities.

- Upgrade culverts for greater rainfall capacity.
- Raise roads (especially School Street) and bridges (Route 62).
- Create a Riverwalk from East Street to the Ipswich River Easement and develop the rail trail to increase connectivity through Town.
- Add emergency power backups at Fire and Police Stations and upgrade facilities.
- Expand reach of Swift 911 and practice town staff Emergency Response Communication Plan.
- Build communication infrastructure redundancies.
- Ensure that backup power at schools is sufficient for use as shelters.
- Update development regulations to include LID, green infrastructure, and additional climate resiliency items to subdivision regulations.
- Incorporate climate resilience into design of the new and rehabilitated municipal buildings including green infrastructure, water conservation technology, and geothermal energy.
- Improve drainage along roadways with nature-based solutions.
- Identify neighborhood volunteers to support outreach and public safety efforts, such as checking on elderly neighbors.
- Increase forest management efforts in the north side of town to reduce brush fire.
- Develop a robust tree management plan to aid Municipal Light in reducing power outages.

Next Steps

The Town of Middleton is dedicated to implementing the findings of this plan and documenting the process. As a now eligible community for funding through the MVP Program and FEMA, the Town will look to secure resources, and to work with regional and local stakeholders, to complete the projects identified herein. The Town will also continue to document hazard impacts and needed improvements to the Town's capacity to mitigate and adapt. Lastly, the Town will proactively incorporate the hazard mitigation and climate adaptation goals into municipal planning, budgeting, and operations. By doing so, the Town will be ready to update this plan in five years to maintain its eligibility for grant funding.

1.0 INTRODUCTION

The Town of Middleton prepared a joint Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HMP-MVP Plan) to create an action roadmap to reduce the impacts of natural hazards and climate change within the community and the region. The Middleton HMP-MVP Plan was adopted by the Board of Selectmen on May 4th, 2021 and replaces the previous Town of Middleton Hazard Mitigation Plan (MAPC, 2012).

1.1 What is a Hazard Mitigation Plan?

Natural disasters such as earthquakes, hurricanes, and flooding, can result in loss of life, disruptions to everyday life, and property damage. Hazard mitigation is the effort to reduce these impacts through community planning, policy changes, education programs, infrastructure projects, and other activities (FEMA, 2020a). Hazard mitigation planning uses a stepped process with participation of a wide range of stakeholders to:

1. Define local hazards.
2. Assess vulnerabilities and risks.
3. Review current mitigation measures.
4. Develop priority action items.

The resulting hazard mitigation plan (HMP) and implementation saves lives and money. For every dollar spent on federal hazard mitigation grants, an average of six dollars are saved (FEMA, 2018a). There are many additional benefits of mitigation planning. HMPs increase public awareness of natural hazards that may affect the community. They allow state, local, and tribal governments to work together and combine hazard risk reduction with other community goals and plans. HMPs focus resources and attention on the community's greatest vulnerabilities. The vulnerability assessment of an HMP documents data related to the National Flood Insurance Program (NFIP), such as repetitive loss sites and ongoing work by the community related to floodplain management.

Figure 1-1. FEMA Hazard Mitigation Planning Saves Money Graphic (FEMA, 2018a)

By completing an HMP, municipalities also become eligible for specific federal funding and allow potential funding sources to understand a community's priorities (FEMA, 2019a). Hazard mitigation funding is available through the Federal Emergency Management Agency (FEMA). To be eligible for FEMA Grants, local governments are required to prepare an HMP meeting the requirements established in the *Robert T. Stafford Disaster Relief and Emergency Assistance Act*, as amended by the *Disaster Mitigation Act of 2000.*

Table 1-1. FEMA Grants

FEMA Grants	Purpose
Hazard Mitigation Grant Program (HMGP)	Helps communities implement hazard mitigation measures following a Presidential Major Disaster Declaration.
Pre-Disaster Mitigation Program (PDM)	Assists in implementing a sustained pre-disaster natural hazard mitigation program, in order to reduce risk to the population and structures from future hazard events.
Public Assistance Grant Program (PA)	Provides supplemental grants so that communities can quickly respond and recover from major disasters or emergencies.
Fire Management Assistance Grant Program (FMAG)	Available for the mitigation, management, and control of fires on publicly or privately owned forests or grasslands.

(FEMA, 2020b)

1.2 What is a Municipal Vulnerability Preparedness Plan?

In 2017, the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) initiated the Commonwealth's Municipal Vulnerability Preparedness (MVP) grant program to help communities become more resilient to the impacts of climate change. The program provides two grant phases. The first grant phase is the planning grant, which funds a planning process to identify priority action items to address vulnerabilities and utilize strengths in preparation for climate change.

The MVP planning process includes convening a team of municipal staff, engaging stakeholders in a Community Resilience Building Workshop (CRB) following a guidebook developed by the Nature Conservancy and engaging the public. Communities that complete the planning grant program and prepare an MVP Plan become eligible for the second phase of MVP grant funding, the action grants, and receive increased standing in other state grant programs. MVP action grants fund the implementation of priority climate adaptation actions described in the MVP Plan. Since these action grants are only distributed to Massachusetts municipalities, they are much less competitive than similar grants awarded at the nation level.

1.3 Hazard Mitigation and Municipal Vulnerability Preparedness Planning in Middleton

The Town of Middleton received an MVP Planning Grant to simultaneously prepare an MVP Plan and an HMP. Many of the required steps of the MVP process also satisfy requirements for updating an HMP. As a result, the Town prepared this joint HMP-MVP Plan in accordance with FEMA guidelines for hazard mitigation planning (*Title 44 Code of Regulations (CFR) 201.6*) and with the Massachusetts Executive Office of Energy & Environmental Affairs' (EEA) requirements. This enabled Middleton to consider the impacts of climate change in its hazard mitigation planning, following the lead established by the Commonwealth when it adopted the first-ever Massachusetts State Hazard Mitigation and Climate Adaptation Plan (EEA and EOPSS, 2018).

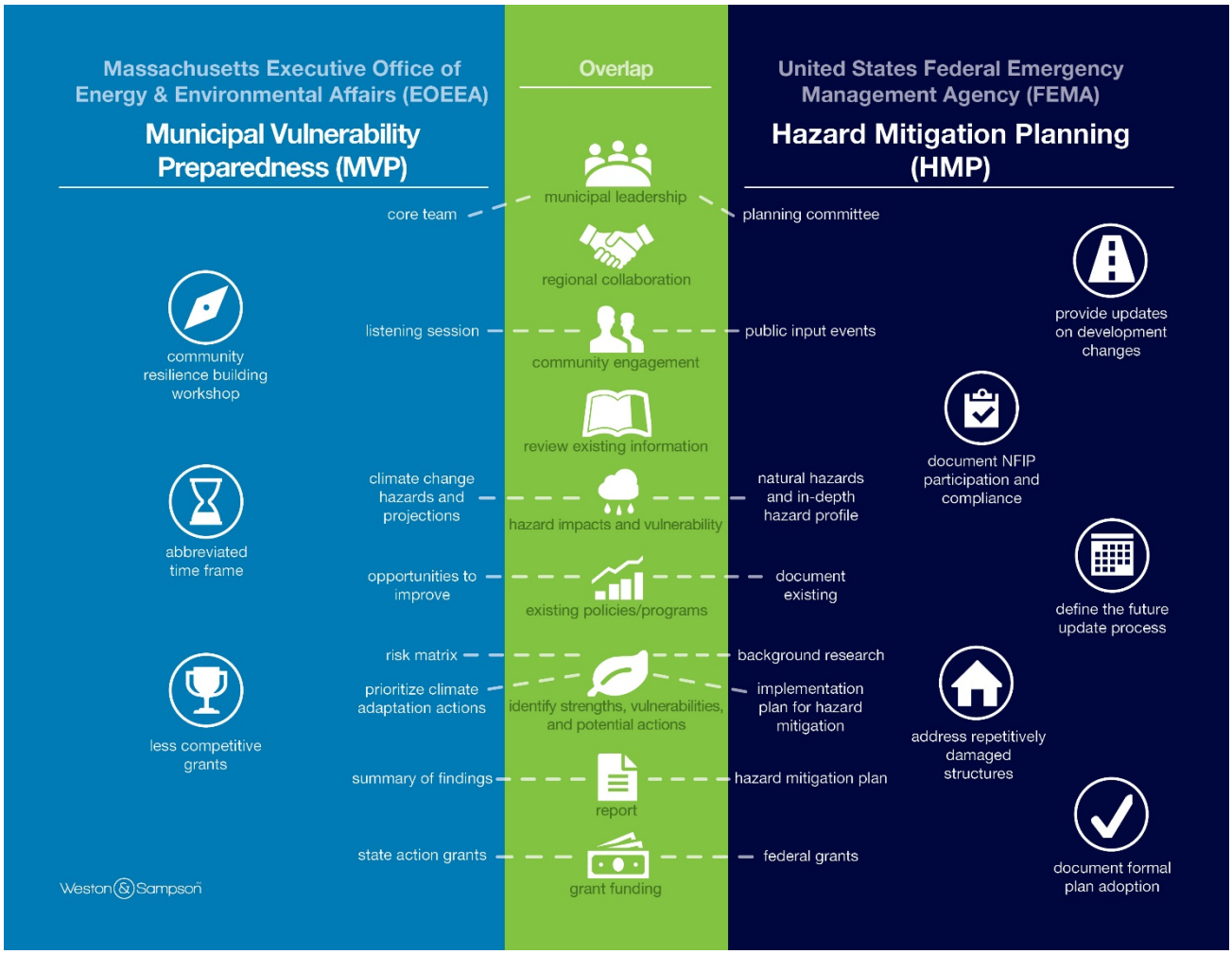

Figure 1-2. Comparison of the MVP and HMP Process (Weston & Sampson)

1.4 Planning Process Summary

The joint HMP- MVP Plan convened a Core Team of municipal leaders to lead the process and provide local expertise. The Core Team met once and corresponded via email and contributed through interviews. Stakeholder engagement followed the process described in the Community Resilience Building (CRB) Workshop Guidebook, which was developed by The Nature Conservancy (The Nature Conservancy, n.d.). The Guidebook provides a clear approach on how to organize the public process for mitigating the impacts of, and increasing resilience against, natural hazards and climate change. An important aspect of the CRB Workshop is the discussion among community members about creating a safer, more resilient community, which lead to the development of a plan that reflects the Town of Middleton's values and priorities. The public was also engaged through online engagement techniques rather than in person due to the health concerns surrounding COVID-19. The planning process also included a risk and vulnerability analysis of critical facilities and assets, in addition to the documentation of the Town's capacity to mitigate hazards and adapt to future climate projections.

CRB Workshop Guidebook

The CRB Workshop Guidebook provides a process for developing resilience action plans. The process has been implemented and successful in over one-hundred communities. The process, outlined below, is rich in information and dialogue and results in actionable plans and strong collaboration.

The CRB Workshop Guidebook's central objectives are to:

- Define top local natural and climate-related hazards of concern.
- Identify existing and future strengths and vulnerabilities.
- Develop prioritized actions for the Community.
- Identify immediate opportunities to collaboratively advance actions to increase resilience.

1.4.1 Core Team

The Town of Middleton convened the Core Team to act as a steering committee for the development of the HMP-MVP Plan. The Core Team met on November 7,, 2019 to plan for the Workshop, review public comments, develop the mitigation plan, and transition to implementation of the plan's mitigation strategies. More information on these meetings is included in Appendix A.

The Core Team established goals for the plan, provided information on hazards affecting the Town, identified critical infrastructure, identified key stakeholders, reviewed the status of existing mitigation measures, and developed proposed mitigation measures for this plan. Members of the Core Team are listed in Table 1-2.

Table 1-2. Middleton's Core Team

Name	Title
Andrew Sheehan	Town Administrator
Katrina O'Leary	Town Planner
Ken Gibbons	DPW Deputy Superintendent
Thomas J. Martinuk	Fire Chief
James DiGianvittorio	Police Chief
Frank Leary	Food Pantry Director
Kristin Kent	Conservation Agent
Derek Fullerton	Director of Public Health
Jillian Smith	Director of Council on Aging

The Core Team developed the invitation list for the CRB Workshop at which key stakeholders were invited to help the Town identify hazards, vulnerabilities, strengths, and proposed actions to mitigate the

impacts of natural hazards and climate change. The Core Team sought to include municipal leaders as well as politicians, representatives from local nonprofit organizations, other local jurisdictions, regional organizations, and state government. The Core Team also suggested or made available reports, maps, and other pertinent information related to natural hazards and climate change impacts in Middleton. These included:

- Town of Middleton Hazard Mitigation Plan (MAPC, 2012)
- Town of Middleton Master Plan 2019 (Middleton, 2019)
- Town of Middleton Open Space and Recreation Plan 2013 (Middleton, 2013)
- Massachusetts Climate Change Projections (NECSC, 2018)
- Massachusetts Climate Change Adaptation Report (EEA, 2011)
- Massachusetts State Hazard Mitigation and Climate Change Adaptation (EEA and EOPSS, 2018)
- Local Mitigation Plan Review Guide, October 2011 (FEMA, 2011)
- Flood Insurance Rate Maps, MA (FEMA, 2012)
- Storm Events Database, National Center for Environmental Information (NOAA, 2019)
- Decennial Census (US Census Bureau, 2010)
- American Community Survey, 5-year estimates (US Census Bureau, 2018)

1.4.2 Stakeholder Involvement: CRB Workshop

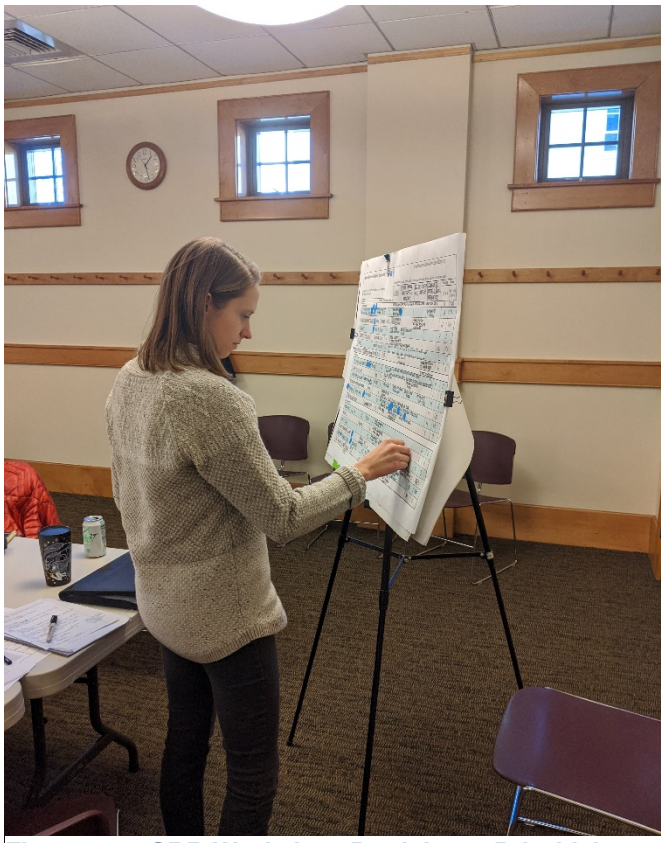

Figure 1-3. CRB Workshop Participant Prioritizing Actions

Stakeholders with subject matter expertise and local knowledge and experience, including public officials, regional organizations, neighboring communities, environmental organizations, and local institutions, were invited to engage in a two-part CRB Workshop, held on January 9th, 2020. During the first part of the CRB Workshop, Weston & Sampson provided information about natural hazards and climate change and participants identified top hazards; infrastructural, societal and environmental features in the Town that are vulnerable to or provide strength against these challenges. During the second part of the Workshop, participants identified and prioritized key actions that would improve the Town's resiliency to natural and climate-related hazards. There were multiple representatives present at the workshop that could provide regional input, including the Massachusetts State Representatives office, members of the Ipswich River Watershed Association, and the Essex County Greenbelt. Additionally, there were members of agencies that have the authority to regulate development, including the Conservation Commission and Planning Board.

Leadership from the neighboring communities of Boxford, Topsfield, Danvers, Peabody, Lynnfield, North Reading, North Andover were invited to participate in the Workshop, and representatives from the Town of Danvers attended. A table in Appendix C notes the names and positions of those stakeholders who were invited to and those who attended the Workshop. This broad representation of local and regional entities ensures the HMP-MVP Plan aligns with the operational policies and any hazard mitigation strategies at different levels of government and implementation.

1.4.3 Listening Session and Public Engagement

To gather information from the general public and to educate the public on hazard mitigation and climate change, the Town posted a video summary of the report and an accompanying online survey to collect comments. The draft plan was also posted on the Town's website between 05/08/2020 to 05/29/2020. Three responses were received. The plan, video, and survey was publicized by posting a notice on the webpage, posting to social media, and sending an email to the stakeholder list or invitees to the CRB workshop with a request to send it throughout their networks. A summary of the comments is available in the Appendix.

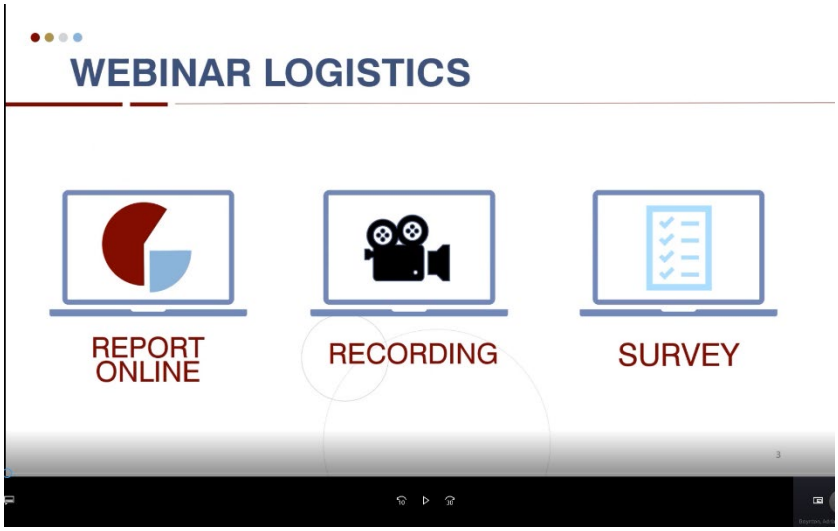

Figure 1-4. Screenshot of Public Listening Session Webinar

1.4.4 Report Layout

The report presents the results and input derived from the Core Team, CRB Workshop, and Listening Session in addition to the documentation of features, hazard profiles, and a vulnerability assessment. Features are assets or characteristics of the town that may contribute to the Towns resilience or may be a considered a vulnerability. Features are categorized into several types: societal, economic, infrastructure, land use, and environmental. The strength and vulnerability of these features are generally documented in Chapter 3, but Chapter 4 provides a more detailed assessment of the Town's vulnerability and strengths by hazard type. The hazard types cover the following: flooding, wind-related risk (hurricanes, tropical storms, tornados, nor'easters, and severe thunderstorms), winter storms, geological hazards (earthquakes and landslides), brush fires, extreme temperatures, and drought. Each hazard type's historic occurrences and impact, frequency, level of risk, and climate change projections are also described in each hazard profile. Chapter 5 lays out the existing mitigation measures the Town is already taking. Chapter 6 provides an update on the previous HMP's actions and lays out the action plan for moving forward. Chapter 7 describes the plan adoption, maintenance, and details on implementation.

1.5 Planning Timeline

The HMP-MVP planning process proceed according to the timeline below.

2.0 HAZARD MITIGATION AND CLIMATE ADAPTATION GOALS

The Town of Middleton's Core Team convened to reviewed and discussed the hazard mitigation and climate adaptation goals for the HMP-MVP Plan. The following seven goals were developed and endorsed by the Core Team.

1. Prevent and reduce the loss of life, injury, public health impacts and property damage resulting from all identified natural hazards and projected hazards under climate change.

2. Build and enhance local mitigation capabilities to ensure individual safety, reduce damage to public and private property and ensure continuity of emergency services.

3. Increase cooperation and coordination among private entities, Town officials and Boards, neighboring communities, State agencies and Federal agencies.

4. Increase awareness of the benefits of hazard mitigation and climate resiliency measures through outreach and education.

5. Identify and seek funding for measures to mitigate or eliminate each known significant hazard area and reduce the impacts of climate change.

6. Ensure that future development meets federal, state, and local standards for preventing and reducing the impacts of natural hazards today and under climate change projections.

7. Integrate hazard mitigation planning and climate change projections as an integral factor in all relevant municipal departments, committees and boards.

3.0 COMMUNITY PROFILE, LAND USE AND DEVELOPMENT TRENDS

3.1 Community Profile

Middleton is a Town full of involved citizens who care for their community. The Town prides itself on its ability to plan for future generations, while simultaneously protecting the past. The Town was first developed as a farming community in 1728 and its rich farming history is still evident to this day. Although Middleton continues to hold on to its small-town character, it is one of the fastest growing communities in the Commonwealth. The Town participates in state-of-the-art local and regional public education and is home to the most up-to-date Town facilities (Town of Middleton, 2019), making it a great place to live and raise a family. In 2010, the population of Middleton was 8,987 and by 2018 it had increased by more than 10%, up to 10,050 residents (U.S. Census Bureau). However, despite this growth, the Town has been able to maintain over 300 acres of open space and recreation land, under both public and private ownership (Town of Middleton, 2019).

Middleton lies on the eastern border of Essex County and is a neighbor to North Reading to the west, North Andover to the northwest, Boxford to the northeast, Topsfield to the east, Danvers to the southeast, Peabody to the south, and Lynnfield to the Southwest. Middleton is part of a tri-town regional school district with Boxford and Topsfield, which share Masconomet Regional High School. Middleton is 23 miles north of Boston and is just west of Interstate 95. The Town operates under an open town meeting form of government, presided over by a Town Moderator. A Town Administrator and five-member Board of Selectmen govern the Town. The Town maintains a website at http://www.middletonma.gov.

Table 3-1. Population Demographics

2018	Middleton	Massachusetts
Population	10,050	6,902,149
Under 18 years old	19%	20%
65+ Over 65 years old	18%	17%
Bachelor's degree or higher	40%	42%
Median household income	$107,727	$74,167
Individuals Living Below the Poverty Line	4%	10%
With a Disability	9%	8%
Limited English-Speaking Skills	8%	18%
Housing Units	3,045	2,864,989
Renter-Occupancy Rate	14%	38%
Burdened by Housing Costs	35%	50%

(US Census Bureau, 2018)

3.2 Societal Features

Middleton is a Town that prides itself on its sense of community and wealth of dedicated volunteers. The Town offers numerous social services, including a Senior Center, Public Library, and a Food Pantry. The Town's volunteer base and services are strengths that can be utilized for hazard mitigation planning, especially to reach the Town's most vulnerable populations. Vulnerable populations are people whose everyday stressors make it harder to adapt and recover when shocks or hazards occur. In Middleton, seniors, youth, people with disabilities, and low-income individuals are considered vulnerable. Due to the excellent school system and the proximity to jobs, the population of Middleton is growing quickly. As more families move into Middleton, the youth population continues to grow. Middleton's rapidly growing population may also be considered a vulnerability, as well as a strength. Emergency services capacity will need to grow at the same rate of population growth.

CRB Workshop Discussion of Societal Features

Workshop participants identified those key societal aspects of Middleton that are most vulnerable to, or provide protection against, natural hazards and climate change impacts.

Table 3-2. Societal Features and Natural Hazards/Climate Change in Middleton

Strengths	Vulnerabilities
• Schools • Senior Center services • Food pantry • Emergency shelters • Local economy • Youth population	• Backup power at schools, 55+ housing, and large apartment buildings • Transportation and mobility for people who do not drive • Need for more coordination with Essex County Jail and Department of Youth Services Facility • Emergency communication and outreach • People vulnerable to isolation (elderly and disabled)

3.3 Economic Features

A small, primarily residential community, many of Middleton's residents commute to work. Large storms and flooding can disrupt commutes and at times cause economic loss. Ensuring residents are safe traveling to and from work is a top priority. Middleton's rapid population growth has helped it become a more business-friendly community. There are many economic development resources available, including the Middleton Board of Trade, which is an organization of over 100 local business owners, managers, and residents whose purpose is to advance the commercial, industrial, civic, and general interests of the Town of Middleton (Town of Middleton, 2020). The top employment industries within Middleton are management, business, science, and arts occupations (U.S. Census Bureau, 2018). Communication between businesses and the Town will be key when moving forward the hazard mitigation planning efforts and ensuring large employers have emergency protocols in place.

Table 3-3. 2018 Economic Statistics

	Middleton	Massachusetts
Labor Force	7,984	3,755,481
Unemployment Rate	5.4%	6.0%
Employed in Top Employment Industry	48.4%	28.2%
Commuters who drove to work	91%	78.1%

(United States Census Bureau, 2010 and United States Census Bureau, 2018)

3.4 Infrastructure Features

Route 114 is the backbone of Middleton, running north-west to south-east through the center of Town. This connects Middleton to all major highways in the area, including I-95, I-495, and I-93 by extension. Middleton is in a centralized location, with easy access to Massachusetts' Northshore, Boston, and into New Hampshire. The nearby MBTA stops in Reading and Beverly provide commuter rail access to Boston. Roads and bridges are impacted by snow, ice, downed trees, and in some cases flooding. Danvers supplies water for the majority of Middleton, and the rest of the town is on private wells. Public drinking water is primarily provided by surface water supply from three reservoirs. There are two well fields, located in Middleton and Danvers, that can provide supplemental supply. The water treatment plant for these two towns is owned by Danvers and located in Middleton. Although the Danvers Water Department is responsible for the treatment and supply of the potable water, the Middleton Water Division is responsible for the water quality during transmission through the distribution system. The distribution system consists of 36 miles of water lines, 398 fire hydrants, 1,385 residential service connections and 141 commercial and institutional service connections (Middleton, 2013). This water system supplies 35,480 customers across the two towns (Danvers, 2019). Approximately 13% of the population of Middleton is serviced by sewer. Sewer lines are located on Village Road, Locust Street, Mansfield Road, Nichols Lane. The sewer system ties into the South Essex Sewer District, which connects to the treatment plant located in Salem, MA (Town of Middleton, 2013).

Middleton is home to the Middleton Electric Light Department (MELD), which provides electric power to the Town of Middleton. As an environmentally conscious company, MELD purchases electricity from a variety of sustainable sources, including hydro, wind, solar, and nuclear. A photovoltaic array is located in Middleton as well.

CRB Workshop Discussion of Existing Infrastructure

Workshop participants identified those key infrastructure features in Middleton that are most vulnerable to, or provide protection against, natural hazards and climate change impacts, which can be seen in Table 3-4 below.

Table 3-4. Infrastructure Features and Natural Hazards/Climate Changes in Middleton

Strengths	Vulnerability
• Municipal Light Department • Opportunities for green infrastructure at the library and other municipal buildings • Opportunity to expand solar • Emergency response facilities • Water treatment plant • Communications infrastructure • Municipal departments and services	• Flooding of bridges, for example the decreased access to east corner of town and to the Water Treatment Plant, • Flooding of roadways School St, Route 144, South Main St, and East St • Undersized culverts • Dam conditions, maintenance, and need for communicated emergency action plans • Communication and electric redundancies • Water supply during drought • Private well management • Flooding of Town Hall • Cooling of municipal buildings • Rising groundwater impact on septic systems

3.5 Environmental Features

The Town has a total land area of approximately 14.5 square miles. Much of the land in Middleton has been acquired to preserve as open space. Middleton has a plethora of ponds, reservoirs, river, and other water resources. The Ipswich River runs through Middleton. Other bodies of water in the Town include the Emerson Brook Reservoir, Middleton Pond, Creighton Pond, Upper Boston Brook Pond, Lower Boston Brook Pond, Boston Brook, and an unnamed tributary flowing from Middleton Pond to the Ipswich River. All of these water resources are possible sources of localized flooding. Nonpoint source pollution is a concern within many of the water bodies from stormwater runoff, agriculture, and yard fertilizers among other sources.

There are several aquifers within the town boundaries which are protected by the town. Other protection areas include water supply protection areas, reservoir watershed protection area, as well as other water resource areas. One of the water supply wells is located on the Ipswich River, and the other well is just across the town line. Both wells are located within a single water supply protection area (Town of Middleton, 2013). The main water supply sources located in Middleton are Middleton Pond and the Emmerson Brook Reservoir. Other facilities of concern are located within protection areas, including a landfill located in a reservoir watershed protection district. Ten percent of land in Middleton is owned by Danvers for its reservoirs and protection areas.

Thousands of years ago, glaciers tore their way through Middleton. As glacial deposits blocked the flow of water, the lower areas filled with organic matter, slowing infiltration, and these areas developed into bogs and swamps. Approximately one-quarter of the land area in Middleton is classified as wetlands. The Town of Middleton contains a range of soil types from well drained soils formed in glacial outwash, all the way to very poorly drained organic soils.

The Massachusetts DEP Bureau of Waste Site Cleanup lists 72 sites in Middleton where reportable release of oil and/or hazardous material have occurred. However, no known areas of protected open space are impacted by contamination from these hazardous waste sites. There are four landfills in Middleton, all dating from the 20th century. Two landfills, the Town Landfill and the Rubchinuk Landfill, are being monitored.

CRB Workshop Discussion of the Environment

Workshop participants identified those key environmental features in Middleton that are most vulnerable to, or provide protection against, natural hazards and climate change impacts.

Table 3-5. Environmental Features and Natural Hazards/Climate Change in Middleton

Strengths	Vulnerabilities
• Waterbodies • Stream Team • Conservation land • Agricultural land • Open space and forests • Trails • Wildlife	• Need to update regulations and bylaws to protect open space, the north end of town is especially vulnerable to sprawling development • Groundwater pollution and groundwater rising • Water quality issues in waterbodies and increased temperatures • Beaver dams and flooding • Low flows and water levels during drought • Air quality • Hazardous waste management • Invasive species and increase in vector borne diseases

3.6 Land Use

The Land Use Summary Statistics figure below displays land use in the Town of Middleton. The most recent land use statistics available are based on 2020 digital ortho imagery. Figure 3-1 displays the land use categories within Middleton by percent cover. Total residential use makes up 44% of the town land. The second greatest land use type is institution and tax-exempt, which includes all Massachusetts-owned land. This accounts for 18% of the Town. Commercial use makes up 8%, while industrial makes up 3%. Recreation, open space, and open water make up 14% of the total area. However, this does not include any state-owned land, including DCR & DCAMM property, which is classified under tax-exempt or institutional.

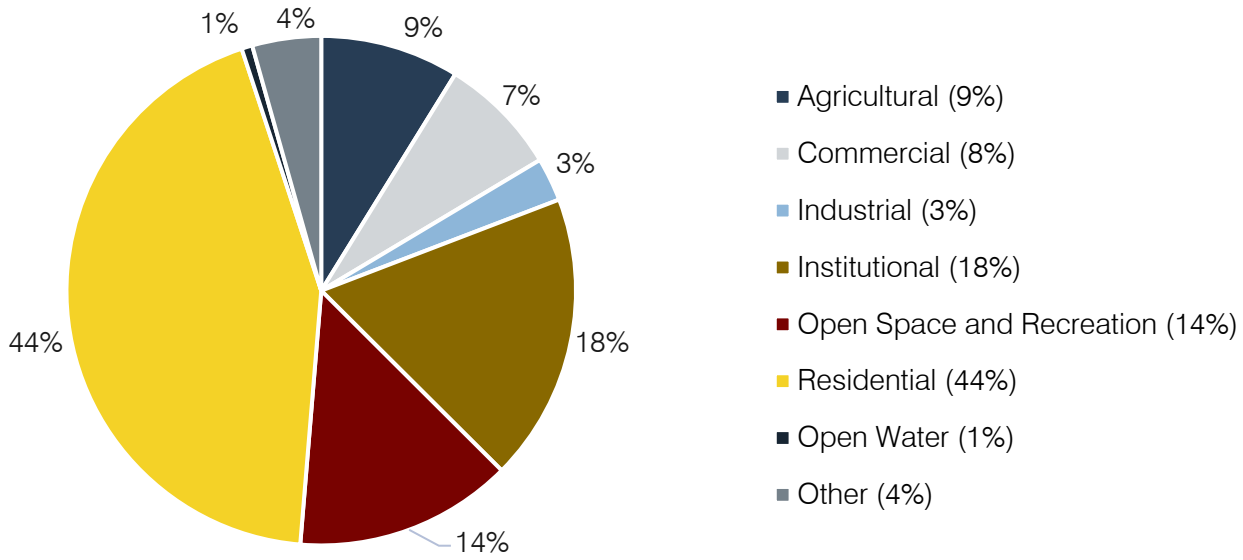

Figure 3-1. Middleton Land Use
(Mass GIS, 2020)

Recent and Planned Development

The Middleton Conservation Agent reviewed recent and potential future development within the Town. The Middleton Conservation Commission is proactive in encouraging new developments to stay outside of the setbacks to wetlands, and to preserve wetlands, riverfront areas, and open space with conservation restrictions. Recent development has mainly been residential and commercial, with much of the development along Main Street in addition to subdivision clusters. Middleton will continue to monitor and regulate development to protect the Town's natural resources. Beyond protecting natural resources, stormwater impacts are a growing concern with new development, and new regulatory updates may be necessary to reduce polluted runoff from entering waterways.

Developments were identified using MAPC's MassBuilds Database, which provides an inventory of recent, future, and potential development. This table was cross checked for accuracy by the Town's Conservation Agent. The final database included twelve residential developments, nine industrial/commercial developments and one educational development recently completed or planned in Middleton. Also included in the MassBuilds Database are several attributes of the new development,

including development acreage, number of housing units, commercial area, and project type for recent, in construction, and planning-phase development (Table 3-6).

Table 3-6. Current and Future Development in Middleton

Name	Address	Year Completed	Housing Units	Commercial Square Feet	Project Type
97 North Main Street	97 North Main Street	In Construction (2020)	19	0	Residential
North Shore Business Center	30 Log Bridge Road	2015	0	77,000	Institutional
Old Essex Estates	17 Old Essex Street	2020	6	0	Residential
East Meadow Farm	East Meadow Lane	2018	21	0	Residential
11 East Street	11 East Street	2015	0	4,200	Commercial
Beech Brook Farms Subdivision	161 Essex Street	Planning (2020)	5	0	Residential
81 North Main Street	81 North Main Street	2019	0	5,030	Commercial
Apex Chimney Company Inc.	2 1/2 Debush Avenue	2018	0	100	Industrial
NorthShore Bank/Circle Furniture	237 South Main Street	2014	0	17,400	Commercial
North Meadow Village	225 North Main Street	2018	42	0	Residential
Cumberland Farms	4 South Main Street	2018	0	100	Commercial
Ferncroft Country Club	8 Village Road	2016	0	8,564	Commercial
Bay Property North	177 North Main Street	In Construction (2020)	0	199,150	Commercial
Ridgewood Estates	84 East Street	In Construction (2020)	55	0	Residential
Estates on the Green	18 Village Road	2019	8	0	Residential
Ohlson Way Subdivision	64/64R East Street	2018	5	0	Residential
Middleton Crossing	147 South Main Street	2016	0	29,227	Commercial
Essex Woods Estates	127 Essex Street	2019	9	0	Residential
Lewis Drive Subdivision	77 South Main Street	2019	9	0	Residential
59 South Main Street	59 South Main Street	Planning (2020)	45	0	Residential

Table 3-6. Current and Future Development in Middleton

Name	Address	Year Completed	Housing Units	Commercial Square Feet	Project Type
63 South Main Street	63 South Main Street	Planning (2020)	4	0	Residential
217R South Main Street	217R South Main Street	Planning (2020)	0	55,750	Industrial/ Commercial
Total			228	396,321	

(MAPC, 2020; Kent, 2020)

3.7 Critical Facilities and Vulnerable Populations

Critical facilities are extremely essential components to the Town's function and protecting them from natural hazards is paramount. Critical facilities range in function from: 1) resources that can be utilized to respond and recover from natural hazards; 2) facilities where additional assistance might be needed; and 3) hazardous sites that could be dangerous if it is compromised during a natural disaster. Critical facilities in the Town of Middleton have been identified with help from knowledgeable Town staff, MassGIS data, existing Town and Regional Plans, and the assessment of other Town features presented in previous sections. Critical facilities and vulnerable populations have been broken into four categories: Emergency Response, Non-Emergency Response, Dangerous/Hazard Materials and Facilities, and Facilities and Populations to Protect. Emergency response facilities that are necessary for the Town in the event of a disaster. Non-emergency facilities are considered essential for the everyday operation of Middleton.

Table 3-7. Category 1 - Emergency Response Facilities

Type	Name	Location
Public Safety	Police Department	65 North Main Street
	Fire Department	4 Lake Street
Town Facilities	Department of Public Works	195 North Main Street
	Electric Department	197 North Main Street
	Danvers Water Treatment Facility	30 Lake Street
Communication and Utilities Infrastructure	Verizon Telephone Hut	14 Maple Street
	MIT Public Communication Tower	21 Manning Ave
	Northshore Regional 911 Center	18 Manning Ave
	Cell Tower	Oak Street
	Communication Tower	Ajootian Way
Emergency Shelters	Fuller Meadow School	141 South Main Street
	Howe-Manning School	26 Central Street
Primary Evacuation Routes	Route 114	
	Route 62	
Critical Bridges, Intersections, and Sites	Thunder Bridge Maple Street Bridge	

Table 3-7. Category 1 - Emergency Response Facilities

Type	Name	Location
	Route 114 Bridge	

Table 3-8. Category 2 – Non-Emergency Response Facilities

Type	Name	Location
Traffic Control Points	South Main at River Street	
	Maple Street at Gregory Street	
	North Main St at Forest Street	
	South Main Street at Maple Street	
	South Main Street at Boston Street	
Town Facilities	Town Hall	48 South Main Street
	Senior Center	38 Maple Street
	Flint Public Library	1 South Main Street
Natural Resources	Middleton Pond	
	Creighton Pond	
	Emerson Brook Reservoir (Forest Street Pond)	
	Upper Boston Brook Pond	
	Traggetts Pond	
	Prichard's Pond	
	Mill Pond	
	Curtis Pond	
	Ipswich River	
	Aunt Betts Pond	
	Boston Brook	
	Nichols Brook	
	Lower Boston Brook Pond	

Table 3-9. Category 3 – Dams and Hazardous Sites

Type	Name	Location
Dams	Middleton Pond Outlet Dam	
	Middleton Pond Southeast Dike	
	Ipswich River Dam	
	Paradise Park Dam	
	Creighton Pond Dam	
	Curtis Pond Dam	
	Mill Pond Dam	
	Prichard Pond Dam	
	Middleton Landfill	
Landfills	Rubchinuk Landfill	
	Mizichuk Landfill	
	Johnson Dump Site	

Table 3-9. Category 3 – Dams and Hazardous Sites

Type	Name	Location
	Ferrell Gas	156 S Main Street
Fuels & Hazardous Materials (Tier II Site)	Bostik, Inc.	211 Boston Street
	Bouchard's Getty	212 Maple Street
	Maritime Gas Line/Northeast pipeline	5 Batchelder Road

Table 3-10. Category 4 - Vulnerable Populations and Community Facilities

Type	Name	Location
Housing Authority Properties	Middleton Housing Authority	Orchard Circle
Elderly Housing/Assisted Living	Oak Knoll	61 North Main Street
	North Shore Senior Care LLC	2 South Main Street
Special Needs Facilities	North Shore Assoc. for the Mentally Handicapped	59 North Main Street
	Turning Point Group Home	37 Gregory Street
Youth Services	Department of Youth Services	33 Gregory Street
Schools	Fuller Meadow School	143 South Main Street
	Howe-Manning Elementary School	26 Central Street
	The Goddard School of Middleton	244 Maple Street
	MIT Bates Research and Engineering Center	21 Manning Have
Daycare	Great Expectations Child Care	13 Rundlett Way
	Amy's Family Daycare	18 Webb Street
	Magical Beginnings River Academy	225 Maple Street
	Rachel Perrella	42 East Street
Grocery and Supplies Stores	Walgreens	230 South Main Street
	CVS Pharmacy	220 Maple Street
	Farmer Browns	210 Maple Street
	Richardson's Dairy	156 South Main Street
	Market Basket	230 South Main Street
Religious Centers	St. Agnes Parish	22 Boston Street
	Middleton Congregational Church	66 Maple Street
Corrections Facilities	Essex County House of Corrections	20 Manning Ave
	Northeast Family Institute	33 Gregory Street
Mortuary Facilities / Cemeteries	Peterson-O'Donnell Funeral Home	167 Maple Street
	Lyons & Sons Funeral Home	28 Elm Street
	Oakdale Cemetery	83 Maple Street
	Mackey Funeral Home	128 South Main Street
Census Tracts	25% are younger than age 18	See map in Appendix C
	25% are greater than age 65	See map in Appendix C

4.0 HAZARD PROFILES, RISK ASSESSMENT & VULNERABILITIES

Each hazard profile contains information on the areas vulnerable to the hazard, documentation of historic events, a risk and vulnerability assessment, and projected climate risk. The risk and vulnerability assessment examines both the frequency and severity of hazards and their potential impact to the Town of Middleton. Each hazard risk and vulnerability assessment uses previous occurrences and along with climate projects to determine areas that are more at risk as well as the likelihood that a hazard will occur. The vulnerability analysis looks at various factors in the community, such as existing and future buildings, infrastructure, and critical facilities. In some cases, an estimate of the potential dollar loss to vulnerable structures is available. Land uses and development trends were of particular interest in the flood vulnerability assessment.

The hazard profiles were updated with information from the *2013 Massachusetts State Hazard Mitigation Plan* (MEMA and DCR, 2013); the *2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan* (SHMCAP) (EEA and EOPSS, 2018) and additional research and assessment. The Core Team, CRB Workshop, and Listening Session results provided local accounts of each hazard. A Geographic Information System (GIS) assessment was conducted to analyze the potential impact of flooding in Middleton on current and future development. FEMA's Hazus software was used to model potential damage of hurricanes and earthquakes.

4.1 State-wide Overview of Hazards

4.1.1 Massachusetts State Hazard Mitigation and Climate Adaptation

The 2013 Massachusetts State Hazard Mitigation Plan (MEMA and DCR, 2013) and the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) (EEA and EOPSS, 2018) examined the natural hazards that have the potential to impact the Commonwealth. These plans summarize the frequency and severity of hazards of greatest concern. The frequency classification ranges from very low to high. Severity classifications are listed as a range from minor severity to catastrophic. The box below gives further definitions of the Frequency and Severity characterizations.

Definitions used in the Commonwealth of Massachusetts State Hazard Mitigation Plan

Frequency

- *Very low frequency*: events that occur less frequently than once in 100 years or less than 1% per year.
- *Low frequency*: events that occur from once in 50 years to once in 100 years or 1% to 2% per year.
- *Medium frequency*: events that occur from once in 5 years to once in 50 years or 2% to 20% per year.
- *High frequency*: events that occur more frequently than once in 5 years or greater than 20% per year.

Severity

- *Minor*: Limited and scattered property damage; limited damage to public infrastructure and essential services not interrupted; limited injuries or fatalities.
- *Serious*: Scattered major property damage; some minor infrastructure damage; essential services are briefly interrupted; some injuries and/or fatalities.
- *Extensive*: Widespread major property damage; major public infrastructure damage (up to several days for repairs); essential services are interrupted from several hours to several days; many injuries and/or fatalities.
- *Catastrophic*: Property and public infrastructure destroyed; essential services stopped; numerous injuries and fatalities.

Table 4-1 summarizes the frequency and severity of hazard risk in the Commonwealth. These frequency and severity classifications will assist the Town in prioritizing mitigation actions for each hazard.

Table 4-1. Hazard Risk Summary

Hazard	Frequency	Severity
	Massachusetts	Massachusetts
Inland Flooding	High (1 flood disaster declaration event every 3 years; 43 floods per year of lesser magnitude)	Serious to Catastrophic
Dam failures	Very Low	Extensive to Catastrophic
Coastal Hazards	High (6 events per year over past 10 years)	Serious to Extensive
Tsunami	Very Low (1 event every 39 years on East Coast, 0 in MA)	Extensive to Catastrophic
Hurricane/Tropical Storm	High (1 storm every other year)	Serious to Catastrophic
High Wind	High (43.5 events per year)	Minor to Extensive
Tornadoes	High (1.7 events per year)	Serious to Extensive
Thunderstorms	High (20 to 30 events per year)	Minor to Extensive
Nor'easter	High (1 to 4 events per year)	Minor to Extensive
Snow and Blizzard	High (1 per year)	Minor to Extensive
Ice Storms	High (1.5 per year)	Minor to Extensive
Earthquake	Very Low (10-15% probability of magnitude 5.0 or greater in New England in 10 years)	Minor to Catastrophic
Landslide	Low (once every two years in western MA)	Minor to Extensive
Brush Fires	High (at least 1 per year)	Minor to Extensive
Extreme Temperatures	High (1.5 cold weather and 2 hot weather events per year)	Minor to Serious
Drought	High (8% chance of "Watch" level drought per month)	Minor to Serious

(MEMA and DCR, 2013 and EEA and EOPSS, 2018)

Not all hazards included in the 2018 SHMCAP apply to the Town of Middleton. Given Middleton's inland location, coastal hazards and tsunamis are unlikely to affect the Town. However, some of the

neighboring communities would be more affected by coastal threats. Given the smaller scale of fires that have occurred in Middleton's history and in the northeast region of the country, the Town will focus on brushfires rather than wildfires due to their smaller size. It is assumed that the entire Town of Middleton and its critical facilities are exposed to earthquakes, high wind events, hurricanes, winter storms, temperature extremes and snow and ice, to a similar extent. Flood risk from riverine flooding is elevated in the vicinity of the flood zones. Landslides are more likely in areas with more unstable soil types.

4.1.2 Federally Declared Disasters in Massachusetts

Tracking historic hazards and federally declared disasters that occur in Massachusetts, and more specifically Essex County, helps planners understand the possible extent and frequency of hazards. Historically, Massachusetts has experienced multiple types of hazards, including flooding, blizzards, and hurricanes. Since 2000, there have been 29 storms in Massachusetts that resulted in federal or state disaster declarations. Twenty-two disaster declarations occurred in Essex County. Federally declared disasters open up additional FEMA grant opportunities for regional recovery and mitigation projects. The hazard profiles contain further information about federally declared disasters.

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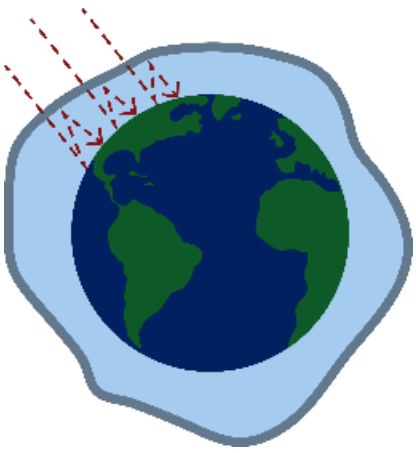
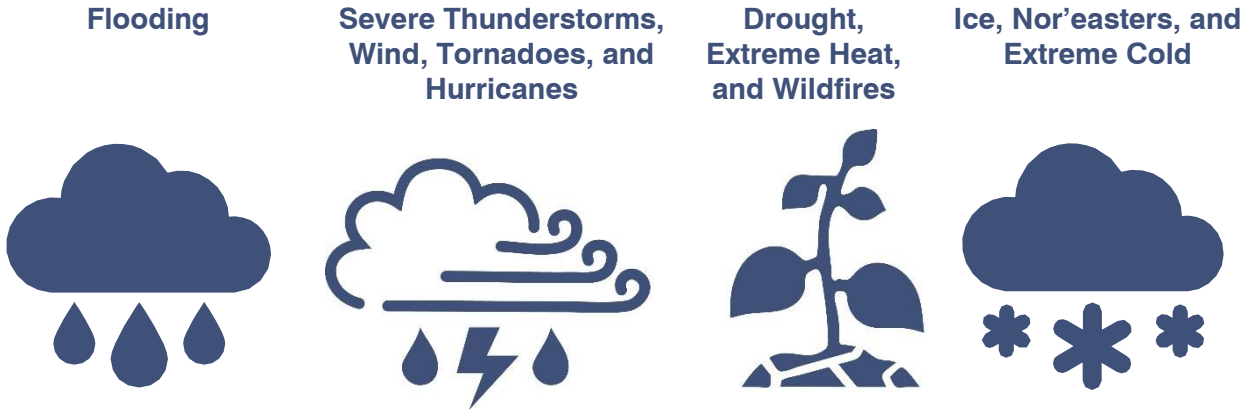
4.1.3 Impacts of Climate Change



Many of the hazards that Middleton commonly experiences are projected to worsen due to climate change. Climate change refers to changes in regional weather patterns that are linked to warming of the Earth's atmosphere as a result of both human activity and natural fluctuations. The Earth's atmosphere has naturally occurring greenhouse gases (GHGs), like carbon dioxide (CO2), that capture heat and contribute to the regulation of the Earth's climate. When fossil fuels (oil, coal and gas) are burned, GHGs are released into the atmosphere and the Earth's temperature tends to increase. The global temperature increase affects the jet stream and climate patterns. The climate in Massachusetts is expected to reflect historic climate patterns of Southern New England or Mid-Atlantic States depending upon GHG emission scenarios. Climate change has already started to change the climate in Massachusetts and these trends are likely to continue. Climate change is likely to affect Massachusetts' typical precipitation cycle, leading to more intense rainfall and storms and more episodic or flash droughts. Temperatures will increase in both summer and winter. Each of the hazard profiles provided below includes more detail on how hazard frequency and intensity are likely to shift with climate change.

4.1.4 Top Hazards as Defined in the CRB Workshop

Workshop participants were asked to identify the four top hazards/climate change impacts that Middleton faces (see below).



Flooding of roadways, bridges and other infrastructure were listed as key examples and reasons to focus on flooding. Severe storms and wind also have an impact on electric utilities. However, the Electric Light Department's proactive tree maintenance program was credited for decreasing the vulnerability of the system. Drought was chosen as a top priority because of the potential decrease is water supply. As a community with a lot of forested land, Middleton is also susceptible to brush fires. Ice storms, Nor'easters, and winter weather can result in property damage and threats to public safety

Participants identify hazards and vulnerabilities during Middleton's CRB Workshop

4.2 Flood-Related Hazards

Flooding was one of the four main hazards identified by participants during Middleton's CRB workshop. Flooding can be caused by various weather events including hurricanes, extreme precipitation, thunderstorms, nor'easters, and winter storms. While Middleton currently experiences these events, the

impacts of climate change will likely lead to increasingly severe storms and, therefore, increasingly severe flooding. In addition, undersized stormwater system components and culverts lead to flooding in Middleton, which is further described below. Beaver dam activity and poor soil drainage also cause flooding in certain areas.

The effects of flooding include injury or death, property damage, and traffic disruption. Flood hazards are directly linked to erosion, which can compromise receiving water quality, slope stability, and the stability of building foundations. This puts current and future structures and populations located near steep embankments at risk. Erosion can also undercut streambeds and scour around stream crossings, creating a serious risk to roadways. Areas within the FEMA Flood Zones, repetitive loss sites, and local areas identified as flood prone are more vulnerable to the impacts of flooding.

The following sub-sections provide more information on historic flooding events, potential flood hazards, a vulnerability assessment, locally identified areas of flooding, and information on the risk of dam failures. This analysis of flood hazard areas was informed by the FEMA NFIP Flood Insurance Rate Maps (FIRMs), a GIS vulnerability analysis, information from Middleton town staff, and accounts of past flood events provided by participants during the Middleton CRB Workshop.

4.2.1 Areas Vulnerable to Flooding

Flooding can be both riverine (topping the banks of streams, rivers, ponds) and from stormwater, if the drainage system is blocked or undersized.

Riverine Flooding

Middleton is located entirely within the Ipswich River Watershed. The Ipswich River flows through 13 communities before emptying into Plum Island Sound and Ipswich Bay. A series of lakes, ponds, river, and smaller waterbodies dot the landscape of the town. These include:

- Emerson Brook Reservoir
- Middleton Pond
- Creighton Pond
- Traggerts Pond
- Prichard's Pond
- Mill Pond
- Emerson Bog
- Pond Meadow (Pout) Pond
- Aunt Bett's Pond
- Ipswich River
- Boston Brook

FEMA Flood Insurance Rate Maps (FIRM) designate areas likely to experience flooding. The FIRM delineates both the special flood hazard areas and the risk premium zones under the NFIP. This includes high risk areas that have a one percent chance of being flooded in any year (often referred to as the "100-year floodplain"), which under the NFIP, is linked to mandatory purchase requirements for federally backed mortgage loans. It also identifies moderate to low risk areas, defined as the area with a 0.2 percent chance of flooding in any year (often referred to as the "500-year floodplain"). The definitions of these flood zones are provided below. FEMA-designated flood zones for Middleton (FEMA, 2012) are included in Appendix C. The FEMA flood zone surrounds most of the water bodies and wetlands areas listed above.

Flood Insurance Rate Map Zone Definitions

Zone A (1% annual chance): Zone A is the flood insurance rate zone corresponding to the 100-year floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods. Detailed hydraulic analyses are not performed for such areas, therefore, no BFEs (base flood elevations) or depths are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zone AE and A1-A30 (1% annual chance): Zones AE and A1-A30 are the flood insurance rate zones that correspond to the 100-year floodplains that are determined in the FIS by detailed methods. In most instances, BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

Zone X (0.2% annual chance): Zone X is the flood insurance rate zone that corresponds to the 500-year floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs or depths are shown within this zone.

(FEMA, 2019b)

Repetitive Loss Sites

As defined by FEMA and the NFIP, a repetitive loss property is any insured property which the NFIP has paid two or more flood claims of $1,000 or more in any given 10-year period since 1978 (FEMA, 2019e). Middleton has two repetitive loss structures. Both of these structures are located within B, C, or X zones, which are defined by FEMA as areas of moderate or minimal flood Hazard (DCR, 2020a). One of the repetitive loss structures is insured through the National Flood Insurance Program.

Table 4-2. Flood Insurance Data and Repetitive Loss Data

Flood Insurance Data		Repetitive Loss (RL) Data	
Flood Insurance Policies in Force	29	RL Buildings	2
Premium	$16,044	RL Losses	4
Insurance in Force	$8,811,000	RL Payments (total)	$14,389
Number of Closed Paid Losses	9	RL Payments (building)	$14,389
Dollar Amount of Closed Paid Losses	$135,171	RL Payments (contents)	$0

It is important to remember that repetitive loss data only includes buildings that qualify for the repetitive loss designation, which does not represent all losses due to flooding. The numbers of buildings that experience losses due to flooding is likely higher than what is reported above.

Stormwater Flooding

Stormwater flooding occurs during a precipitation event where the rate of rainfall is greater than the stormwater management system can handle. This may be due to an undersized culvert, poor drainage, topography, high amounts of impervious surfaces, or debris that causes the stormwater system to function below its design standard. In these cases, the stormwater management system becomes overwhelmed, causing water to inundate roadways and

properties. Stormwater flooding can occur anywhere in Town and is not limited to areas surrounding water bodies.

Most stormwater systems in Massachusetts are aging and have been designed with rainfall data that is no longer accurate. Figure 4-1 shows how the amount of rainfall of design storm data has increased from 1961 to 2015, especially for the larger 24-hour, 100-year event. Green infrastructure or low impact development improvements can help reduce stress on the capacity of the existing stormwater system by increasing infiltration on site. A rain garden or pervious pavement are example strategies. Upsizing culverts with new rainfall data is also recommended.

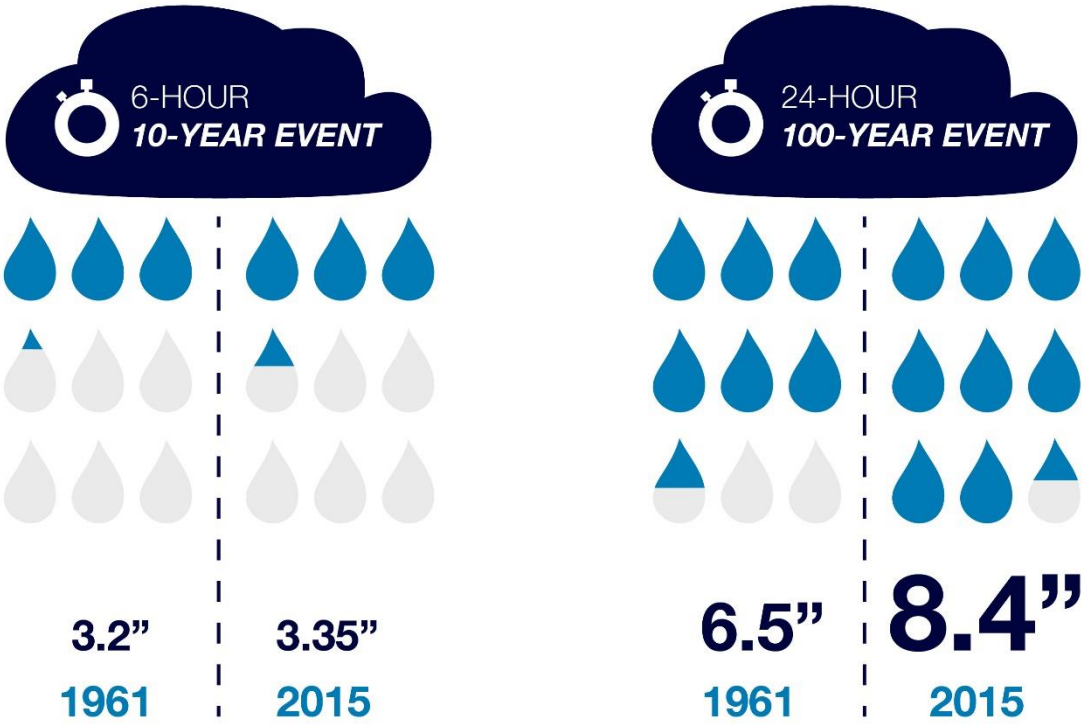


Figure 4-1. Stormwater Design Standards (US Weather Bureau, 1961 and NOAA, 2015)

Locally Identified Areas of Flooding

Town staff and stakeholders helped identify local areas of flooding, summarized in Table 4-3 below. These areas may or may not directly overlap with the FEMA-designated flood zones previously discussed; however, these areas have been noted to flood during a significant rain event. This is often due to topography and/or insufficient stormwater drainage.

Table 4-3. Locally Identified Areas of Flooding

Name	Description
Route 114, Evacuation Route	Low lying area with critical infrastructure. Bridge in need of repair, increased elevation, and protection of utilities.
Route 62, Evacuation Route	Narrow road in bad condition that often floods. Bridge in need of repair, increased elevation, and protection of utilities.
Town Hall	Basement floods
Aunt Betts Pond	Beaver flooding
Brigadoon Development (South Main Street)	Lower part of the development often floods, this causes issues with the septic systems
Peabody and East Streets	Flooding in streets causes damage to residences
Lonergan Road	Loss of flood storage along the Ipswich River led to flooding on this road
River Street	Several undersized culverts
Essex Street	Low spot in the road and culverts are undersized
Perkins Road	Undersized culvert
Thunderbridge Neighborhood	Low spot in road floods during large storm events

Middleton and Essex Flooding Events

NOAA's National Centers for Environmental Information Storm Events Database (NOAA, 2019a) provides information on previous flood and flash flood events for Essex County. Flash flood events are considered by the NOAA's National Centers for Environmental Information Storm Events Database as "A life-threatening, rapid rise of water into a normally dry area beginning within minutes to multiple hours of the causative event (e.g., intense rainfall, dam failure, ice jam)" (US Department of Commerce et al., 2018, p.A-15). Floods are considered, "Any high flow, overflow, or inundation by water which causes damage. In general, this would mean the inundation of a normally dry area caused by an increased water level in an established watercourse, or ponding of water, that poses a threat to life or property" (US Department of Commerce et al., 2018, p.A-20).

Between 2000 and 2019, Essex County has had 63 flood events and 33 flash flood events. Two deaths and three injuries were reported due to the flood events. The property damage totaled $38.276 million dollars (not adjusted for inflation). The flooding in March 2010 caused approximately one-third of the total property damage reported during this time period (over $13 million). Property damage ranged from $500 to $10 million, showing the magnitude and range of the amount of damage possible. Damage that occurs regionally can also have an indirect impact on Middleton because of its central location and regional utilities. The database provides details on several flood events in Middleton or describes flooding of the Ipswich River. The dates of the major flood events that affected the Town are below (NOAA, 2019a).

May 13, 2006 — Heavy rainfall, most of it falling over a 100-hour period, caused widespread flooding of small streams the Ipswich River. The Ipswich River had record flows, higher than the crests of the 1938 Hurricane and 1936 heavy rain/snowmelt floods. Storm rainfall totaled 8 to 12 inches across the area with a few locations in Essex County even exceeding 12 inches. The event was a federally declared disaster.

March 14, 2010	The event had rainfall totals on the order of six to ten inches and caused flooding across Essex County, including the Ipswich River in south Middleton. A 15-year-old girl was hospitalized for hypothermia after spending 45 minutes in the Ipswich River when the canoe she was in capsized. Strong winds from the storm also resulted in numerous downed trees and wires and some minor structural damage to a few buildings in Essex County. The event was a federally declared disaster.
March 30 - April 1, 2010	Three to seven inches of rain fell across Essex County. Small streams and the Ipswich River in south Middleton flooded. A coastal front along the I-95 corridor enhanced rainfall. Flooding was worsened because the waterbodies were already quite full following the heavy rainfall and record flooding event in mid-March (above) as well as a second lesser rain event about a week prior. The event was a federally declared disaster.
June 27, 2017	Heavy rain resulted in twelve inches of standing water on Boston Street in Middleton.
September 18, 2018	Post-Tropical Cyclone Florence brought heavy downpours and damaging thunderstorms to Massachusetts. Storm total rainfall amounts reached two to five inches. Maple Street in Danvers, near the Middleton town line, had flooding up to one foot. A garage on Belleview Avenue in Middleton flooded. Village Road in Middleton was flooded and impassable.
November 3, 2018	In Middleton, there was significant flooding on a portion of Maple Street.

A disaster declaration is a statement made by a community when the needs required by a disaster or emergency is beyond the capabilities of that community. Ten disaster declarations were made in Essex County due to flooding between 2000 and 2019, as can be seen in Table 4-4 below.

Table 4-4. Previous Federal Disaster Declarations - Flooding

Disaster Name and Date of Event	Disaster Number	Type of FEMA Assistance	Counties Under Declaration
Severe Storms and Flooding March 5-April 16, 2001	DR-1364	None	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Flooding April 1-30, 2004	DR-1512	Individual & Households Program	Essex, Middlesex, Norfolk, Suffolk, Worcester
Severe Storms and Flooding October 7-16, 2005	DR-1614	Public Assistance; Individual & Households Program	All 14 Massachusetts Counties
Severe Storms and Flooding May 12-23, 2006	DR-1642	Public Assistance; Individual & Households Program	Middlesex, Essex, Suffolk

Table 4-4. Previous Federal Disaster Declarations - Flooding

Disaster Name and Date of Event	Disaster Number	Type of FEMA Assistance	Counties Under Declaration
Severe Storm and Flooding April 15 - 25, 2007	DR-1701	Public Assistance	Essex, Plymouth, Barnstable, Dukes, Hampshire, Hampden, Franklin, Berkshire
Severe Winter Storm and Flooding December 11-18, 2008	DR-1813	Public Assistance	All 14 Massachusetts Counties
Severe Storm and Flooding March 12-April 26, 2010	DR-1895	Public Assistance; Individual & Households Program	Bristol, Essex, Middlesex, Suffolk, Norfolk, Plymouth, Worcester
Severe Winter Storm, Snowstorm, and Flooding February 8-9, 2013	DR-4110	Public Assistance	All 14 Massachusetts Counties
Severe Winter Storm, Snowstorm, and Flooding January 26-28, 2015	DR-4214	Public Assistance	Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester
Severe Winter Storm and Flooding March 02- 03, 2018	DR-4372	Public Assistance	Essex, Norfolk, Bristol, Plymouth, Barnstable, Nantucket

(FEMA, 2019d)

4.2.2 GIS Flooding Exposure Analysis

A flood exposure analysis was conducted for critical facilities and vulnerable populations throughout the municipality utilizing MassGIS data, FEMA flood maps, and information gathered from the municipality. Table 4-5 below displays critical facilities in Middleton that are located within either the 100-year or 500-year FEMA flood zone, and Table 4-6 shows all census blocks in Middleton that contain a high concentration of a vulnerable population.

Table 4-5. Critical Facilities Located within the FEMA Flood Zone

Facility	Address	100-Year Flood Zone	500-Year Flood Zone
Middleton Landfill	11 Natsue Way	X	X
Rubchinuk Landfill	131 East Street	X	X

As can be seen in the table, the only critical facilities in Middleton that are located within a FEMA flood zone are two capped landfills. Both landfills are located within the 100-year FEMA flood zone as well as the 500-year FEMA flood zone. It is important to protect these facilities from flooding, which could threaten the integrity of the landfill and potentially cause water quality and contamination issues downstream if the site were to leach or erode.

During the workshop, stakeholders discussed concern for people who may become isolated. Seniors and youth are more prone to becoming isolated during an event. Sixteen of the 46 Census Blocks in

Middleton are located partially within a FEMA flood zone and also have a higher concentration of youth or seniors.

Table 4-6. Vulnerable Populations Located within the FEMA Flood Zone

Census Block Number	High Concentration of Vulnerable Population	Total Area (acres)	Area in 100-Year Flood Zone (acres)	Area in 500-Year Flood Zone (acres)
250092121001006	Minor (< 18)	592	72	38
250092121001011	Minor (< 18)	640	0	48
250092121001017	Minor (< 18)	105	9	7
250092121002000	Minor (< 18)	650	37	45
250092121002007	Minor (< 18)	37	9	0
250092121002008	Minor (< 18)	46	9	0
250092121002012	Minor (< 18)	2	0	0
250092121002025	Elderly (65+)	7	0	0
250092121003002	Elderly (65+)	78	0	5
250092121003005	Minor (< 18)	24	0	2
250092121004003	Minor (< 18)	197	63	4
250092121004007	Elderly (65+)	87	18	0
250092121004013	Minor (< 18)	152	20	12
250092121004019	Minor (< 18)	11	5	4
250092121004021	Minor (< 18)	125	16	10
250092121004026	Elderly (65+)	331	53	5

From the data available, there is no way of knowing if residents living in the floodplain are seniors and youth. However, the population living in the Census Blocks in Table 4-6 have a greater proportion of seniors or youth and also have some areas within the floodplain. The greater the percentage of the Census Block in the flood zone the greater likelihood that residences, or infrastructure serving the residents, could be impacted by flooding. Because Census Blocks vary greatly by size, the total land area within the flood zone may also indicate how widespread the flooding may be. Other factors, such as population density and location of residences, could help improve the assessment of the exposure of vulnerable populations to flooding.

The Town's existing tax parcel and property value data, obtained from MassGIS, were used to estimate the number of parcels (developed and undeveloped) and buildings located in identified hazard areas along with their respective assessed values. The parcel data set provides information about the parcel size, land use type, and assessed value among other characteristics. The parcel data was also classified into various land use types based on the Massachusetts Department of Revenue's Property Type Classification Code, 2016.

An analysis was conducted on all developed parcels in the Town. To determine the vulnerability of each parcel and building, a GIS overlay analysis was conducted in which the flood hazard extent zones were overlaid with the parcel data and existing building footprint data. These developments were overlaid with historic flood zones to determine these parcels vulnerability to flooding. They were categorized by land

use type, and the exposure of each land use type was documented by the total area and percentage of parcels that overlap with a flood zone. The risk or impact of potential flooding was captured by summarizing the total property value in each parcel.

Approximately 41% of the developed parcels in Middleton are located within the FEMA 100-year flood zone, while an additional 50% is in the 500-year FEMA flood zone. Residential properties have the greatest area located in both flood zones and well as some of the highest property value in both flood zones, although institutional development has a slightly higher property value in the 100-year flood zone. Additionally, over ¾ of institutional parcels are in the 100-year flood zone. Institutional parcels may include municipal and state facilities, schools, hospitals, churches, or jails. The tables below show the exposure of developed parcels in the Town of Middleton.

Table 4-7. Developed Parcels in 100-Year FEMA Flood Zone

Exposure of Developed Parcels to the 100-Year Flood Zone						
Land Use Type	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in the Flood Zone	Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
Residential	2,133	3,329	176	901	27	$47,187,100
Commercial	102	505	20	184	36	$10,058,400
Industrial	17	112	6	64	57	$13,973,700
Institutional	29	804	11	661	82	$55,695,100
Agricultural	1	237	1	237	100	$610,100
Recreation & Open Space	3	52	N/A	N/A	N/A	N/A
Total	**2,285**	**5,039**	**214**	**2,047**	**41**	**$127,524,400**

Table 4-8. Developed Parcels in 500-Year FEMA Flood Zone

Exposure of Developed Parcels to the 500-Year Flood Zone						
Land Use Type	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in the Flood Zone	Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
Residential	2,133	3,329	242	1197	36	$75,578,800
Commercial	102	505	21	286	57	$8,253,400
Industrial	17	112	7	78	70	$15,935,100
Institutional	29	804	7	649	81	$27,225,900
Agricultural	1	237	1	237	100	$610,100
Recreation & Open Space	3	52	1	49	95	$204,500
Total	**2,285**	**5,039**	**279**	**2,496**	**50**	**$127,807,800**

As Table 4-7 demonstrates, there are currently 214 parcels with 2,047 acres in the 100-year flood zone and 279 parcels with 2,496 acres in the 500-year flood zone. The 2012 HMP stated that approximately 209.92 acres, identified by local officials, were areas of known flooding. Since these areas were identified from local knowledge rather than FEMA flood zones, it is difficult to accurately infer whether

flood vulnerability has increased or decreased using this data. However, the previous plan identified 10 proposed development sites that were partially located within a FEMA flood zone. At least two of the ten developments from the previous plan were completed and were included in this plan as recent developments in Chapter 3. Table 4-9 demonstrates that approximately 254 acres that have developed within the past 10 years are in the 100-year floodplain and 98 acres of recently developed parcels are in the 500-year floodplain (see Table 4-10). These recently developed parcels include, but are not limited to, a gas station, country club, and multiple residential properties. While this assessment looks at percentage of parcel, rather than building footprint location, it is likely that there has been an increase in flood vulnerability since the previous HMP was completed.

Information about recent developments, or redevelopments, within the past 10 years (2010 – 2020) was obtained from MassBuilds (MAPC, 2020) and verified by the Town's Conservation Agent (Kent, 2020). An exposure analysis was done on these parcels. To determine the vulnerability of each parcel and building, a GIS overlay analysis was conducted in which the flood hazard extent zones were overlaid with the parcel data for recent developments and building footprint data (when available). These developments were overlaid with historic flood zones to determine these parcels vulnerability to flooding. They were categorized by land use type, and the exposure of each land use type was documented by the total area and percentage of parcels that overlap with a flood zone. The risk or impact of potential flooding was captured by summarizing the total property value in each parcel.

Although MassGIS parcel data is dated 2020, not all property values have been updated to reflect the most recent developments. Some limitations exist in the accuracy of the data resulting from delay in updates to the building and property value.

Table 4-9. Recently Developed Parcels in the 100-Year FEMA Flood Zone

Exposure of Recently Developed Parcels to the 100-Year Flood Zone						
Development Name	Development Address	Development Type	Area of Parcel (acres)	Area I in the Flood Zone (acres)	% of the Parcel in the Flood Zone	Property Value in the Flood Zone
208R South Main Street Solar Installation	208R South Main Street	Agricultural	237	61	26	$610,100
Ferncroft Country Club	8 Village Road	Commercial	32	4	12	$1,660,400
Cumberland Farms	4 South Main Street	Commercial	2	1	9	$731,900
Estates on the Green	18 Village Road	Commercial	32	4	12	$1,660,400
12 Old Forest Street	12 Old Forest Street	Institutional	532	149	28	$2,171,700
Ridgewood Estates	84 East Street	Residential	88	8	9	$10,400*
Ohlson Way Subdivision	64/64R East Street	Residential	7	1	7	N/A[1]

Essex Woods Estates	127 Essex	Residential	2	1	27	N/A[1]
5 Kassiotis Lane	5 Kassiotis Lane	Residential	25	1	3	$252,50
49 North Liberty Street	49 North Liberty Street	Residential	5	1	3	$478,100
19 Peaslee Circle	19 Peaslee Circle	Residential	20	13	63	$464,400
17 Peaslee Circle	17 Peaslee Circle	Residential	20	13	63	$464,400
15 Zaloga Way	15 Zaloga Way	Residential	1	1	13	N/A[1]
Total			1,004	254	25	$8,504,300

[1]Building and property values have not yet been updated

Table 4-10. Recently Developed Parcels in the 500-Year Flood Zone

Exposure of Recently Developed Parcels to the 500-Year Flood Zone						
Development Name	Development Address	Development Type	Area of Parcel (acres)	Area I in the Flood Zone (acres)	% of the Parcel in the Flood Zone	Property Value in the Flood Zone
12 Old Forest Street	12 Old Forest Street	Institutional	532	87	16	$2,171,700
208R South Main Street Solar Installation	208R South Main Street	Agricultural	237	5	2	$610,100
Ridgewood Estates	84 East Street	Residential	88	4	4	$10,400[1]
5 Kassiotis Lane	5 Kassiotis Lane	Residential	25	1	2	$252,500
19 Peaslee Circle	19 Peaslee Circle	Residential	20	1	2	$464,400
17 Peaslee Circle	17 Peaslee Circle	Residential	20	1	2	$464,400
North MeadowVillage	225 North Main Street	Residential	29	1	1	$337,400
Ohlson Way Subdivision	64/64R East Street	Residential	70	1	3	N/A[1]
Total			595	98	10	$4,310,900

[1]Building and property values have not yet been updated

Middleton is a growing community and as the population grows, so does the demand for additional facilities in the town. To further resiliency in the Town, a flood exposure analysis was completed on all vacant, developable parcels. The analysis was conducted utilizing MassGIS data, FEMA flood maps,

and information from the Town. The result of this analysis will bring light to future flooding that could occur on these parcels if they were to be developed.

The output of the ArcGIS overlay analysis showed all vacant, developable parcels that intersected with a flood zone. The number of parcels was totaled for each land use type within each of FEMA Flood Zones. While 3,438 acres of land in Middleton are vacant and developable, 67% of that land is located within the 100-year flood zone and an additional 65% in the 500-year flood zone. This demonstrates that there is potential for flood vulnerability to increase, but the Town is constantly working to protect vulnerable areas by enforcing zoning regulations, including the floodplain overlay district and the watershed protection overlay district. It is recommended that as the Town expands development, additional analysis be conducted on these parcels to reduce damage from flooding.

Table 4-11. Developable, Vacant Land in the 100-Year FEMA Flood Zone

Exposure of Developable, Vacant Land to the 100-Year Flood Zone					
Land Use Category	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in Flood Zone	Area of Parcels in Flood Zone (acres)	Percentage of Parcels in the Flood Zone
Residential	138	558	41	287	51
Commercial	26	122	2	3	2
Industrial	13	71	4	35	49
Institutional	75	883	40	621	70
Agricultural	11	576	7	516	89
Recreation & Open Space	95	1227	43	828	68
Total	**358**	**3438**	**137**	**2289**	**67**

Table 4-12. Developable, Vacant Land in the 500-Year FEMA Flood Zone

Exposure of Developable, Vacant Land to the 500-Year Flood Zone					
Land Use Category	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in Flood Zone	Area of Parcels in Flood Zone (acres)	Percentage of Parcels in the Flood Zone
Residential	138	558	30	233	42
Commercial	26	122	5	81	66
Industrial	13	71	5	42	60
Institutional	75	883	26	378	43
Agricultural	11	576	8	535	93
Recreation & Open Space	95	1227	42	960	78
Total	**358**	**3438**	**116**	**2229**	**65**

Planned development noted by MassBuilds (MAPC, 2020) were reviewed and updated by the Conservation Agent (Kent, 2020). These parcels were overlaid with FEMA flood zone maps to determine the vulnerability to flooding. They were categorized by development type. The exposure of potential

development within each land use type was documented by the area and percentage of parcels that overlap with a flood zone.

Of the 5 planned developments in Middleton, three of these parcels are in the 100-year flood zone. Two of these planned developments are also located on parcels in the 500-year flood zone, and one additional planned residential development is also located on a parcel in the 500-year flood zone. This can be seen in Tables 4-13 and 4-14 below.

Table 4-13. Planned Development in the 100-Year FEMA Flood Zone

Exposure of Locally Identified Areas for Potential Development to the 100-Year Flood Zone					
Development Name	Development Address	Development Type	Area of Parcel (acres)	Area of Parcel in Flood Zone (acres)	Percentage of Parcel in the Flood Zone
97 North Main Street	97 North Main Street	Residential	9	0.4	4%
Old Essex Estates	17 Old Essex Street	Residential	8.5	1.4	16%
Beech Brook Farms Subdivision	161 Essex Street	Residential	6	0.1	1%
Total			**23.5**	**1.9**	**8%**

Table 4-14. Planned Development in the 500-Year FEMA Flood Zone

Exposure of Locally Identified Areas for Potential Development to the 500-Year Flood Zone					
Development Name	Development Address	Development Type	Area of Parcel (acres)	Area of Parcel in Flood Zone (acres)	Percentage of Parcel in the Flood Zone
59 South Main Street	N/A	Residential	22.2	8.8	39.7
Old Essex Estates	17 Old Essex Street	Residential	8.6	0.3	3.5
Beech Brook Farms Subdivision	161 Essex Street	Residential	5.9	0.2	3.0
Total			**36.7**	**9.3**	**25.3**

All planned developments located in the FEMA flood zones are along Main Street and Essex Street, both of which have been noted by residents as areas prone to flooding. Drainage upgrades and stormwater BMPs should be considered in order to protect these developments from future flood events.

4.2.3 Dams and Dam Failure

Dam failure is defined as a collapse of an impounding structure resulting in an uncontrolled release of impounded water from a dam (DCR, 2017a). There are two types of dam failures that can occur. Catastrophic failure occurs when there is a sudden, rapid, uncontrolled release of impounded failure. The other is design failure, which occurs as a result of minor overflow events. Dam overtopping occurs when floods exceed the capacity of the dam and can occur as a result of inadequate spillway design, or other outside factors such as settlement of the dam crest or back of spillways. Thirty-four percent of all dam failures that occur in the United States are a result of overtopping (EEA and EOPSS, 2018). Dam failures during flood events are of concern in Massachusetts, given the high density of dams constructed in the 19th century (MEMA and DCR, 2013).

Many dam failures in the United States have been secondary results of other disasters. The prominent causes are earthquakes, landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, and sabotage (MEMA and DCR, 2013). Dam failure can cause property damage, injuries, and potentially fatalities. These impacts can be at least partially mitigated through advance warning to communities impacted by a dam failure. In addition, the breach may result in erosion on the rivers and stream banks that are inundated.

Climate change may indirectly affect dam breaches for a variety of reasons. Dams are typically designed based on historic water flows and known hydrology. Climate change projections indicate that the frequency, intensity, and amount of precipitation will increase in New England. Increased precipitation may push dams over capacity. Therefore, dams will have to be monitored for safety. There are several mechanisms in place to manage increases in water, such as slowly releasing water. It is advised that these events are monitored as it can add additional stress on the dam infrastructure.

There have been no recorded dam failures in Middleton, and although dam failure is classified as a very low frequency event in the town, a dam failure can still present a high level of risk and could result in a catastrophic event with extreme damage and loss of life. As defined by the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (EEA and EOPSS, 2018), a very low frequency hazard may occur less frequently than once in 100 years (less than a 1% chance per year).

According to town officials and the Massachusetts Department of Conservation and Recreation's (DCR) Office of Dam Safety, there are ten dams in Middleton. Information related to these dams is summarized in Table 4-15. This summary table includes the hazard classification for each dam, which is defined by DCR as described below:

- *High:* Dams located where failure or mis-operation will likely cause loss of life and serious damage to home(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).
- *Significant:* Dams located where failure or mis-operation may cause loss of life and damage home(s), industrial or commercial facilities, secondary highway(s) or railroad(s), or cause interruption of use or service or relatively important facilities.
- *Low:* Dams located where failure or mis-operation may cause minimal property damage to others. Loss of life is not expected.

Table 4-15. Inventory of Dams in Middleton

Dam Name	Dam Owner	Hazard Potential Classification
Emerson Brook Dam	Town of Danvers, Board of Selectmen	Low Hazard
Middleton Pond Outlet Dam	Town of Danvers, Board of Selectmen	Low Hazard
Curtis Pond Dam	Town of Danvers, Board of Selectmen	N/A
South Middleton Dam	Bostik, Inc.	Significant Hazard
Creighton Pond Dam	Boys and Girls Club of Lynn	Low Hazard
Prichard Pond Dam	Joan Cudhea	N/A
Middleton Pond Southeast Dike	Town of Danvers, Board of Selectmen	Low Hazard
Mill Pond Dam	Abandoned	Significant Hazard
Coppermine Road Dam	Town of Middleton	N/A
Paradise Park Dam	Five H LLC	N/A

(ACOE, 2020)

As of February 2017, all dams classified as high hazard potential or significant hazard potential were required to have an Emergency Action Plan (EAP) (DCR, 2020b). This plan must be updated annually and submitted to the Commissioner and the Massachusetts Emergency Management Agency. The plan should also be retained by the dam owned and the Town in which the dam is located. Guidelines and a template were established by the Office of Dam Safety to ensure that all EAPs follow the proper format.

4.2.4 Climate Change Impacts: Flooding

Boston's average annual precipitation is 53.32 inches (NOAA, 2020a). Extreme rain and snow events are becoming increasingly common and severe particularly in the Northeast region of the country (Figure 4-2). Large rain or snow events that happened once a year in the middle of the 20th century now occur approximately every nine months. Additionally, the largest annual events now generate 10% more rain than in 1948. Regionally, New England has experienced the greatest increase in frequency of extreme rain and snow events. These events now occur 85% more frequently than they did 60 years ago (Madsen and Willcox, 2012).

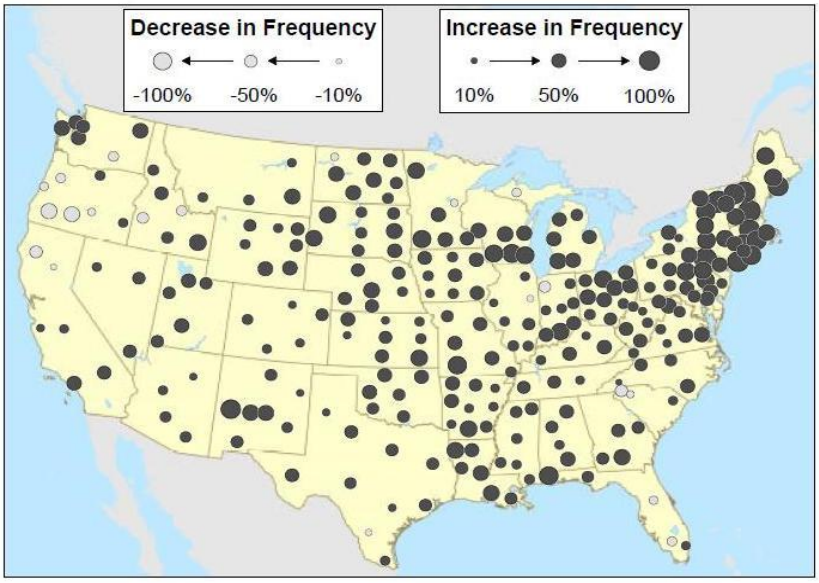


Figure 4-2. Changes in Frequency of Extreme Downpours
(Madsen and Willcox, 2012)

4.3 Wind Related Hazard

High winds can occur during hurricanes, tropical storms, tornadoes, nor'easters, and thunderstorms. The entire planning area is vulnerable to the impacts of high wind. All current and future buildings including critical facilities and populations are considered to be vulnerable during high wind events. Wind may down trees and power lines. High wind and storm events cause property damage and hazardous driving conditions. While Middleton's current 100-year wind speed is 97 mph (ASCE, 2018), climate change will likely increase events and severity.

Extreme winds can take down trees and branches that cause service disruptions. Although there are occasional issues with downed power lines, the Town of Middleton is fortunate to have its own Electric Light Department (MELD) that can quickly respond to any issues of power outages. Additionally, MELD is proactive in maintaining trees around powerlines.

NOAA's National Centers for Environmental Information offers thunderstorm wind, high wind, and strong data for Essex County. Between 2000 and 2019, 400 wind entries were uploaded into the database and 223 were related to thunderstorms. Other wind events were related to coastal storms, low pressure cells, rains, and other hazard events. Over this time period there were no deaths, seven injuries, and nearly $7 million worth of damage. Winds ranged from 28 miles per hour to 85 miles per hour. Several events identified damage in Middleton including downed trees on Essex Street (2007), State Route 62 (2018), Maple Street (2018) Peabody Street and Mill Street (2017).

4.3.1 Severe Storms and Thunderstorms

Thunderstorms are typically less severe than other events discussed in this section. However, thunderstorms can cause local damage and are a town-wide risk in Middleton. Thunderstorms can include lightning, winds of up to 60 mph, heavy rain, hail, and sometimes tornadoes. Thunderstorms typically last for about 30 minutes. During periods of drought, lightning from thunderstorm cells can also

result in fire ignition. Thunderstorms with little or no rainfall are rare in New England but have occurred (EEA and EOPSS, 2018).

Table 4-16. Previous Federal Disaster Declarations – Severe Storms

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Severe Storms & Flooding March 5-April 16, 2001	DR-1364	None	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Severe Storm February 17-18, 2003	EM-3175	FEMA Public Assistance	All 14 Massachusetts Counties
Severe Storms and Flooding October 7-16, 2005	DR-1614	FEMA Public Assistance; FEMA Individual & Households Program	All 14 Massachusetts Counties
Severe Storms and Flooding May 12-23, 2006	DR-1642	FEMA Public Assistance; FEMA Individual & Households Program	Middlesex, Essex, Suffolk
Severe Storm and Flooding April 15, 2007 - April 25, 2007	DR-1701	FEMA Public Assistance	Essex, Plymouth, Barnstable, Dukes, Hampshire, Hampden, Franklin, Berkshire
Severe Storm and Flooding March 12-April 26, 2010	DR-1895	FEMA Public Assistance; FEMA Individual & Households Program	Bristol, Essex, Middlesex, Suffolk, Norfolk, Plymouth, Worcester
Severe Storm October 29 -30, 2011	EM-3343	None	Middlesex, Essex, Norfolk, Worcester, Hampshire, Hampden, Franklin, Berkshire

(FEMA, 2019d)

Winds associated with thunderstorms can knock down trees resulting in power outages and blocked evacuation and transportation routes. Extreme rain during thunderstorms can cause inland flooding around waterbodies or due to surcharged drainage systems.

Thunderstorms are considered high frequency events in Middleton. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard may occur more frequently than once in 5 years (a greater than 20% chance per year).

4.3.2 Tornadoes

A tornado is a narrow, violently rotating column of air that extends from the base of a cloud to the ground. Tornadoes are the most violent of all atmospheric storms (EEA and EOPSS, 2018). According to the 2018 SHMCAP, the following are common factors in tornado formation:

- Very strong winds in the middle and upper levels of the atmosphere
- Clockwise turning of the wind with height
- Increasing wind speed in the lowest 10,000 feet of the atmosphere (i.e. 20 mph at the surface and 50 mph at 7,000 feet)
- Very warm, moist air near the ground, with unusually cooler air aloft
- A forcing mechanism such as a cold front or leftover weather boundary from previous shower or thunderstorm activity

Tornadoes can be spawned by tropical cyclones or the remnants thereof, and weak tornadoes can even form from little more than a rain shower if air is converging and spinning upward. The most common months for tornadoes to occur are June, July, and August. There are exceptions: the Great Barrington, Massachusetts, tornado in 1995 occurred in May; and the Windsor Locks, Connecticut, tornado in 1979 occurred in October (EEA and EOPSS, 2018).

The Fujita Tornado Scale measures tornado severity through estimated wind speed and damage. The National Weather Service began using the Enhanced Fujita-scale (EF-scale) in 2007, which led to increasingly accurate estimates of tornado severity. Table 4-17 provides more detailed information on the EF Scale.

Table 4-17. Enhanced Fujita Scale

Fujita Scale			Derived		Operational EF Scale	
F Number	Fastest ¼ mile (mph)	3-second gust (mph)	EF Number	3-second gust (mph)	EF Number	3-second gust (mph)
0	40 – 72	45 – 78	0	65 – 85	0	65 – 85
1	73 – 112	79 – 117	1	86 – 109	1	86 – 110
2	113 – 157	118 – 161	2	110 – 137	2	111 – 135
3	158 – 207	162 – 209	3	138 – 167	3	136 – 165
4	208 – 260	210 – 261	4	168 – 199	4	166 – 200
5	261– 318	262 – 317	5	200 – 234	5	Over 200

(MEMA and DCR, 2013)

Massachusetts experiences an average of 1.7 tornadoes per year. The most tornado-prone areas of the state are the central counties. In 2019, Massachusetts had three tornadoes on the Cape in Yarmouth and East Harwich. In 2018, there were seven tornado events were recorded and affected communities in Worcester County and Bristol Counties. Tornadoes are comparatively rare in eastern Massachusetts, although Essex County is considered an at-risk location (EEA and EOPSS, 2018). There have been 11 recorded tornadoes in Essex County since 1950. No fatalities and four injuries were reported (NOAA, 2019a). Table 4-18 below provides additional information. The most devastating tornado in Massachusetts in the history of recorded weather occurred in Worcester County in 1953, it killed 90 people, injured more than 1,200, and caused more than $250 million in damages (NOAA, 2019a) (not adjusted for inflation).

Table 4-18. Tornado Records for Essex County 1950-2019

Date	Fujita	Fatalities	Injuries	Property Damage (in thousands of dollars)
08/21/1951	F2	0	0	$2,500
6/13/1956	F1	0	0	$2,500
11/21/1956	F2	0	0	$25,000
12/18/1956	F1	0	0	$250
7/13/1960	F0	0	0	$30
7/21/1962	F1	0	3	$25,000
5/19/1964	F0	0	0	$2,500
5/19/1964	F1	0	0	$2,500
8/10/1965	F1	0	0	0
7/1/1968	F1	0	1	$250,000
7/21/1972	F1	0	0	$2,500
8/15/1991	F1	0	0	$250,000
Total		0	4	$562,780

(NOAA, 2019a)

Although tornadoes are a potential town-wide hazard in Middleton, there have been no recorded tornadoes in the town. If a tornado were to occur in Middleton, damages would depend on the track of the tornado and would be most likely due to the prevalence of older construction and the density of development that exist. Structures built before current building codes may be more vulnerable. Evacuation, sheltering, debris clearance, distribution of food and other supplies, search and rescue, and emergency fire and medical services may be required. Critical evacuation and transportation routes may be impassable due to downed trees and debris, and recovery efforts may be complicated by power outages.

Tornado events in Middleton are a very low frequency event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard may occur less than once in 100 years (a less-than 1% chance per year). Tornadoes are difficult to simulate well in climate models because of their small size. However, it is predicted that the frequency of tornadoes in eastern Massachusetts will rise in the future due to climate change.

4.3.3 Hurricanes and Tropical Storms

Tropical cyclones (including tropical depressions, tropical storms, and hurricanes) form over the warm waters of the Atlantic, Caribbean, and Gulf of Mexico. A tropical storm is defined as having sustained winds from 39 to 73 mph. If sustained winds exceed 73 mph, it is categorized a hurricane. The Saffir-Simpson scale ranks hurricanes based on sustained wind speeds from Category 1 (74 to 95 mph) to Category 5 (156 mph or more). Category 3, 4, and 5 hurricanes are considered “Major” hurricanes. Wind gusts associated with hurricanes may exceed the sustained winds and cause more severe localized damage (EEA and EOPSS, 2018).

When hurricanes and tropical storms occur, they will impact the entire planning area. All existing and future buildings including critical facilities and populations are at risk to the hurricane and tropical storm hazard (including critical facilities). Hurricane events have a large spatial extent and would potentially affect all of Middleton's infrastructure and buildings. Impacts include water damage in buildings from building envelope failure, business interruption, loss of communications, and power failure. Flooding is a major concern as slow-moving hurricanes can discharge tremendous amounts of rain on an area.

The official hurricane season runs from June 1 to November 30. However, storms are more likely to occur in New England during August, September, and October (EEA and EOPSS, 2018). The Saffir/Simpson scale categorizes or rates hurricanes from 1 (minimal) to 5 (catastrophic) based on their intensity. This is used to provide an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on context (EEA and EOPSS, 2018). More information is included in Table 4-19.

Table 4-19. Saffir/Simpson Scale

Scale No. (Category)	Winds (mph)	Potential Damage
1	74 – 95	Minimal: damage is primarily to shrubbery and trees, mobile homes, and some signs. No real damage is done to structures.
2	96 – 110	Moderate: some trees topple, some roof coverings are damaged, and major damage is done to mobile homes.
3	111 – 130	Extensive: large trees topple, some structural damage is done to roofs, mobile homes are destroyed, and structural damage is done to small homes and utility buildings.
4	131 – 155	Extreme: extensive damage is done to roofs, windows, and doors; roof systems on small buildings completely fail; and some curtain walls fail.
5	> 155	Catastrophic: roof damage is considerable and widespread, window and door damage are severe, there are extensive glass failures, and entire buildings could fail.

(MEMA and DCR, 2013) (table originally created by NOAA)

The region has been impacted by hurricanes throughout its history, starting with the Great Colonial Hurricane of 1635. Between 1938 and 2019, Massachusetts experienced over twenty hurricanes or related storm events. The most recent FEMA disaster declaration in Massachusetts due to a hurricane was Hurricane Sandy in 2012 (FEMA, 2019b). Hurricanes that have occurred in the region since 1938 are listed in Table 4-20 and 4-21. Four were Category 3 events.

Table 4-20. Hurricane Records for Eastern Massachusetts, 1938 to 2000

Hurricane Event	Date
Great New England Hurricane*	September 21, 1938
Great Atlantic Hurricane*	September 14-15, 1944
Hurricane Doug	September 11-12, 1950
Hurricane Carol*	August 31, 1954
Hurricane Edna*	September 11, 1954
Hurricane Diane	August 17-19, 1955
Hurricane Donna	September 12, 1960
Hurricane Gloria	September 27, 1985
Hurricane Bob	August 19, 1991
Hurricane Grace – Perfect Storm Nor'easter	October 31, 1991
Hurricane Floyd	September, 1999

*Category 3 (EEA and EOPSS, 2018 and Blake et al., 2007)

Table 4-21. Hurricanes and Tropical Storms, 2000-2019

Event	Date
Hurricane Katrina	September 13, 2005
Tropical Storm Hanna	September 6, 2008
Hurricane Bill	August 22, 2009
Tropical Storm - Hurricane Earl	September 4, 2010
Tropical Storm Irene	August 28, 2011
Hurricane Sandy	October 29-30, 2012
Tropical Storm-Hurricane Arthur	July 4, 2014
Tropical Storm Hermine	September 5, 2016
Tropical Storm Jose	September 20, 2017
Post Tropical Storm - Hurricane Florence	September 18, 2018
Tropical Storm Dorian	September 7, 2019

(NOAA, 2019a)

Hurricane damage in Middleton was estimated using a hurricane modeling software. Hazus Multi-Hazard (Hazus) is a GIS model developed by FEMA to estimate losses in a defined area due to a specified natural hazard. The Hazus hurricane model allows users to input specific parameters in order to model a defined hurricane magnitude, which is based on wind speed. The largest hurricane ever witnessed in Massachusetts was a Category 3 hurricane, which occurred in 1954. For the purpose of this analysis, in order to estimate potential damage, both a Category 2 and a Category 4 hurricane were modeled. Although there have been no recorded Category 4 hurricanes recorded in Massachusetts, storm was modeled to show the impact that could occur from an extreme scenario, something that could possibly happen in the future due to climate change.

In Massachusetts, the return period for a Category 2 hurricane is approximately 0.01 percent, and for a Category 4 hurricane it is approximately 0.005 percent. Hazus models hurricanes based upon their

return period. Therefore, a Category 2 was modeled as a 100-year hurricane and a Category 4 was modeled as a 500-year hurricane. In order to model each of these hurricanes, the study region must first be defined. The Town of Middleton was outlined by the census tracts in the Town and the probabilistic scenario was used. This scenario considers the associated impact of thousands of storms that have a multitude of tracks and intensities. The output shows the potential impact that could occur in Middleton if either a Category 2 or a Category 4 hurricane passed by. Hazus is based on 2010 Census data and 2014 dollars. The tables below show the estimated damage from both a Category 2 and a Category 4 hurricane in the municipality.

Table 4-22. Category 2 Hurricane Damage

Infrastructural Damage from a Category 2 Hurricane on Buildings in Middleton				
Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged[1]	Percent of Buildings Damaged[1]	Total Value of Building Damage[2]
Residential	2,346	62	2.7%	$6,606,220
Commercial	180	3	1.9%	$132,460
Industrial	62	1	1.9%	$37,000
Others	46	1	1.8%	$24,770
TOTAL	**2,634**	**67**	**2.5%**	**$6,800,450**

[1]Includes Slight, Moderate, Extensive, and Complete Damage
[2]Includes Building, Content and Inventory

Table 4-23. Category 4 Hurricane Damage

Infrastructural Damage from a Category 4 Hurricane on Buildings in Middleton				
Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged[1]	Percent of Buildings Damaged[1]	Total Value of Building Damage[2]
Residential	2,346	395	16.8%	$22,460,730
Commercial	180	23	12.7%	$1,000,470
Industrial	62	7	12.0%	$484,810
Others	46	6	12.2%	$226,990
TOTAL	**2,634**	431	**16.4%**	**$24,203,010**

[1]Includes Slight, Moderate, Extensive, and Complete Damage
[2]Includes Building, Content and Inventory

In addition to the infrastructural damage, Hazus also calculated the potential societal impact of a Category 2 and Category 4 hurricane on the community. Additional property damage and business interruption loss were calculated as well, and a full Hazus risk report for each hurricane category can be found in Appendix B.

Hurricanes are a town-wide hazard in Middleton and are considered a medium frequency event. As defined by the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, this hazard will occur on average once every two years (a 50% chance per year).

4.3.4 Nor'easters

A nor'easter is characterized by large counterclockwise wind circulation around a low-pressure center that often results in heavy snow, high winds, waves, and rain along the East Coast of North America. The term nor'easter refers to their strong northeasterly winds blowing in from the ocean. These winter weather events are among the season's most ferocious storms, often causing beach erosion, flooding, and structural damage (EEA and EOPSS, 2018).

Nor'easters generally occur on at least an annual basis, typically in late fall and early winter. Some years bringing up to four nor'easter events. This is currently the most frequently occurring natural hazard in the state. The storm radius is often as much as 100 miles and sustained wind speeds of 20 to 40 mph are common, with short-term gusts of up to 50 to 60 mph. Nor'easters are commonly accompanied by a storm surge equal to or greater than two feet. High surge and winds during a hurricane can last from 6 to 12 hours, while these conditions during a nor'easter can last from 12 hours to three days (EEA and EOPSS, 2018). Some of the historic events described in the "Flood-Related Hazards" section of this report was preceded by nor'easters, including the 1991 "Perfect Storm." The Blizzard of '78 was a notable storm. More recently, winter storms in 2015 and 2018 caused significant snowfall amounts.

The Town of Middleton is vulnerable to high winds, snow, and extreme rain during nor'easters. These impacts can lead to property damage, downed trees, power service disruptions, surcharged drainage systems, and localized flooding. These conditions can impact evacuation and transportation routes and complicate emergency response efforts. Due to its inland location, Middleton is not subject to the coastal hazards often associated with nor'easters.

Nor'easters in Middleton are high frequency events. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard may occur more frequently than once in 5 years (a greater than 20% chance per year).

4.4 Winter Storms

Winter storm events are atmospheric in nature and can impact the entire planning area. All current and future buildings and populations are considered to be at risk of winter storms, which have a variety of potential impacts. Heavy snow loads may cause roofs and trees to collapse leading to structural damage. Deaths and injury are also possible impacts. Additional impacts can include road closures, power outages, business interruption, business losses (i.e. due to road closures), hazardous driving conditions, frozen pipes, fires due to improper heating, and second-hand health impacts caused by shoveling (such as a heart attack). Public safety issues are also a concern, as streets and sidewalks can become difficult to pass. This issue may be especially difficult for vulnerable populations such as elderly people who may have trouble crossing at intersections due to large accumulations of snow. Impassable streets can also complicate emergency response efforts during an extreme event.

Winter storms are a potential town-wide hazard in Middleton. These events can include wind, heavy snow, blizzards, and ice storms. Blizzards and ice storms in Massachusetts can range from an inconvenience, to extreme events that cause significant impacts and require a large-scale, coordinated response.

Table 4-24. Previous Federal Disaster Declarations – Winter Weather

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Snowstorm March 05, 2001 - March 07, 2001	EM-3165	FEMA Public Assistance	Middlesex, Essex, Norfolk, Worcester, Hampshire, Franklin, Berkshire
Snowstorm December 6-7, 2003	EM-3191	FEMA Public Assistance	Middlesex, Essex, Suffolk, Norfolk, Bristol, Plymouth, Barnstable, Worcester, Hampshire, Hampden, Franklin, Berkshire
Snowstorm January 22 - 23, 2005	EM-3201	FEMA Public Assistance	All 14 Massachusetts Counties
Severe Winter Storm and Flooding December 11-18, 2008	DR-1813	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Winter Storm December 11-18, 2008	EM-3296	None	Middlesex, Essex, Suffolk, Bristol, Worcester, Hampshire, Hampden, Franklin, Berkshire
Severe Winter Storm and Snowstorm January 11-12, 2011	DR-1959	FEMA Public Assistance	Berkshire, Essex, Hampden, Hampshire, Middlesex, Norfolk, Suffolk
Severe Winter Storm, Snowstorm, and Flooding February 8-9, 2013	DR-4110	FEMA Public Assistance	All 14 Massachusetts Counties
Severe Winter Storm, Snowstorm, and Flooding January 26-28, 2015	DR-4214	FEMA Public Assistance	Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester
Severe Winter Storm and Flooding March 02- 03, 2018	DR-4372	FEMA Public Assistance	Essex, Norfolk, Bristol, Plymouth, Barnstable, Nantucket
Severe Winter Storm and Snowstorm March 13-14, 2018	DR-4379	FEMA Public Assistance	Essex, Middlesex, Norfolk, Suffolk, Worcester

(FEMA, 2019d)

4.4.1 Heavy Snow and Blizzards

A blizzard is a winter snowstorm with sustained wind or frequent wind gusts of 35 mph or more, accompanied by falling or blowing snow that reduces visibility to or below a quarter of a mile. These conditions must be the predominant condition over a 3-hour period. Extremely cold temperatures are often associated with blizzard conditions but are not a formal part of the criteria. However, the hazard created by the combination of snow, wind, and low visibility increases significantly with temperatures below 20°F. A severe blizzard is categorized as having temperatures near or below 10°F, winds exceeding 45 mph, and visibility reduced by snow to near zero (EEA and EOPSS, 2018).

Winter storms include multiple risks, such as wind, ice, and heavy snow. The National Weather Service defines "heavy snow" as snowfall accumulating to 4" or more in 12 hours or less; or snowfall accumulating to 6" or more in 24 hours or less (NOAA) and National Weather Service, 2019). Winter storms can be combined with the nor'easters discussed previously in the "Wind-Related Hazards" section.

The National Centers for Environmental Information has 184 winter storm entries between 2000 and 2019 totaling $3.6 million of storm damage. Five of the entries were categorized as a blizzard and 59 were categorized as a winter storm. No injuries or deaths were reported. The following 120 events were categorized as winter weather and heavy snow.

During Middleton's CRB Workshop in December 2019, participants discussed past examples of severe winter weather, including one snowstorm that occurred over a day in March 2018, and left 14.5 inches in Middleton. Participants discussed the snow removal procedure and opportunities for improvement.

Blizzards are classified as high frequency events in Middleton. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard can occur more than once in five years (a greater than 20% chance of occurring each year).

4.4.2 Ice Storms

Ice storm conditions are defined by liquid rain falling and freezing on contact with cold objects creating ice build-ups of ¼ inch or more that can cause severe damage. An ice storm warning, now included in the criteria for a winter storm warning, is for severe icing. This is issued when ½ inch or more of accretion of freezing rain is expected. This may lead to dangerous walking or driving conditions and the weighing down of power lines and trees. Icy roads can also complicate emergency response efforts during an extreme event. Ice storms are classified as medium frequency events in Middleton. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard can occur between once in five years and once in 50 years (a 2% to 20% chance of occurring each year).

Sleet occurs when raindrops fall into subfreezing air thick enough that the raindrops refreeze into ice before hitting the ground. Sleet differs from hail: sleet is a wintertime phenomenon, while hail usually falls during thunderstorms in the spring and summer (MEMA and DCR, 2013). There were no data entries for sleet in the NOAA's National Centers for Environmental Information Storm Events Database (NOAA, 2019a).

NOAA's National Centers for Environmental Information Storm Events Database offers hail events data for Essex County (NOAA, 2019a). Between 2000 and 2019, there were 60 hail events that caused $155,000 in property damage. No deaths or injuries were reported. Hail size ranged from 0.75 to three inches in diameter. Middleton was specifically mentioned in the hail events occurring in 2004, 2007, and 2017.

The 2008 ice storm in Essex County was the only ice storm between 2000 to 2019 and resulted in two million dollars of property damage. Ice storms are classified as medium frequency events in Middleton. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard can occur between once in five years and once in 50 years (a 2% to 20% chance of occurring each year).

4.5 Geological Hazards

Geologic hazards can include earthquakes, landslides, sinkholes, and subsidence. Town officials did not identify any local areas that were previously recorded as being vulnerable to geologic hazards.

4.5.1 Earthquakes

An earthquake is the vibration, sometimes violent, of the earth's surface that follows a release of energy in the earth's crust due to fault fracture and movement. The magnitude or extent of an earthquake is a seismograph-measured value of the amplitude of the seismic waves. The Richter magnitude scale (Richter scale) was developed in 1932 as a mathematical device to compare the size of earthquakes. The Richter scale is the most widely known scale that measures earthquake magnitude. It has no upper limit and is not a direct indication of damage. An earthquake in a densely populated area, which results in many deaths and considerable damage, can have the same magnitude as an earthquake in a remote area that causes no damage. Table 4-25 summarizes Richter scale magnitudes and corresponding earthquake effects (MEMA and DCR, 2013).

Table 4-25. Richter Scale and Effects

Richter Magnitudes	Earthquake Effects
Less than 3.5	Generally, not felt, but recorded
3.5- 5.4	Often felt, but rarely causes damage
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1-6.9	Can be destructive in areas up to about 100 km across where people live.
7.0- 7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred meters across.

(Louie, 1996)

Earthquakes occur occasionally in New England as compared to other parts of the country but are oftentimes so small that they are not felt. The first recorded earthquake was noted by the Plymouth Pilgrims and other early settlers in 1638. Of the over 5,000 earthquakes recorded in the Northeast Earthquake Catalog through 2008, 1,530 occurred within the boundaries of the six New England States, with 366 earthquakes recorded for Massachusetts between 1627 and 2008. Historically, moderately damaging earthquakes strike somewhere in the region every few decades, and smaller earthquakes are felt approximately twice per year. (MEMA and DCR, 2013). A summary of historic earthquakes in the Boston area is included in Table 4-26 below.

Table 4-26. Historical Earthquakes in Massachusetts and Surrounding Area, 1727-2020

Location	Date	Magnitude
MA - Cape Ann	11/10/1727	5
MA - Cape Ann	12/29/1727	NA
MA - Cape Ann	2/10/1728	NA
MA - Cape Ann	3/30/1729	NA
MA - Cape Ann	12/9/1729	NA

Table 4-26. Historical Earthquakes in Massachusetts and Surrounding Area, 1727-2020

Location	Date	Magnitude
MA - Cape Ann	2/20/1730	NA
MA - Cape Ann	3/9/1730	NA
MA - Boston	6/24/1741	NA
MA - Cape Ann	6/14/1744	4.7
MA - Salem	7/1/1744	NA
MA - Off Cape Ann	11/18/1755	6
MA - Off Cape Cod	11/23/1755	NA
MA - Boston	3/12/1761	4.6
MA - Off Cape Cod	2/2/1766	NA
MA - Offshore	1/2/1785	5.4
MA - Wareham/Taunton	12/25/1800	NA
MA - Woburn	10/5/1817	4.3
MA - Marblehead	8/25/1846	4.3
MA - Brewster	8/8/1847	4.2
MA - Boxford	5/12/1880	NA
MA - Newbury	11/7/1907	NA
MA - Wareham	4/25/1924	NA
MA - Cape Ann	1/7/1925	4
MA - Nantucket	10/25/1965	NA
MA - Boston	12/27/1974	2.3
VA - Mineral	8/23/2011	5.8
MA - Nantucket	4/12/2012	4.5
ME - Hollis	10/17/2012	4.0
MA – Newburyport	2/20/2013	2.3
NH – Contoocook	10/11/2013	2.6
MA – Freetown	1/9/2014	2.0
MA – Bliss Corner	2/11/2014	2.2
MA – off Northshore	8/18/2014	2.0
CT - Deep River Center	8/14/2014	2.7
CT – Wauregan	1/12/2015	3.3
CT – Wauregan	1/13/2015	2.6
RI – Newport	2/3/2015	2.0
NH – Epsom	8/2/2015	2.2
NH – Contoocook	3/21/2016	2.8
MA – Rockport Coast	6/1/2016	2.2
NH – Bedford	2/11/2017	2.2
NH – East Kingston	2/15/2018	2.7
ME – Cape Neddick	7/16/2018	2.1
MA – Nantucket	8/18/2018	2.4
MA – Templeton	12/21/2018	2.1
MA – Gardner	12/23/2018	2.2
RI – Charlestown	3/1/2019	2.3

Table 4-26. Historical Earthquakes in Massachusetts and Surrounding Area, 1727-2020

Location	Date	Magnitude
MA – Rockport	4/27/2019	2.1
MA – North Plymouth	12/3/2019	2.1

(USGS, 2020)

Ground shaking or ground motion is the primary cause of earthquake damage to man-made structures. Ground motion from earthquakes is amplified by soft soils and reduced by hard rock. Ground motion is measured by maximum peak horizontal acceleration expressed as a percentage of gravity (%g). Peak ground acceleration in the state ranges from 10 %g to 20 %g, with a 2% probability of exceedance in 50 years. Figure 4-3 provides additional information.

Middleton is located in an area with a PGA of 16%g to 18%g with a 2% probability of exceedance in 50 years (Figure 4-3). This is the fourth/fifth highest zone in the state: in other words, a moderate area of earthquake risk. Compared to the rest of the United States, Massachusetts overall has a low risk of earthquakes.

No earthquake epicenters have been recorded within Middleton. Although new construction under the most recent building codes generally will be built to seismic standards, much of the development in the town pre-dates the current building code. If an earthquake occurs, the entire region, not just the town, would face significant challenges. Earthquakes often trigger fires. The water distribution system may be disrupted, thus posing a risk for public health and safety.

A serious earthquake in Massachusetts is possible. These events can strike without warning and can have a devastating impact on infrastructure and buildings constructed prior to earthquake resistant design considerations.

It can be assumed that all existing and future buildings and populations are at risk to an earthquake hazard. Impacts from earthquakes can be from slight to moderate building damage, to catastrophic damage and fatalities, depending on the severity of the earthquake event. Events may cause minor damage such as cracked plaster and chimneys, or broken windows, or major damage resulting in building collapse. Based on the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, the degree of exposure “depends on many factors, including the age and construction type of the structures where people live, work, and go to school; the soil type these buildings are constructed on; and the proximity of these building to the fault location.” Furthermore, the time of day exposes different sectors of the community to the hazard. Earthquakes can lead to business interruptions, loss of utilities and road closures which may isolate populations. People who reside or work in unreinforced masonry buildings are vulnerable to liquefaction (liquefaction is the phenomenon that occurs when the strength and stiffness of a soil is reduced by earthquake).

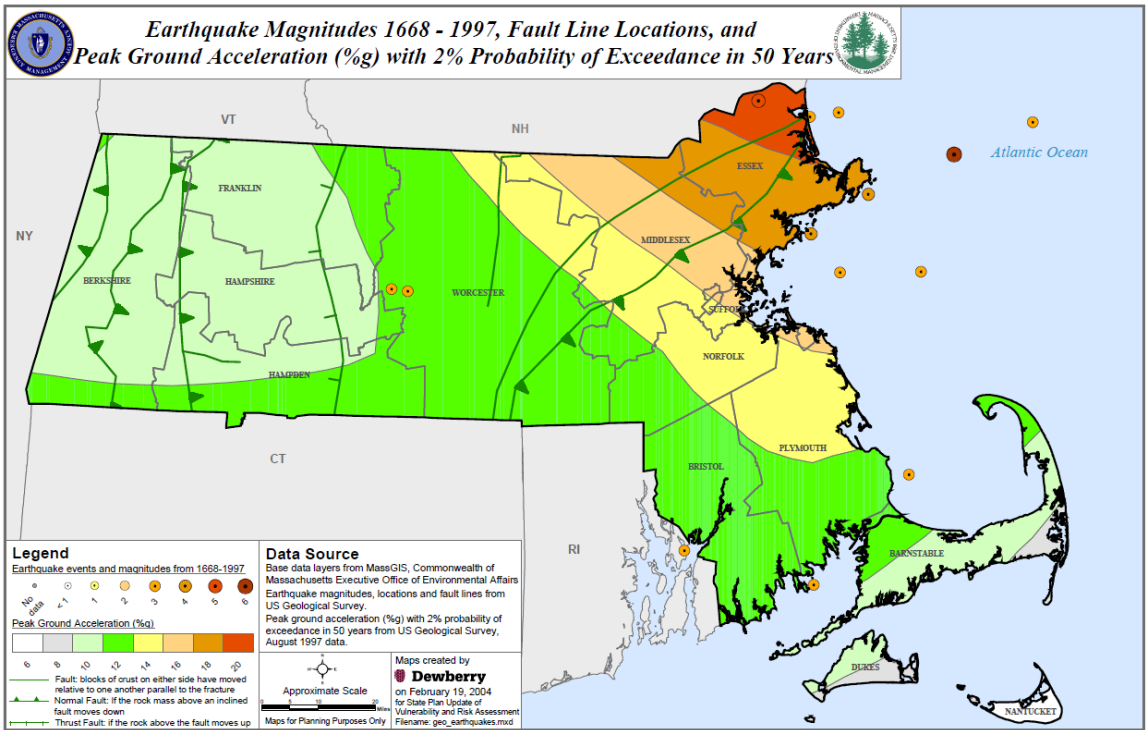


Figure 4-3. State of Massachusetts Earthquake Probability Map

(EEA and EOPSS, 2018)

Potential earthquake damage was modeled for Middleton using Hazus. The Hazus earthquake model allows users to input specific parameters in order to model a defined earthquake magnitude, with the epicenter located at the center of the municipality. In this analysis, two earthquakes were modeled: a magnitude 5.0 and a magnitude 7.0 earthquake. While large earthquakes are rare in Massachusetts, there was a magnitude 5.0 earthquake recorded in 1963. There is a possibility for larger scale earthquakes to occur in Massachusetts at some point, therefore a magnitude 7.0 earthquake was modeled as well to demonstrate the damage that could occur.

In order to model each of these earthquakes, the study region must first be defined. The Town of Middleton was outlined by the census tracts in the Town. The arbitrary event scenario was used for Middleton. This scenario allows the user to input the magnitude, depth, with, and epicenter of the earthquake. This must be done for each earthquake magnitude chosen. The output shows the potential impact that could occur in Middleton if either a magnitude 5.0 or a magnitude 7.0 earthquake occurred with the epicenter located in the center of the Town. Hazus is based on 2010 census data and 2014 dollars. The tables below show the estimated damage from both a magnitude 5.0 and a magnitude 7.0 earthquake in the municipality.

Table 4-27. Magnitude 5.0 Earthquake Damage

Infrastructural Damage from a Magnitude 5.0 Earthquake on Buildings in Middleton				
Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged	Percent of Buildings Damaged	Total Value of Building Damage[1]
Residential	2,276	1,047	46.0%	$88,030,700
Commercial	180	141	78.2%	$42,957,500
Industrial	62	49	79.2%	$15,150,300
Others	46	34	74.9%	$11,869,400
TOTAL	**2,564**	**1,271**	**49.6%**	**$158,007,900**

[1]Includes Slight, Moderate, Extensive, and Complete Damage
[2]Includes Building, Content and Inventory

Table 4-28. Magnitude 7.0 Earthquake Damage

Infrastructural Damage from a Magnitude 7.0 Earthquake on Buildings in Middleton				
Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged	Percent of Buildings Damaged	Total Value of Building Damage[1]
Residential	2,276	2,271	99.8%	$727,272,400
Commercial	180	180	100%	$261,217,600
Industrial	62	62	100%	$90,776,100
Others	46	46	100%	$72,620,900
TOTAL	**2,564**	**2,559**	**99.8%**	**$1,151,887,700**

[1]Includes Slight, Moderate, Extensive, and Complete Damage
[2]Includes Building, Content and Inventory

In addition to the infrastructural damage, Hazus also calculated the potential social impact of a magnitude 5.0 and magnitude 7.0 earthquake on the community. Additional property damage and business interruption loss were calculated as well, and a full Hazus risk response report for each earthquake category can be found in Appendix B.

Earthquakes are classified as a low frequency event in Middleton. As defined by the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, the probability of a magnitude 5.0 or greater earthquake centered in New England is about 10-15% in a 10-year period.

4.5.2 Landslides

Landslides include a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity, acting on an over steepened slope, is the primary reason for a landslide, there are other contributing factors. These contributing factors can include erosion by rivers or ocean waves over steepened slopes; rock and soil slopes weakened through saturation by snowmelt or heavy rains; earthquake created stresses that make weak slopes fail; excess weight from accumulation of rain or snow; and stockpiling of rock or ore from waste piles or man-made structures (USGS, 2019).

Landslides occur throughout the United States, causing an estimated $1 billion in damages and 25-50 deaths each year. Any area composed of very weak or fractured materials resting on a steep slope will likely experience landslides. Although the physical cause of many landslides cannot be removed, geologic investigations, good engineering practices, and effective enforcement of land-use management regulations can reduce landslide hazards (USGS, 2019). Landslides can damage buildings and infrastructure and cause sedimentation of water bodies. Landslide intensity can be measured in terms of destructiveness, as demonstrated by Table 4-29 below.

Table 4-29. Landslide Volume and Velocity

Estimate Volume (m^3)	Expected Landslide Velocity		
	Fast moving (rock fall)	Rapid moving (debris flow)	Slow moving (slide)
<0.001	Slight intensity	--	--
<0.5	Medium intensity	--	--
>0.5	High intensity	---	--
<500	High intensity	Slight intensity	--
500-10,000	High intensity	Medium intensity	Slight intensity
10,000 – 50,000	Very high intensity	High intensity	Medium intensity
>500,000	--	Very high intensity	High intensity
>>500,000	--	--	Very high intensity

(Cardinali et al., 2002)

All of Middleton is classified as having a low risk for landslides. No significant landslides have been recorded for Middleton or Essex County (EEA and EOPSS, 2018). Local officials indicate that there are occasionally localized issues of erosion during construction, as a result of development, or as a result of clearing vegetation. Landslides are classified as low frequency events in Middleton. These events can occur once in 50 to 100 years (a 1% to 2% chance of occurring each year).

4.6 Fire Related Hazards

Middleton is more likely to experience a brushfire compared to a wildfire (or a fire with a large impact area). wildfires and brushfires can occur in the vegetative wildland, including grass, shrub, leaf litter, and forested tree fuels. Fires can be caused by natural events, human activity or in an intentional controlled manner, as in the case of prescribed fire (MEMA and DCR, 2013, 252). The State Hazard Mitigation and Climate Adaptation Plan (EEA and EOPPS, 2018) states:

> *"The ecosystems that are most susceptible to the wildfire hazard are pitch pine, scrub oak, and oak forests, as these areas contain the most flammable vegetative fuels. Other portions of the Commonwealth are also susceptible to wildfire, particularly at the urban-wildland interface…. Interface communities are defined as those in the vicinity of contiguous vegetation, with more than one house per 40 acres and less than 50 percent vegetation, and within 1.5 miles of an area of more than 500 hectares (approximately 202 acres) that is more than 75 percent vegetated."*

Brush fires are classified as medium frequency events in Middleton. As defined by the 2013 State Hazard Mitigation Plan, these events occur between once in five years to once in 50 years (a 2% to 20% chance of occurring per year). Fire risk is influenced by fuel (the type of material), terrain and weather. Strong

winds can exacerbate extreme fire conditions, especially wind events that persist for long periods, or ones with significant sustained wind speeds that quickly promote fire spread through the movement of embers or exposure within tree crowns. Fires can spread quickly into developed areas.

Brush fires can lead to property damage and injury. The areas of Middleton most vulnerable to brush fire are primarily heavily wooded areas, such as the north side of town, Bald Hill, and along the rail trail. The fire department has equipment and resources to respond to fires in these and other areas. However, ongoing maintenance in the more forested areas of Town would aid in the reduction of brush fire spread.

All individuals whose homes or workplaces are located in brush fire hazard zones are exposed to this hazard. The most vulnerable members of this population are those who would be unable to evacuate quickly (EEA EOPSS, 2018). Secondary effects from brush fire include contamination of reservoirs; destroyed power, gas, water, broadband, and oil transmission lines. Brush fires can also contribute to flooding as they strip slopes of vegetation, thereby exposing them to greater amounts of runoff which may cause soil erosion and ultimately the chance of flooding. Additionally, subsequent rains can worsen erosion because brush fires burn ground vegetation and ground cover.

Although they are usually minor, the Middleton Fire Department responds to a fair amount of brush fires annually. In 2018, Middleton experienced 21 fires, which included 10 structure fires, 2 vehicle fires, and the remaining 9 were brushfires or other types of fire. This number was slightly lower than the 29 fires experienced in 2017. The total monetary loss due to fires in 2017 was $22,600, and in 2018 was $42,500.

4.7 Extreme Temperatures

4.7.1 Extreme Cold

Massachusetts has four clearly defined seasons. Extreme temperatures fall outside of the ranges typically experienced during these seasons. For example, Boston's average winter temperature, from December to February, is 32.2°F. Boston's average summer temperature, from June to August, is 73.8°F (NOAA, 2018). Extreme temperatures are considered a town-wide hazard in Middleton and generally last from an afternoon to a few days. Extremely cold temperatures are measured using the Wind Chill Temperature Index provided by the National Weather Service (NWS). The updated index was implemented in 2001 and helps explain the impact of cold temperatures on unexposed skin. Figure 4-4 below provides more information.

Extremely cold temperatures can create dangerous conditions for homeless populations, stranded travelers, and residents without sufficient insulation or heat. The homeless, the elderly, and people with disabilities are often most vulnerable. In Middleton, 18% of the population is over 65 years old and 9% of the population has a disability (US Census Bureau, 2018). Cold weather events can also have significant health impacts such as frostbite and hypothermia. Furthermore, power outages during cold weather may result in inappropriate use of combustion heaters, cooking appliances, and generators in poorly ventilated areas which can lead to increased risk of carbon monoxide poisoning

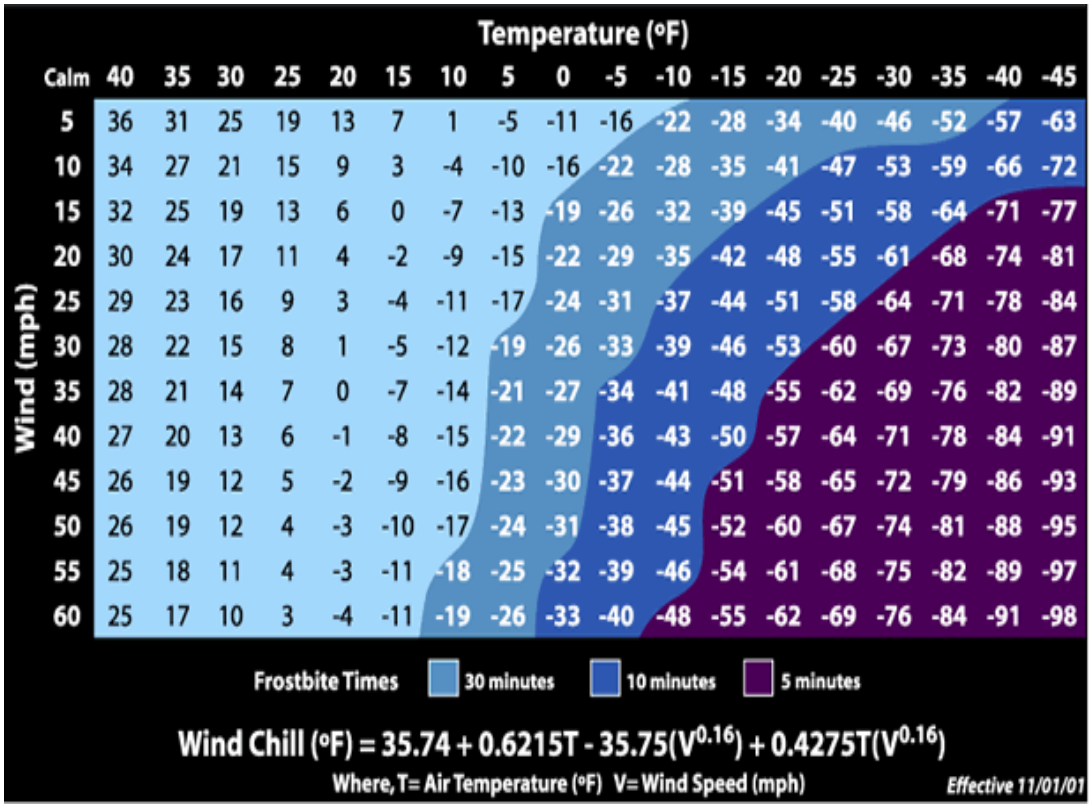


Figure 4-4. Windchill Temperature Index and Frostbite Risk

(NOAA, n.d.)

NOAA's National Centers for Environmental Information Storm Events Database provides data for extreme cold events (NOAA, 2019a). Between 2000 and 2019, Essex County experienced four extreme cold and will chill events, which caused no deaths, injuries, or property damage.

4.7.2 Extreme Heat

Increased temperatures will impact all locations within Middleton. Projected heat days and heat waves can have an increased impact in densely settled urban areas. These can become "heat islands" as dark-colored asphalt and roofs store the heat from the sun. According to the Centers for Disease Control and Prevention, the populations most vulnerable to extreme heat impacts include the following:

- People over the age of 65 (e.g., with limited mobility),
- Children under the age of five,
- Individuals with pre-existing medical conditions that impair heat tolerance,
- Low-income individuals who cannot afford proper cooling,
- Individuals with respiratory conditions,
- The general public who may overexert themselves during extreme heat events.

Homeless people are increasingly vulnerable to extreme heat. The capacity of homeless shelters is typically limited. Impacts from heat stress can exacerbate pre-existing respiratory and cardiovascular conditions. Based on Figure 4-5 below, compiled by the Massachusetts Department of Public Health Bureau of Environmental Health (DPH, 2019), Middleton has a population density of 624 per square

mile. The total number of population vulnerability measures in each Census Tract is 2. These population vulnerability measures include low income, low English proficiency, non-white (Hispanic and non-Hispanic ethnicities), and elderly.

The NWS issues a Heat Advisory when the Heat Index (Figure 4-6) is forecast to reach 100-104˚ F for two or more hours (NOAA, n.d.). The NWS issues an Excessive Heat Warning if the Heat Index is forecast to reach 105˚+F for two or more hours. Heat waves cause more fatalities in the U.S. than the total of all other meteorological events combined. In Boston, over 50 people die each year due to heat-related illnesses. From 1979-2012, excessive heat exposure caused in excess of 8,000 deaths in the United States (MEMA and DCR, 2013). During this period, more people in this country died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined.

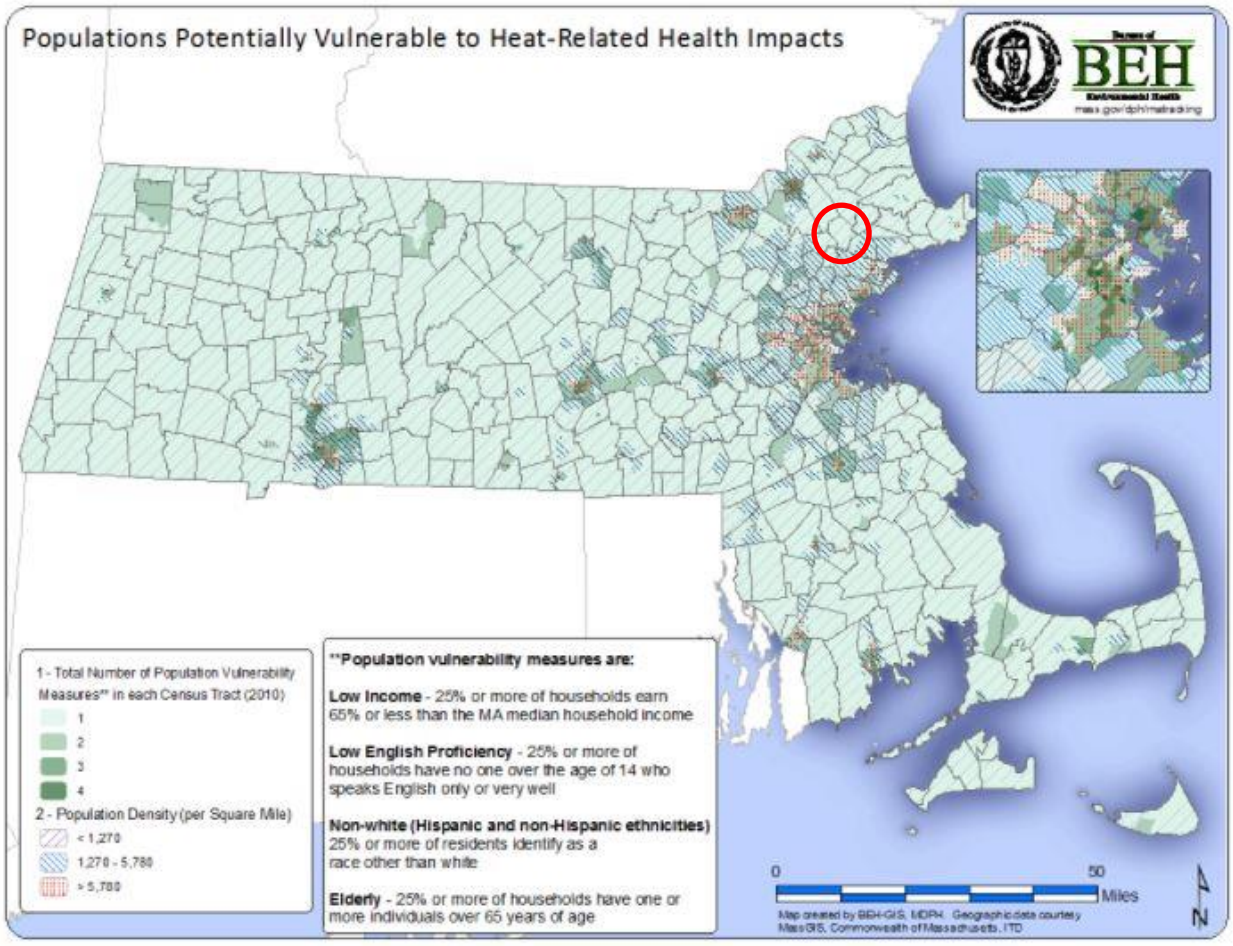


Figure 4-5. Populations Potentially Vulnerable to Heat Related Health Impacts (Middleton is shown as a red circle).
(DPH, 2019)

On July 6, 2013, a postal worker in MA collapsed and died as the Heat Index reached 100°F (EEA and EOPSS, 2018). Because most heat-related deaths occur during the summer, people should be aware of who is at greatest risk and what actions can be taken to prevent a heat-related illness or death. The

populations at greater risk are the elderly, children, and people with certain medical conditions, such as heart disease. In Middleton, children under eighteen years old make up 19% of the population, and 18% are over 65 years old (US Census Bureau, 2018). However, even young and healthy individuals can succumb to heat if they participate in strenuous physical activities during hot weather. Some behaviors also put people at greater risk: drinking alcohol, taking part in strenuous outdoor physical activities in hot weather, and taking medications that impair the body's ability to regulate its temperature or that inhibit perspiration (MEMA and DCR, 2013).

	Temperature (°F)																
Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Category	Heat Index	Health Hazards
Extreme Danger	130 °F – Higher	Heat Stroke or Sunstroke is likely with continued exposure.
Danger	105 °F – 129 °F	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Extreme Caution	90 °F – 105 °F	Sunstroke, muscle cramps, and/or heat exhaustions possible with prolonged exposure and/or physical activity.

Figure 4-6. Heat Index Chart

(NOAA, n.d.)

Increased temperatures can lead to a longer growing season, which in turn leads to a longer pollen season. Warmer weather can also support the migration of invasive species and lead to an increase in vector-borne diseases. Increasing temperatures can also worsen air pollution, which can lead to negative health impacts such as respiratory problems.

The Town of Middleton does not collect data on heat occurrences. The best available local data are for Essex County, through the National Environmental Information Center. NOAA's National Centers for Environmental Information Storm Events Database provides data on excessive heat (NOAA, 2019a). Between 2000 and 2019, Essex County experienced six extreme heat days, which did not result in injury, death, or property damage.

Extreme temperatures are classified as medium frequency events. According to the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (EEA and EOPSS, 2018), between four and five heat waves (3 or more consecutive days of 90˚+F temperatures) occur annually in Massachusetts.

4.7.3 Climate Change Impacts: Extreme Temperatures

Between 1961 and 1990, Boston experienced an average of one day per year in excess of 100°F. That could increase to six days per year by 2070, and 24 days per year by 2099. Under these conditions by the end of the century, Massachusetts's climate would more closely resemble that of Maryland or the Carolinas (refer to Figure 4-7 below). These changes in temperature would also have a detrimental impact on air quality and public health concerns including asthma and other respiratory conditions (Frumhoff et al. 2007).

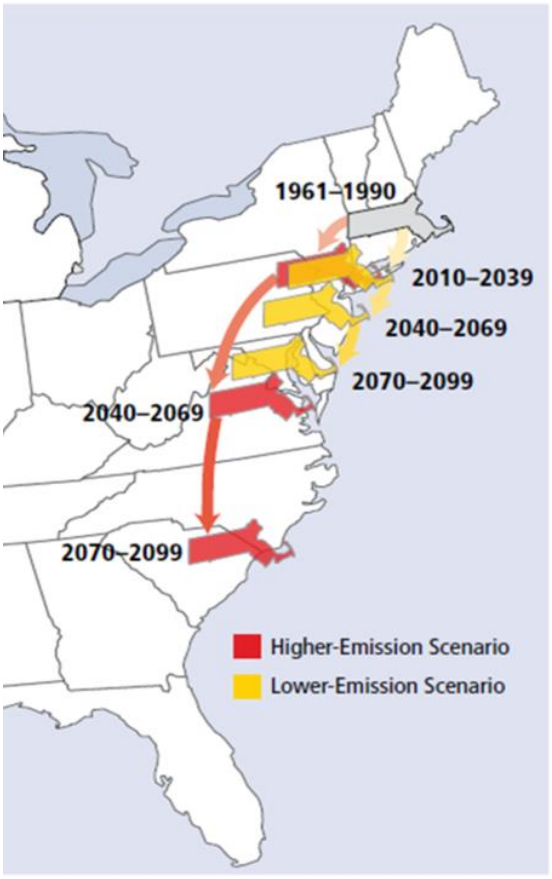


Figure 4-7. Massachusetts Extreme Heat Scenarios
(Frumhoff et al., 2007)

4.8 Drought

Drought is an extended period of deficient precipitation. Drought conditions occur in virtually all climatic zones, yet its characteristics vary significantly from one region to another since it is relative to the normal precipitation in that region. Agriculture, the water supply, aquatic ecosystems, wildlife, and the economy are vulnerable to the impacts of drought (EEA and EOPSS, 2018). Water supply was the largest concern at the CRB Workshop.

Although Massachusetts is relatively small, it has a number of distinct regions that experience significantly different weather patterns and react differently to the amounts of precipitation they receive. In accordance with the Massachusetts Drought Management Plan, the Drought Management Task Force will make recommendations to the Secretary of Energy & Environmental Affairs about the location and severity of drought in the Commonwealth. The Drought Management Plan divides the state into regions. Middleton is located within the Northeast region (EEA and MEMA, 2013).

Five levels of drought have been developed to characterize drought severity: Normal, Advisory, Watch, Warning, and Emergency; these correspond to Level 0 – Normal, Level 1 - Mild Drought, Level 2 - Significant Drought, Level 3 - Critical Drought (was Warning), and Level 4 - Emergency Drought (was Emergency), respectively, of the draft Drought Management Plan update. The drought levels are based on the severity of drought conditions and their impacts on natural resources and public water supplies.

The Drought Management Plan specifies the agency response and interagency coordination and communication corresponding to the various drought levels. During normal conditions, data are routinely collected and distributed. There is heightened vigilance with additional data collection during an advisory, and increased assessment and proactive education during a watch. Water restrictions might be appropriate at the watch or warning stage, depending on the capacity of each individual water supply system. A warning level indicates a severe situation and the possibility that a drought emergency may be necessary. A drought emergency is one in which use of emergency supplies become necessary

or in which the Governor may exercise his authority to require mandatory water restrictions or (EEA and MEMA, 2013).

A variety of drought indices are available to assess the various impacts of dry conditions. The Commonwealth uses a multi-index system to determine the severity of a drought or extended period of dry conditions. A determination of drought level is based on seven indices: Standardized Precipitation Index, Precipitation (percent of normal), Crop Moisture Index, Keetch-Byram Drought Index (KBDI), Groundwater levels, Stream flow levels, and Index Reservoir levels. (In its draft updated Drought Management Plan, the Drought Management Trask Force has proposed to eliminate the precipitation index that is based on percent of normal precipitation.)

Drought level is determined monthly based on the number of indices which have reached a given drought level. A majority of the indices would need to be triggered in a region in order for a drought designation to move to a more severe level. Drought levels are declared on a regional basis for each of the six regions in Massachusetts. Drought levels may also be made county by county or be watershed specific. The end of a drought is determined by precipitation and groundwater levels since these have the greatest long-term impact on streamflow, water supply, reservoir levels, soil moisture and potential for forest fires (EEA and MEMA, 2013).

Figure 4-8 illustrates statewide drought levels in Massachusetts from 1850 to 2012, using the Standardized Precipitation Index (SPI). Table 4-30 below summarizes a history of Massachusetts droughts between 1879 and 2017.

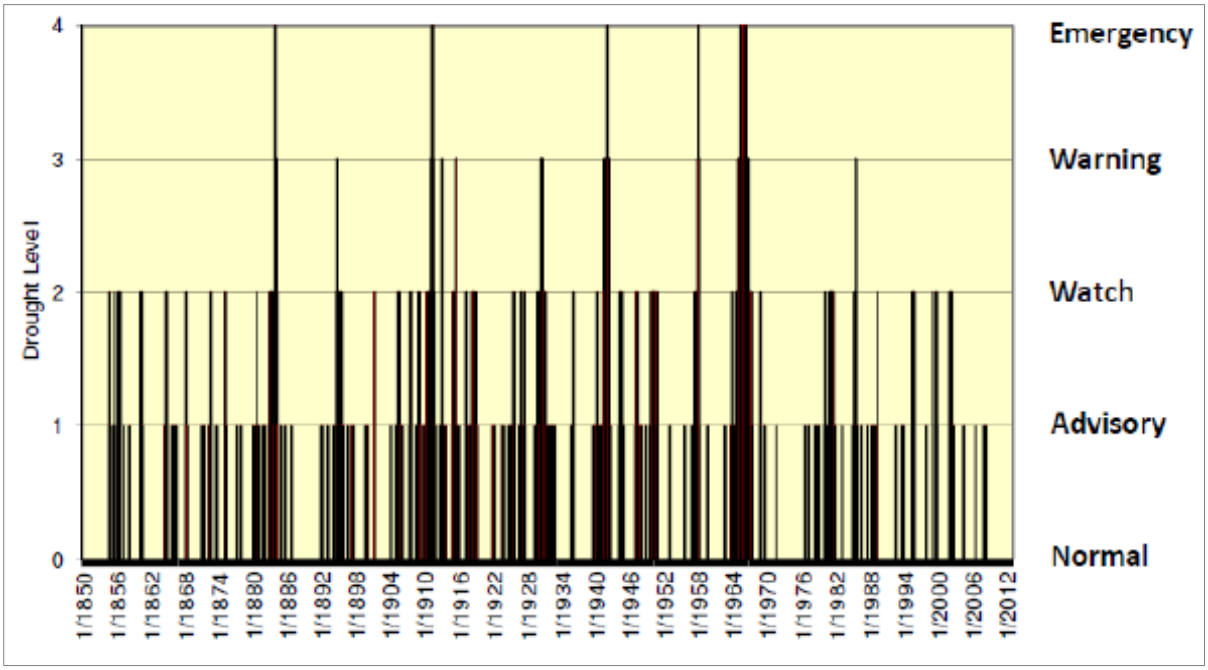


Figure 4-8. Statewide Drought Levels Using SPI Thresholds, 1850 to 2012.
(EEA and MEMA, 2013)

Table 4-30. Droughts in Massachusetts Based on Instrumental Records

Date	Area Affected	Recurrence Interval (years)	Remarks
1879 to 1883	–	–	–
1908 to 1912	–	–	–
1929 to 1932	Statewide	10 to >50	Water-supply sources altered in 13 communities. Multistate.
1939 to 1944	Statewide	15 to >50	More severe in eastern and extreme western Massachusetts. Multistate.
1957 to 1959	Statewide	5 to 25	Record low water levels in observation wells, northeastern Massachusetts.
1961 to 1969	Statewide	35 to >50	Water-supply shortages common. Record drought. Multistate.
1980 to 1983	Statewide	10 to 30	Most severe in Ipswich and Taunton River basins; minimal effect in Nashua River basin. Multistate.
1985 to 1988	Housatonic River Basin	25	Duration and severity unknown. Streamflow showed mixed trends elsewhere.
1995	–	–	Based on statewide average precipitation.
1998 to 1999	–	–	Based on statewide average precipitation.
2001 to 2003	Statewide	–	Level 2 drought (out of 4 levels) was reached statewide for several months.
2007 to 2008	Statewide except West and Cape and Islands regions	–	Level 1 drought (out of 4 levels)
2010	Connecticut River Valley, Central and Northeast regions	–	Level 1 drought (out of 4 levels)
2014	Southeast and Cape and Islands regions	–	Level 1 drought (out of 4 levels)
2016-2017	Statewide	–	Level 3 drought (out of 4 levels).

(EEA and EOPSS, 2018)

There are five drought emergencies on record in Massachusetts: 1883, 1911, 1941, 1957, and 1965-1966. The 1965-1966 drought is considered the most severe Massachusetts drought in modern times, given its length. On a monthly basis over the 162-year period of record, there is a one percent chance of being in a Drought Emergency (EEA and MEMA, 2013). Drought Warning levels not associated with Drought Emergencies would have occurred in 1894, 1915, 1930,1985, 2016, and 2017. On a monthly basis over the 162-year period of record, there is a two percent chance of being in a drought Warning level (EEA and MEMA, 2013; DCR, 2017b). NOAA's Storm Database listed an additional severe drought even in April 2012 in Essex County (NOAA, 2019a)

Drought Watches not associated with higher levels of drought generally would have occurred three to four times per decade between 1850 and 1950. The Drought Emergency declarations dominated the 1960s. There were no Drought Watches or above in the 1970s. In the 1980s, there was a lengthy Drought Watch level of precipitation between 1980 and 1981, followed by a Drought Warning in 1985. A frequency of drought Watches at a rate of three years per decade resumed in the 1990s (1995, 1998, 1999). In the 2000s, Drought Watches occurred in 2001 and 2002. The overall frequency of being in a Drought Watch is eight percent on a monthly basis over the 162-year period of record (EEA and MEMA, 2013). There were six drought watches in Massachusetts in 2002, five drought watches in 2016, and two drought watches in 2017 (DCR, 2017b). Figure 4-9 presents an example of drought conditions in the six drought regions.

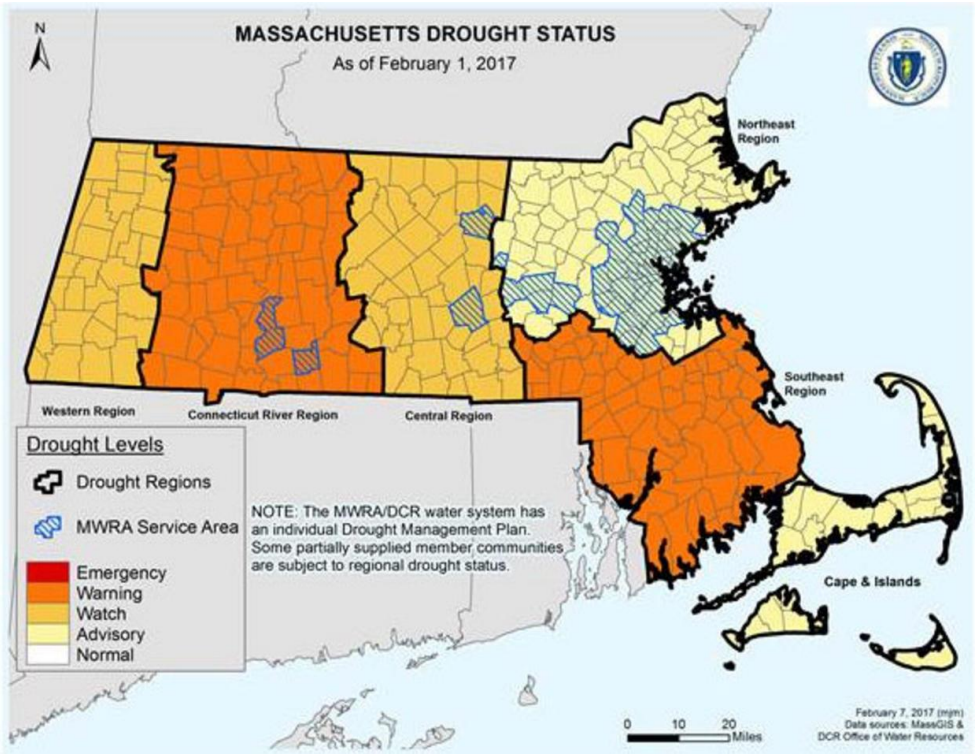


Figure 4-9. Massachusetts Drought Status, February 2017

(DCR, 2017b)

Drought is a potential town-wide hazard in Middleton. As noted previously, temperature is projected to increase and may lead to exacerbated drought conditions especially in summer and fall months. Droughts can also increase fire risk: fires can be caused by lightning, and a 2014 study found that the

frequency of lightning strikes could increase by more than 10% for every degree Celsius of warming (EEA and EOPSS, 2018).

A long-term drought could lead to impacts to Middleton's water resources. It could also have significant adverse impacts to the Town's water supply. Although Middleton water comes from the Danvers water treatment plant, many of the sources are located in Middleton. The Town currently works with its residents to conserve water, especially during times of drought or low water levels.

Droughts are classified as a low frequency natural hazard event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, these events can occur between once in 50 years to once in 100 years (a 1% to 2% chance of occurring per year).

4.8.1 Climate Change Impacts: Drought

Under climate change, drought conditions will be exacerbated with projected increasing air temperatures and changes in precipitation. Between 1970 and 2000, the median number of consecutive dry fall days in Massachusetts was 11.4 days. This is in comparison to a projected median of 13.5 consecutive days by the end of the century (EEA, 2018a).

5.0 EXISTING MITIGATION MEASURES

FEMA categorizes hazard mitigation measures into four types as displayed in Table 5-1 (FEMA, 2013). The existing protective measures available to the Town of Middleton are a combination of zoning, land use, and environmental regulations, infrastructure maintenance, and drainage infrastructure improvement projects. Infrastructure maintenance generally addresses localized drainage clogging problems, while large scale capacity problems may require pipe replacement or invert elevation modifications. These more expensive projects are subject to the capital budget process. The Town's existing mitigation measures are described by hazard type here and are detailed in section 5.2. Upgrades to existing measures are also noted in the following sections.

Table 5-1. FEMA's Types of Mitigation Actions

Measure	Action	Examples
Local Plans and Regulations	These actions include government authorities, policies, or codes that influence the way land and buildings are developed and built.	• Comprehensive plans • Land use ordinances • Subdivision regulations • Development review • Building codes and enforcement • NFIP Community Rating System • Capital improvement programs • Open space preservation • Stormwater management regulations and master plans
Structure and Infrastructure Projects	These actions involve modifying existing structures and infrastructure to protect them from a hazard or remove them from a hazard area. This could apply to public or private structures as well as critical facilities and infrastructure. This type of action also involves projects to construct manmade structures to reduce the impact of hazards.	• Acquisitions and elevations of structures in flood prone areas • Utility undergrounding • Structural retrofits. • Floodwalls and retaining walls • Detention and retention structures • Culverts • Safe rooms
Natural Systems Protection	These are actions that minimize damage and losses and preserve or restore the functions of natural systems.	• Sediment and erosion control • Stream corridor restoration • Forest management • Conservation easements • Wetland restoration and preservation

Education and Awareness Programs	These are actions to inform and educate citizens, elected officials, and property owners about hazards and potential ways to mitigate them. A greater understanding and awareness of hazards and risk among local officials, stakeholders, and the public is more likely to lead to direct actions.	• Radio or television spots • Websites with maps and information • Real estate disclosure • Presentations to school groups or neighborhood organizations • Mailings to residents in hazard-prone areas. • StormReady • Firewise Communities

(FEMA, 2013)

5.1 Summary of Existing Mitigation

There are numerous existing natural hazard mitigation measures already in place in Middleton. These were identified through feedback from the Core Team, CRB Workshop participants, and additional stakeholders. These mitigation measures are summarized in Table 5-2.

Table 5-2. Existing Mitigation Measures

Type of Existing Mitigation Measures	Area Covered	Effectiveness	Improvements
MULTIPLE HAZARDS			
Northeast Regional Emergency Planning Committee	Region-Wide	Effective	Should meet more often
Comprehensive Emergency Management Plan (CEMP)	Town-Wide	Effective	Needs to be updated periodically
Public Education	Town-wide	Effective	Continue to expand outreach; potential for additional fire risk public education
Alert Center	Town-wide	Effective	None
Northshore Regional 911 Center	Regional	Effective	None
Town Facilities as Emergency Shelters	Town-wide	Effective	None
Multi-Department Review of Development	Town-wide	Effective	None
Zoning Regulations	Town-wide	Effective	The Town will be redrafting its current zoning bylaw following completion of the Master Plan.
Massachusetts State Building Code	State-wide	Effective	None
Middleton Food Pantry	Town-wide	Effective	None
FEMA Deployment	State-wide	Effective	None

Table 5-2. Existing Mitigation Measures

Type of Existing Mitigation Measures	Area Covered	Effectiveness	Improvements
FLOOD HAZARDS			
Participation in the National Flood Insurance Program (NFIP). The Town actively enforces the floodplain regulations.	Areas identified on the FIRM maps	Effective	None
Culvert priority and risk assessment	Town-wide	Effective	Should be periodically updated
IDDE Program Implementation	Town-wide	Effective	Continue implementation
Street sweeping	Town-wide	Effective	None
Catch basin cleaning	Town-wide	Effective	None
Ongoing Drainage Improvement Program	Town-wide	Effective	Ongoing improvements needed
Zoning – Floodplain Overlay District	Floodplain District	Effective	None
Zoning – Watershed Protection Overlay District	Watershed District	Effective	None
Subdivision Regulations	Town-wide	Effective	Updated with LID principles
Wetlands Protection Act	Wetland Resource Areas	Effective	Possibly adopt a local wetlands bylaw
Massachusetts Stormwater Regulations	Conservation Commission jurisdictional areas	Effective	None
Middleton Stormwater Management Bylaw	Town-wide	Effective	Revisions needed for MS4 compliance
Cross-Connection Control Program	Town-wide	Effective	None
Middleton Open Space and Recreation Plan	Town-wide	Effective	In process of updating
Site Plan Review	Town-wide	Effective	None
Public Education on Stormwater	Town-wide	Effective	Continue to update and inform the public
NPDES Phase II Stormwater Program	Town-wide	Effective	Continue implementation
DAM HAZARDS			
DCR dam safety regulations and permitting	State-wide	Somewhat effective	Improvements to the statewide system for dam inspections.
Permits required for construction.	State-wide	Effective	None

Table 5-2. Existing Mitigation Measures

Type of Existing Mitigation Measures	Area Covered	Effectiveness	Improvements
Emergency Action Plan (EAP)	State-wide	Effective	Communicate EAP protocols with private dam owners
WIND HAZARDS			
The Massachusetts State Building Code	State-wide	Effective	None
Tree Maintenance by MELD	Town-wide	Effective	None
WINTER HAZARDS			
Snow-Plowing Operations	Town-wide	Effective	None
Snow Removal Requirements in the General Bylaw	Town-wide	Effective	None
BRUSH FIRE HAZARDS			
Open Burning Permits Required	Town-wide	Effective	None
Public Education	Town-wide	Effective	None
Backup Firefighting Supplies			
Fire Department Review of Proposal Developments	Town-wide	Effective	None
Statewide Fire Mobilization Plan	State-wide	Effective	None
GEOLOGIC HAZARDS			
The Massachusetts State Building Code	Town-wide	Effective	None
EXTREME TEMPERATURE RELATED HAZARD			
Heating and Cooling Shelter	Public Library	Effective	None

5.2 Existing Multi-Hazard Mitigation Measures

Northeast Regional Emergency Planning Committee - Under the Emergency Planning and Community Right to Know Act of 1986, communities are required to establish Local Emergency Planning Committees to develop a response plan for chemical emergencies. In accordance with this legislation, the region has created a regional emergency planning committee, which includes the Town of Middleton.

Comprehensive Emergency Management Plan (CEMP) – Every community in Massachusetts is required to have a Comprehensive Emergency Management Plan. This plan addresses mitigation, preparedness, response and recovery from a variety of natural and man-made emergencies. Included in this plan is important information regarding flooding, hurricanes, tornadoes, dam failures, earthquakes, and winter storms.

Public Education – Emergency Preparedness public education is available on the Town's website, via the Fire Department, Police Department, and Health Department. Documents are available to assist in individual preparation for a disaster, including how to assemble an emergency supply kit and family emergency planning.

Northshore Regional 911 Center – Regional Communications Center for Amesbury, Essex, Middleton, Topsfield and Wenham, MA.

Town Facilities as Emergency Shelters – The Fuller Meadow School and Howe-Manning School would serve as shelters in the event of a disaster. The Flint Public Library may also be used as a warming and cooling facility.

Multi-Department Review of Developments – Multiple departments, including the Town Administrator, Planning, Zoning, Building, Health, Highway, Conservation, Police, and Fire, thoroughly review all subdivision and site plans prior to approval.

Zoning Regulations – The Town will be redrafting its current zoning bylaw following completion of the Master Plan, including possibly adopting measures to preserve open space and concentrate new growth in already developed areas.

Massachusetts State Building Code – The Massachusetts State Building Code contains many detailed regulations regarding wind loads, earthquake resistant design, flood-proofing, and snow loads.

Middleton Food Pantry – The Middleton Food Pantry's mission is to feed needy families in the local community.

FEMA Deployment – FEMA can deploy vehicles in the case of an emergency.

5.3 Existing Town-Wide Mitigation for Flood Related Hazards

Middleton employs a number of practices to help minimize potential flooding, reduce impacts from flooding, and to proactively maintain existing drainage infrastructure. Existing Town-wide mitigation measures include the following:

Participation in the NFIP – Middleton participates in the National Flood Insurance Program (NFIP). The NFIP is a Federal program administered by FEMA enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for State and community floodplain management regulations that reduce future flood damages (FEMA, 2019f). NFIP offers flood insurance to communities that comply with the minimum standards for floodplain management.

NFIP uses a Community Rating System (CRS) to award communities that go beyond the minimum standards with lower flood insurance premiums for property owners. The incentives are awarded upon a credit system for various activities. Points are awarded to communities that prepare, adopt, implement, and update a comprehensive flood hazard mitigation plan using a standard planning process. Middleton is not currently eligible to participate in the CRS Program (as of May 2019) (FEMA, 2019c).

Middleton participates in the NFIP with 29 policies in force as of September 30, 2019 (DCR, 2020a). FEMA maintains a database on flood insurance policies and claims. This database can be found on the FEMA website at s://www.fema.gov/policy-claim-statistics-flood-insurance.

The following information is provided for the Town of Middleton:

Table 5-3. National Flood Insurance Program in Middleton

Flood Insurance Data		Repetitive Loss (RL) Data	
Flood Insurance Policies in Force	29	RL Buildings	2
Premium	$16,044	RL Losses	4
Insurance in Force	$8,811,000	RL Payments (total)	$14,389
Number of Closed Paid Losses	9	RL Payments (building)	$14,389
Dollar Amount of Closed Paid Losses	$135,171	RL Payments (contents)	$0

(DCR, 2020a)

The Town complies with the NFIP by enforcing floodplain regulations, maintaining up-to-date floodplain maps, and providing information to property owners and builders regarding floodplains and building requirements.

Culvert Priority and Risk Assessment – The Town has completed a study on the priority and risk of most culverts in Middleton.

Street Sweeping – The Town performs street sweeping at a minimum of once per year on all roads.

Catch basin cleaning – The Town clears debris from its catch basins annually.

Ongoing Drainage Improvement Program – The Public Works Department provides maintenance to culverts, drainage pipes, and other drainage infrastructure on an as-needed basis.

Illicit Discharge Detection and Elimination (IDDE) Program Implementation – The Town's written IDDE Program was created in 2019 and will be implemented over the next few years. The Town will complete a storm system map and sample all outfalls for water quality.

Zoning Regulations – Zoning is intended to protect public health and safety through the regulation of land use. The Middleton Zoning Bylaw includes a Floodplain Overlay District and a Watershed Protection Overlay District. The Town is currently proposing the addition of a Groundwater Protection Overlay District.

Subdivision Regulations – Subdivision regulations require that the quantity of runoff shall not exceed peak runoff from the site prior to development.

Floodplain Overlay District – The Town's Floodplain District is defined by the 100-year floodplain as designated by FEMA. The Floodplain Overlay District regulates certain activities within a flood zone.

Massachusetts Stormwater Regulations – These regulations are applied to developments within the jurisdiction of the Conservation Commission.

Middleton Stormwater Management Bylaw – The Town has a Stormwater Management Bylaw to protect the Town's waters from the harmful effect of stormwater runoff. Revisions will be needed at the Town Meeting to comply with MS4 requirements.

Cross-Connection Control Program – In order to protect the public potable water supply serviced by the Middleton Water Division from contamination or pollution, this program aims to isolate these contaminants or pollutants which could backflow into the water system.

Wetlands Protection Act – The Middleton Conservation Commission administers the State's Wetlands Protection Act to protect resource areas in and around wetlands, including land subject to flooding.

Middleton Open Space and Recreation Plan (OSRP) – The Town has a wealth of conservation areas and recreation spaces, and the OSRP aims to maintain, promote use, and increase the number of these spaces. An OSRP update is needed.

Site Plan Review – Multiple Town staff and boards provide reviews of new developments. The Town has a Development Review Group which is composed of the Town Administrator, Town Planner, Conservation Agent, Building Commissioner, Police Chief, Health Director, Middleton Electric Light Manager, and Assessor. This group will provide comments and recommendations for all construction projects that requires new construction or will result in a change in the outside appearance or change of use of a building.

Public Education on Stormwater – The Town continues to implement its NPDES Phase II stormwater program, which includes public education programs through Greenscapes.

NPDES Phase II Stormwater Program – The Town continues to implement an aggressive NPDES stormwater program that includes measures for public education and outreach, illicit discharge detection and elimination, construction and post-construction controls, and Town-wide good housekeeping and stormwater maintenance procedures.

5.4 Existing Dam Mitigation Measures

DCR Dam Safety Regulations – All jurisdictional dams are subject to the Division of Conservation and Recreation's dam safety regulations (302 CMR 10.00). The dams must be inspected regularly, and reports filed with the DCR Office of Dam Safety. There are no Town-owned dams in Middleton.

Permits Required for Construction – State law requires a permit for the construction of any dam.

Emergency Action Plans – DCR requires that all dams classified or reclassified as high hazard potential and significant hazard potential have an Emergency Action Plan.

5.5 Existing Town-Wide Mitigation for Wind-Related Hazards

Massachusetts State Building Code – The Town enforces the Massachusetts State Building Code whose provisions are generally adequate to protect against most wind damage. The code's provisions are the most cost-effective mitigation measure against tornados given the extremely low probability of occurrence. If a tornado were to occur, the potential for severe damages would be extremely high.

Tree Maintenance by Town – The Town maintains street trees and numerous trees on public grounds, historic sites, conservation areas, park areas and cemeteries. Middleton recently got a large tree grant from a local bank.

Tree Trimming by MELD and DOT – Middleton Electric Light Department and the Massachusetts Department of Transportation trims trees along the power lines and roadways.

5.6 Existing Town-Wide Mitigation for Winter-Related Hazards

Snow Removal Requirements in the General Bylaw – No person shall pile, push, throw, shovel, plow, or by any other method or means cause snow to be deposited or placed on any public roadway or sidewalk of the Town so as to impede, obstruct, or interrupt or otherwise adversely affect the unrestricted flow of traffic or the safe travel of any pedestrian on such roadway or sidewalk (General Bylaw, Article V).

Snow-Plowing Operations – The Public Works Department provides standard snow plowing operations, including salting.

5.7 Existing Town-Wide Mitigation for Fire-Related Hazards

Open Burning Permits Required – The Town allows controlled open burning in accordance with state regulations, but a permit is required from the Fire Department for each day of intended burning. Burning is only allowed during the burning season, typically January through April each year.

Fire Department Review of Proposed Development – The Fire Department reviews all subdivision and site plans for compliance with site access, water supply needs, and other applicable regulations within their jurisdiction.

Backup Firefighting Supplies – the amount of backup firefighting supplies in Middleton is dependent on the budget.

Public Education – The Fire Department provides some public education on fire prevention by way of the burning season regulations.

Statewide Fire Mobilization Plan – The state has a fire mobilization plan for brush fires, as well as a separate plan for Middleton's Fire District.

5.8 Existing Town-Wide Mitigation for Extreme Temperature-Related Hazards

Heating and Cooling Shelter – The Fuller Meadow School and Howe-Manning School are the Town's emergency shelters and can be used as heating facilities. The Flint Public Library is available as a cooling or heating shelter.

5.9 Existing Town-Wide Mitigation for Geologic Hazards

Massachusetts State Building Code – The State Building Code contains a section on designing for earthquake loads (780 CMR 1612.0). Section 1612.1 states that the purpose of these provisions is "to minimize the hazard to life to occupants of all buildings and non-building structures, to increase the expected performance of higher occupancy structures as compared to ordinary structures, and to improve the capability of essential facilities to function during and after an earthquake". This section goes on to state that due to the complexity of seismic design, the criteria presented are the minimum considered to be "prudent and economically justified" for the protection of life safety. The code also states that absolute safety and prevention of damage, even in an earthquake event with a reasonable probability of occurrence, is not economically achievable for most buildings.

Section 1612.2.5 establishes seismic hazard exposure groups and assigns all buildings to one of these groups according to a Table 1612.2.5. Group II includes buildings which have a substantial public hazard due to occupancy or use and Group III are those buildings having essential facilities which are required for post-earthquake recovery, including fire, rescue and police stations, emergency rooms, power-generating facilities, and communications facilities.

5.10 Mitigation Capabilities and Local Capacity for Implementation

Under the Massachusetts system of "Home Rule," the Town of Middleton is authorized to adopt and from time to time amend a number of local bylaws and regulations that support the Town's capabilities to mitigate natural hazards. These include the Zoning Bylaw, Stormwater Bylaw, Subdivision and Site Plan Review Regulations, Health Regulations, Public Works regulations, and local enforcement of the State Building Code. Local bylaws may be amended to improve the Town's capabilities, and changes to most regulations simply require a public hearing and a vote of the authorized board or commission. The Town of Middleton has recognized several existing mitigation measures that require implementation or improvements, and has the capacity based on these Home Rule powers within its local boards and departments to address them. The Town also has the ability to expand on and improve the existing policies and programs listed above.

6.0 HAZARD MITIGATION AND CLIMATE ADAPTATION STRATEGY

6.1 Implementation Progress on the Previous Plan

Middleton staff and Core Team members reviewed the mitigation measures identified in the 2012 Middleton Hazard Mitigation Plan. Core Team members provided information on whether the priority mitigation action had been implemented or deferred. The 2012 HMP was not integrated into other policy, planning, and other programmatic areas due to staff changes over the years and lack of knowledge of the plan. The deferred measures were evaluated by the Core Team to determine if the measure should be carried forward into the 2020 HMP-MVP Plan. The decision to retain a measure was based on the members' assessment of the continued relevance or effectiveness at addressing vulnerabilities. In some cases, an action was deferred because of the lack of funding or resources. Table 6-1 summarizes the status of the mitigation measures, along with the priority of these measures in 2012. The actions in Table 6-1 that will be included in the updated 2020 HMP-MVP are also integrated into Table 6-2. Table 6-2 is intended to prioritize the proposed measures and provide guidance on how to best allocate the Town's limited resources.

Table 6-1. Progress Report on Priorities from the Middleton's 2012 Hazard Mitigation Plan

Mitigation Measure	2012 Priority	Implementation Responsibility	Status	Included in 2020 HMP?
North Liberty Street - Replace existing 36 inch culvert with 8 x 10 foot pre-cast concrete culvert	High	DPW/ Conservation Commission	Completed	No
Traggert Pond - Install new outlet structure and Beaver Deceivers	High	DPW/ Conservation Commission	Not completed, no longer a priority	No
Lake Street/ Middleton Dam - Reposition discharge pipe at Middleton Dam so it no longer blocks culvert.	High	Danvers/DPW	Completed	No
Locust Street - Extend drain line from Village Road to Locust Street and create detention pond.	High	DPW/ Conservation Commission	Completed	No
Haynes and Oak Street - Install retention basin structures under Haynes Street ROW	High	DPW/ Conservation Commission	Completed	No
Investigate funding options for provision of stormwater treatment and maintenance of town drainage infrastructure.	High& NFIP	DPW	Enacted stormwater management bylaw with filing fees	No

Table 6-1. Progress Report on Priorities from the Middleton's 2012 Hazard Mitigation Plan

Mitigation Measure	2012 Priority	Implementation Responsibility	Status	Included in 2020 HMP?
Digitize the location of all outfalls and catch basins into town GIS database	High & NFIP	DPW	Partially complete - Time constraints delayed progress, currently a medium priority	Yes
Purchase new 4x4, 26,000 GVW woods brush fire pumper truck and new All Terrain Vehicle (ATV).	High	Fire	Financial constraints delayed progress, currently a medium priority	Yes
Purchase 3rd pumper truck.	High	Fire	Completed	No
Implement DCR Fire Wise Program.	High	Fire	Time constraints delayed progress, currently a medium priority	Yes
Design and implement a joint fire road access and management plan with Danvers	High	Fire	Time and financial constraints delayed progress, currently a medium priority	Yes
Design and construct new Public Safety Building.	High	Fire/Police	Purchased property in 2019 and began design process, currently a high priority	Yes
Install new radio repeaters at the Police Station and Middleton Jail, sub-repeater at North Main Street	High	Police	Completed	No
Purchase new Police Station base radio station, if regional dispatch is not used.	High	Police	Completed	No
Upgrade fixed generator at Fuller Meadow School/Emergency Shelter.	High	Fire	Financial constraints delayed progress, currently a medium priority	Yes
Install new generator transfer switch at DPW facility.	High	DPW	Completed	No
Complete and implement Stormwater Management Plan.	Medium & NFIP	DPW/ Conservation Commission	Completed	No

Table 6-1. Progress Report on Priorities from the Middleton's 2012 Hazard Mitigation Plan

Mitigation Measure	2012 Priority	Implementation Responsibility	Status	Included in 2020 HMP?
Mill Street and Mill Street Extension - Maintain culverts and manage beaver removal to prevent re-occurrence of flooding.	Medium	DPW/ Conservation Commission	Completed	No
Develop town-based wetlands mapping and delineations GIS database.	Medium & NFIP	Conservation Commission	Financial constraints delayed progress, no longer a priority	No
Perkins Rd- Install new 8x10 pre-cast concrete box culvert.	Medium	DPW	Not completed, no longer a priority	No
Continue enforcement and monitoring of the Building Code, Zoning, and Subdivision to ensure compliance with the NFIP.	Medium & NFIP	Planning/ Building	Ongoing operations, not an action item	No
Provide public information on NFIP program compliance	Medium & NFIP	Planning/ Building	Ongoing operations, not an action item	No
Update town Flood Information Rate Maps (FIRM) maps and bylaw.	Medium & NFIP	Planning/ Building	Completed	No
Enhance Tree Management Program	Medium	DPW and Building	Ongoing operations, not an action item	No
Support and encourage electrical utilities to use underground construction	Medium	DPW and Muni Electric	Ongoing operations, not an action item	No
Assemble and distribute educational information	Medium	DPW and Building	Ongoing operations, not an action item	No
Evaluate public buildings and critical buildings	Medium	DPW and Building	Completed	No
Partner with agencies such as MEMA and FEMA	Medium	DPW and Muni Electric	Completed	No
Develop partnerships with utility providers and DPW	Medium	DPW and Muni Electric	Completed	No
Elevate low section of Essex Street.	Low	DPW	Financial constraints delayed progress, currently a medium priority	Yes
Investigate options to make all public safety buildings earthquake resistant.	Low	Fire/Police/DPW	Financial constraints delayed progress, currently a low priority	Yes

Table 6-1. Progress Report on Priorities from the Middleton's 2012 Hazard Mitigation Plan

Mitigation Measure	2012 Priority	Implementation Responsibility	Status	Included in 2020 HMP?
Ensure that emergency plans for hazardous facilities within Middleton are up to date and mapped	Low	Fire	Time/staff constraints delayed progress, currently a medium priority	Yes
Upgrade all public safety building fixed generators as needed, provide alternative fuel sources	Low	DPW	Financial constraints delayed progress, currently a medium priority	Yes
Assess slopes which may be potentially vulnerable to failure	Low	DPW/Building	Completed	No

6.2 Identification of Hazard Mitigation and Climate Adaptation Strategies

The Town developed a list of priority hazard mitigation and climate adaptation strategies through a multi-faceted approach. Strategies were discussed and developed upon review of the:

- Community profile, including the Town's strengths and vulnerabilities.
- Hazard and climate change risk assessment.
- Existing measures.
- Input from stakeholders.

Stakeholders were engaged through Core Team meetings, the CRB Workshop, and the public input sessions. The list of action items from the CRB Workshop are available in Appendix B and were integrated into the final list of action items vetted by the Core Team. Table 6-1 below represents the Town's high priority action items. Each of these action items was analyzed for its overall benefit, the estimated cost, timeframe, and implementation responsibility to inform prioritization. A description of each prioritization category is described below.

Priority – Designation of high, medium, or low priority was based on overall potential benefits. A High Priority action is very likely to have political and public support and necessary maintenance can occur following the project. A medium priority action may have political and public support and necessary maintenance had potential to occur following the project. A low priority action may not have political and public support for implementation or the necessary maintenance support following the project.

Mitigation Action – A brief description of each mitigation measure that was identified in this plan.

Primary Responsibility – Most mitigation measures will require a multi-department approach where several Town departments share responsibility. The designation of implementation responsibility in the table was assigned based on general knowledge of the responsibilities of each municipal department. The lead department for each action item is bolded.

Implementation Timeframe – The timeframes represented below are assigned based on the length of time necessary to complete the project. The timeframe is noted in years. Projects that involve multiple phases, maintenance, or don't have a definitive end date will are classified as "ongoing".

Approximate Implementation Cost – Approximate implementation costs are given for all mitigation measures. All cost data would need to be updated at the time of design and construction and is only provided as an estimate.

Potential Funding Sources – Potential sources of grant funding are identified for each mitigation measure in Table 6-2 and further described in Table 6-3. The potential funding sources are listed only if the project will be competitive for the funding source rather than eligible. The funding sources listed is not a guarantee that a specific project will be eligible for or receive funding. Grant funding eligibility and scoring criteria change regularly. Grants should be reviewed before applying and annually for expanded opportunity. Note that some grants may only cover design and others may cover construction. Other grants, like the FEMA FMA grants, are not listed in Table 6-2 because they are only active upon the declaration of a federal disaster. The Town's General Fund is considered a default potential funding source.

While acronyms are used in Table 6-2, the full names of potential funding sources can be found in Table 6-3. An additional description of municipal funding is available in Section 6.3.

Table 6-2. 2020 Priority Action Items

Priority	Mitigation Action	Implementation Responsibility	Timeframe	Approximate Implementation Cost	Potential Funding Sources
High	Upgrade culverts for greater rainfall capacity	Public Works	3-5 years	$250,000 each	DER Culvert Grant, MVP Action Grant, BRIC
High	Raise roads (especially School Street and Essex St) and bridges (Route 62)	Public Works	3-5 years	$1M per road $5M per bridge	Chapter 90 Program, Municipal Small Bridge Program
High	Create a Riverwalk from East Street to the Ipswich River Easement and develop the rail trail to increase connectivity through Town	Conservation	1-3 years	$100,000 to $250,000	MVP Action Grant, MassTrails, PARC, Federal Land and Water Conservation Fund
High	Add emergency power backups at public safety buildings, such as Fire and Police Stations	Fire/Police	1-3 years	$100,000 to $500,000	BRIC

Table 6-2. 2020 Priority Action Items

Priority	Mitigation Action	Implementation Responsibility	Timeframe	Approximate Implementation Cost	Potential Funding Sources
High	Design and construct a new Public Safety Building	Fire/Police	3-5 years	$10 million	BRIC, MVP Action Grant
High	Expand reach of Swift 911 and practice town staff Emergency Response Communication Plan	Fire	1-3 years	$10,000 to $100,000	CCP Grant, MVP Action Grant
High	Build communication infrastructure redundancies	Fire	1-3 years	$100,000 to $250,000	MVP Action Grant, EMPG
High	Ensure that backup power at schools is sufficient for use as shelters and upgrade generator at Fuller Meadow School	Schools/Fire	0-1 years	$10,000 to $100,000	BRIC, MVP Action Grant
High	Incorporate climate resilience into design of the new and rehabilitated municipal buildings; including green infrastructure, water conservation technology, and geothermal energy	Building	3-5 years	$100,000 - $250,000	Green Communities, MVP Action Grant
High	Identify neighborhood volunteers to support outreach and public safety efforts, such as checking on elderly neighbors	Council on Aging	1-3 years	$1,000 to $10,000	CCP Grant, MVP Action Grant
High	Increase forest management efforts in the north side of town to reduce brush fires	Fire	1-3 years	$10,000 to $100,000	Community Forest Stewardship Implementation Grant
High	Develop a robust tree management plan to aid Municipal Light in reducing power outages	Planning	1-3 years	$10,000 to $100,000	General Fund

Table 6-2. 2020 Priority Action Items

Priority	Mitigation Action	Implementation Responsibility	Timeframe	Approximate Implementation Cost	Potential Funding Sources
High	Update development regulations to include LID, green infrastructure, and additional climate resiliency items to subdivision regulations	Conservation	1-3 years	$10,000 to $100,000	MVP Action Grant, Green Communities, Land Use Planning, DOER
High	Improve drainage along roadways with nature-based solutions	Public Works	3-5 years	$100,000 to $500,000	NPS Competitive Grant Program, MVP Action Grant
Medium	Promote water conservation through providing rain barrels for the community and promoting high-efficiency technology	Conservation	1-3 years	$10,000 to $100,000	General Fund
Medium	Add cooling to schools, at minimum in certain parts of schools such as the gym	Schools	3-5 years	$10,000 to $100,000	General Fund
Medium	Assess water quality threats from auto repair facilities and storage	Conservation	3-5 years	$10,000 to $100,000	MVP Action Grant, MassDEP Water Quality Monitoring Grant Program
Medium	Update regulations to remove barriers and encourage the installation of solar panels	Planning	3-5 years	$1,000 to $10,000	EEA Planning Assistance, MVP Action Grant
Medium	Develop a database of elderly and/or disabled residents	Council on Aging	1-3 years	$1,000 to $10,000	CCP Grant, MVP Action Grant
Medium	Implement beaver control to reduce flooding	Conservation	3-5 years	$10,000 to $100,000	General Fund
Medium	Digitize the location of all outfalls and catch basins into town GIS database	Public Works	1-3 years	$10,000 to $100,000	MS4 Municipal Assistance Grant Program
Medium	Purchase new 4x4, 26,000 GVW woods brush fire pumper truck and new All Terrain Vehicle (ATV)	Fire	3-5 years	$10,000 to $100,000	General Fund

Table 6-2. 2020 Priority Action Items

Priority	Mitigation Action	Implementation Responsibility	Timeframe	Approximate Implementation Cost	Potential Funding Sources
Medium	Implement DCR Fire Wise Program	Fire	1-3 years	$1,000 to $10,000	General Fund
Medium	Design and implement a joint fire road access and management plan with Danvers	Fire	3-5 years	$10,000 to $100,000	FP&S
Medium	Ensure that emergency plans for hazardous facilities within Middleton are up to date and mapped	Fire	3-5 years	$1,000 to $10,000	MVP Action Grant
Low	Investigate options to make all public safety buildings earthquake resistant	Fire/Police/DPW	5-10 years	$10,000 to $100,000	BRIC

6.3 Potential Funding Sources

Traditional funding sources within the Town of Middleton, such as funding from the operating and capital budgets, may be able to cover some of the costs of the action items detailed in Table 6-2. Middleton could pursue the adoption of a stormwater enterprise fund for future stormwater-related projects. State revolving funds and other no or low-interest loans may also be of interest. There is a great variety of funding available for Massachusetts municipalities, both through the state and federal governments. A growing list of funding opportunities can be found on the Community Grant Finder webpage. The Community Grant finder provides a streamlined interface where municipalities can easily learn about grant opportunities. Specific funding opportunities related to mitigation actions developed by during the HMP-MVP planning process are listed in Table 6-2 and described in Table 6-3.

Table 6-3. Potential Funding Sources

Source	Grant	Description of Funding
MEMA	Flood Mitigation Assistance Grant Program	Implements cost-effective measures that reduce or eliminate the long-term risk of flood damage
MEMA	Hazard Mitigation Grant Program	Provides funding after a disaster to significantly reduce or permanently eliminate future risk to lives and property from natural hazards
Massachusetts Department of Energy Resources (DOER)	DOER Grants (Green Communities)	The DOER provides grant funding for clean energy-related programs

Table 6-3. Potential Funding Sources

Source	Grant	Description of Funding
Division of Ecological Restoration (DER)	Culvert Replacement Municipal Assistance Grant Program	Grant to replace undersized, perched, and/or degraded culverts located in an area of high ecological value
Department of Conservation and Recreation (DCR)	Community Forest Stewardship Implementation Grant	This grant aids communities in putting Forest Stewardship into practice
EEA	Land Use Planning Grants	Support efforts to plan, regulate, and act to conserve and develop land consistent with the Massachusetts' Sustainable Development Principles
EEA	LAND Grant Program	Helps cities and towns acquire land for conservation and passive recreation
EEA	Federal Land & Water Conservation Fund	Funding for the acquisition, development, and renovation of parks, trails, and conservation areas.
EEA	MassTrails Program	Trail protection, construction, and stewardship projects
EEA	Parkland Acquisitions and Renovations for Communities (PARC) Program	Aids in acquisition and developing land for park and outdoor recreation purposes. Can be sued to acquire parkland, build a new park, or renovate an existing park.
EEA	MVP Program	Provides support in implanting climate change resiliency priority projects
EEA	Planning Assistance Grants	Funds zoning for sustainable housing production, regulations that reduce energy use and GHG emissions, and zoning that results in permanent land conservation.
DEP	MS4 Grant Program	Meeting the requirements of the 2016 MS4 permit and reduce stormwater pollution through partnerships
DEP	Federal Clean Water Act, Section 319 Nonpoint Source (NPS) Competitive Grants Program	Implement projects that address the prevention, control, and abatement of NPS pollution.
DEP	Water Quality Monitoring Grant Program	Enhance MassDEP surface water quality assessment data by building or expanding the capacity of bacteria monitoring data collection.
MEMA	Emergency Management Performance Grant (EMPG)	Reimbursable grant program to assist local emergency management departments to build and maintain an all-hazards emergency preparedness system

Table 6-3. Potential Funding Sources

Source	Grant	Description of Funding
MEMA	Building Resilient Infrastructure & Communities (BRIC)	Provides funding for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event, with a focus on infrastructure projects and "community lifelines". Replaced FEMA's Pre-Disaster Mitigation (PDM) Program.
MEMA	Citizen Corps Program (CCP) Grant	Supports local Community Emergency Response Teams (CERT) and Volunteers in Police Service (VIPS) in preparing for all-hazards. Can be used for planning activities, equipment, training, and exercises.
FEMA	Fire Prevention and Safety Grant (FP&S)	Part of the Assistance to Firefighters grant – supports projects that enhance the safety of the public and firefighters from fire and related hazards.
Department of Fire Services	Senior SAFE	Supports fire and life safety education for seniors
Department of Fire Services	Student Awareness of Fire Education (S.A.F.E.)	Grants for local fire departments to teach fire and life safety to schools
MA Department of Transportation (DOT)	Chapter 90 Program	Reimbursable grants on approved projects
MADOT	Municipal Small Bridge Program	Funding for small bridge replacement, preservation and rehab projects
EPA	Healthy Communities Grant Program	Reduce environmental risk to protect and improve human health and the quality of life

6.4 Regional Partnerships

Mitigating natural hazards is not confined to a local issue. The drainage systems that service communities are often complex systems of storm drains, roadway drainage infrastructure, pump stations, dams, and other facilities owned and operated by a wide variety of agencies including the Massachusetts Department of Transportation (MassDOT) and the Department of Conservation and Recreation (DCR). The planning, construction, operation, and maintenance of these structures are integral to hazard mitigation efforts of communities. These agencies are the Town's regional partners in hazard mitigation efforts.

These agencies also operate under the same constraints as communities do including budgetary and staffing limitations. And as all communities do, they must make decisions about numerous competing priorities. In order to implement many of these mitigation measures, all parties will need to work together towards a mutually beneficial solution.

7.0 PLAN ADOPTION AND MAINTENANCE

7.1 Plan Adoption

The Town of Middleton 2020 HMP-MVP Plan was adopted by the Board of Selectmen on May 4th, 2021. See Appendix E for documentation. The plan was approved by FEMA on June 29, 2021 for a five-year period that will effective through June 28, 2026. See Appendix F for documentation of FEMA approval.

7.2 Plan Implementation

The Core Team will use Table 6-1 as a guide for taking action to mitigate hazards and improve the Town's climate resilience. The time frame, responsible department, and funding mechanisms in Table 6-1 layout out an implementation plan for the Core Team. The Core Team will be held accountable through the tracking mechanisms explained in the following sections. The HMP-MVP Plan will also inform future planning and budgeting processes.

7.3 Plan Maintenance

7.3.1 Tracking Progress and Updates

FEMA's initial approval of this plan is valid for five years. During that time the Town will need to continue to track progress, document hazards, and identify future mitigation efforts. The Core Team, coordinated by the Conservation Agent, will meet annually or on an as-needed basis, whichever is most frequent, to monitor plan implementation. The Core Team will be responsible for tracking information on the implementation progress and the impacts of hazards that have been identified since the plan drafting. The information collected through the annual meetings will be used to formulate a report and/or addendum to the plan. The Core Team will be amended as needed.

7.3.2 Continuing Public Participation

The adopted plan will be posted on the Town's website. The posting of the plan on the Town's website will provide a mechanism for citizen feedback, such as an e-mail address for interested parties to send comments. The Town will encourage local participation whenever possible during the next five-year planning and implementation cycle. The Core Team will incorporate engagement into the implementation of the priority action items. All updates to the plan, including implementation progress, will be placed on the Town's website. All public meetings related to the HMP-MVP Plan will be publicly noticed in accordance with Town and State open meeting laws.

7.3.3 Integration of the Plans with Other Planning Initiatives

Upon approval of the Town of Middleton 2020 HMP-MVP Plan by FEMA, the Core Team will make the plan available to all interested parties and all departments with an implementation responsibility. The group will initiate a discussion with those various departments regarding how the plan can be integrated into their ongoing work. At a minimum, the plan will be reviewed and discussed with the following departments:

- Planning Department
- Department of Public Works
- Police Department
- Fire Department
- Conservation Department
- Health Department
- Council on Aging

Appropriate sections of the HMP-MVP Plan will be integrated into other plans, policies and documents as those are updated and renewed, including the writing of, or updates to, the Town's Comprehensive Plan, Open Space Plan, and Master Plan. Coordination with local organizations, businesses, watershed groups, and state agencies will be required for successful implementation and continued updating.

7.4 Process of Updating

By maintaining the Town of Middleton 2020 HMP-MVP Plan, the Town will have a competitive application when applying to FEMA for funding to update the plan. Once the resources have been secured to update the plan, the Core Team will need to determine whether to undertake the update itself or hire a consultant. If the Core Team decides to update the plan itself, the group will need to review the current FEMA hazard mitigation plan guidelines for any change in the requirements. The update to the Town of Middleton 2020 HMP-MVP Plan will be forwarded to MEMA for review and to FEMA for ultimate approval. The Core Team will begin drafting the full update of the plan in four years. This will help the Town avoid a lapse in its approved plan status and grant eligibility when the current plan expires at the end of year five. Potential sources of funding in the future may include FEMA Pre-Disaster Mitigation grants and the Hazard Mitigation Grant Program. Both grant programs are eligible to pay for 75% of a planning project, with a 25% local cost share requirement.

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United States Weather Bureau. 1961. Technical Paper No. 40 (TP-40): Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years. https://www.nws.noaa.gov/oh/hdsc/PF_documents/TechnicalPaper_No40.pdf.

TOWN OF MIDDLETON

Municipal Vulnerability Preparedness Planning Grant Project

Core Team Meeting

DPW Building, 195 North Main Street
Thursday, November 7, 2019
10:00 am – 11:30 am

AGENDA

Introductions	5 minutes
Project Overview	15 minutes
Core Team Role	2 minutes
Goal Setting and Endorsement	15 minutes
Community Resilience Building Workshop and Review of Materials	35 minutes
Data Sources	3 minutes
Workshop Participants	10 minutes
Wrap Up and Next Steps	5 minutes

APPENDIX A

Core Team Materials

Municipal Vulnerability Preparedness Planning Grant Project
Thursday, November 7, 2019 10:00 am – 11:30 am

Name	Present- Mark with X or Sign
Andrew Sheehan	
Katrina O'Leary	Katrina O'Leary
Ken Gibbons	Ken.gibbons@middletonma.gov
Thomas J. Martinuk	Tom.martinuk@middlie.com
James DiGianvittorio	ChiefDm,dd1,tuPolice.com
Frank Leary	
Kristin Kent	
Derek Fullerton	
Jillian Smith	Jillian.smith@middletonma.gov

Listening Session
- Local TV
- Survey
- questions
-

By Clickers

Weston & Sampson

MVP Core Team Kick Off Meeting 11-7-19

- Developing HMP along w/ MVP report
  ↳ ≈ 5 year HMP Action Plan
- Municipal Electric, so "Green Communities" program unavailable / not beneficial in Middleton
- Hazards for HMP... Town feedback?

- Climate change impacts → public health, built environment, + economical (do people visit downtowns as much during heat + heavy rains?)
  - extreme rain events ≥ 2" of rain
  - gypsy moth caterpillars lasted
  - 2 domestic wells dried up
  - watering bans
  - Ipswich River low
  - increase in stink bugs
  - increased brush fires

  } consequences of drought events

- Precipitation events → marked up maps w/ flood prone areas

- Bald Hill, Candlelight, north part of town → brush fire events

- several microburst events in Middleton, high winds coming through town, 2 events, w/ or w/out rain 20 years ago 7-8 years ago.

- minimal power outages. DPW + Power co. cut back trees, all electric is overhead
- South Middleton dam to be removed summer 2020, MEPA permit done

- Mass Hwy salting effects tributaries + fish kill events

- Salting has minimal effect on water supply or private wells

HAZARDS (earthquakes + hurricanes non-issues)

1. flooding
2. drought, wildfire, extreme heat
3. snowstorm, ice storm, extreme cold
4. severe thunderstorms, winds, tornado, hurricane

Note: use dams as infrastructure features

- Katrina to send Town photos for presentation

Infrastructure feature: 911 tower @ 20 Manning Ave,
~~regio~~ Northshore regional
STATE 911

- Essex county jail
- Population #'s are high ≈ 9,000
- GW. Features add Creighton Park slide 55
- Need data on beaver damming issues
- Side 55 → stormwater bylaw, pending public well protection bylaw; tree clearing program by power co., Danvers Pub. water emergency response, emerg. shelter plan w/ fire dept.
- No tree management bylaw

GOAL ENDORSEMENT

↳ non-binding
↳ example goals generally accepted by the group

STAKEHOLDER LIST

- Ted Spiliotis → state rep
- ~~Zoni~~ ZBA - Tig Nizaro chair
- Camp & Creighton
- Stream Team
- Ipswich River Watershed Association
- STATE 911 - Allison + Chris

- Use Google Drive, sharepoint, dropbox, etc. to share files

- Stakeholder meeting in 1-2 or 3 months, Feb @ latest
- budget meeting 1st Sat of Feb + March

- Host listening session on local TV w/ email for feedback.
- A recorded voice over presentation can be televised (rather than filmed presentation).

(9-5) ~~to 5~~

- CRB workshop ~~Mon~~, Tues - Thurs, January 9 Thurs 9-5
  - ↳ room available @ the library, Kristen to check
    - ↳ January 15 as backup ~~or 16~~

- Full Meadow - How many ~~=~~ shelters
  - ↳ full generator
- Sub division regs for I-I-D

- redoing zoning in next 1-2 years

- Town master plan finished yesterday

TOWN OF MIDDLETON

Core Team Meeting
Thursday, November 7th, 2019

Weston & Sampson

1

WELCOME CORE TEAM

Andrew Sheehan
Katrina O'Leary
Ken Gibbons
Thomas J. Martinuk
James DiGianvittorio
Frank Leary
Kristin Kent

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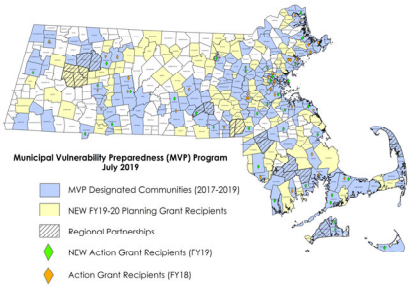
MUNICIPAL VULNERABILITY PREPAREDNESS PROGRAM (MVP)



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MVP COMPONENTS

PHASE 1 - PLANNING

- Receive Planning Grant
- Prioritize Action Items
- Complete MVP Program
- Submit Final Report for Approval
- Become Certified

PHASE 2 - ACTION

- Select an Action Item from Planning Phase
- Apply for Action Grant Funding
- Implement Action Item

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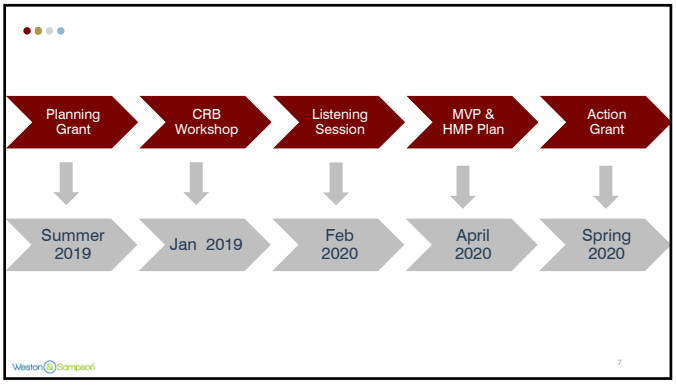

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MVP PLANNING GRANT COMPONENT

HAZARD MITIGATION PLAN UPDATE

- Aligns with MVP Process
- Extended hazard profiles and vulnerability assessment
- Update to previous mitigation measures table

8

ELIGIBLE MVP ACTION GRANT PROJECTS

- Detailed Vulnerability and Risk Assessment
- Public Education and Communication
- Local Bylaws, Ordinances, Plans, and Other Management Measures
- Redesigns and Retrofits
- Energy Resilience Strategies
- Chemical Safety
- Nature-Based Storm-Damage Protection, Drought Prevention, Water Quality, and Water Infiltration Techniques
- Nature-Based, Infrastructure and Technology Solutions to Reduce Vulnerability to Extreme Heat and Poor Air Quality
- Nature-Based Solutions to Reduce Vulnerability to other Climate Change Impacts
- Acquisition of Land to Achieve a Resiliency Objective
- Ecological Restoration and Habitat Management to Increase Resiliency

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CORE TEAM

ROLE

- Confirm framework for process
- Provide data and local expertise
- Participate in the stakeholder workshop
- Finalize priority actions for the final report

TODAY'S OBJECTIVES

- Review Process
- Set Goals
- Prepare for Stakeholder Meeting

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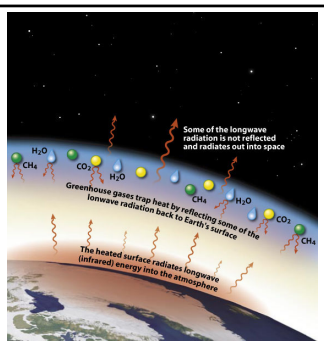
GREENHOUSE GASES (GHG)

- Naturally occurring
- Act as a blanket
- Examples: carbon dioxide and methane

Climate mitigation ensures there is less to adapt to and is a key component of our community's resilience



Smithsonian Environmental Research Center. "Too Much of a Good Thing." http://bprcpes.si.edu/atmosphere/02_04_07.html

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MASSACHUSETTS GHG GOALS

- Established by the Global Warming Solutions Act (GWSA) of 2008
- 25% reduction in GHG emissions by 2020
- 80% reduction in GHG emissions by 2050
- 1990 is the baseline year

Weston & Sampson Source: Commonwealth of Massachusetts. 2019. "Global Warming Solutions Act 10-year Progress Report." 10.

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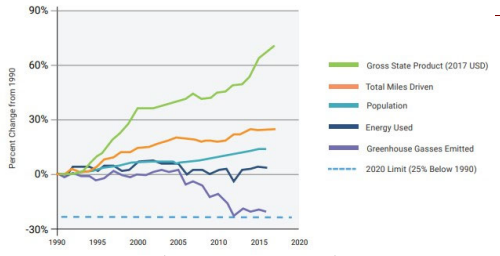
FIGURE 3 | TRENDS OF GROWTH IN GSP, VMT, AND POPULATION WHILE GHG EMISSIONS ARE DECREASING AND ENERGY USE HAS BEEN STABLE



Weston & Sampson Source: Commonwealth of Massachusetts. 2019. "Global Warming Solutions Act 10-year Progress Report." 10.

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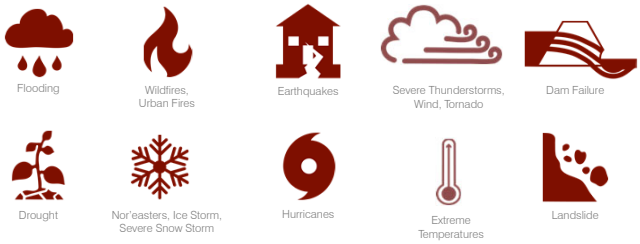
HAZARDS IN MIDDLETON



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EXTREME TEMPERATURES

WARMER ANNUAL AIR TEMPERATURES
UP 0.5°F PER DECADE SINCE 1970, ON AVERAGE

WARMER WINTERS
UP 1.3°F PER DECADE SINCE 1970, ON AVERAGE

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EXTREME TEMPERATURES IN MASSACHUSETTS

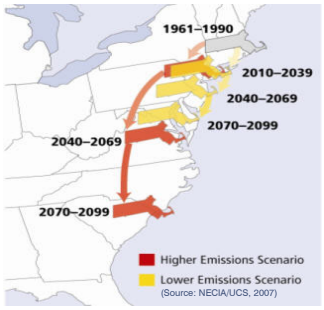
6	24	35
2005 OBSERVED ANNUAL AVERAGE	MID-CENTURY PROJECTED ANNUAL AVERAGE	END-OF-CENTURY PROJECTED ANNUAL AVERAGE

DAYS WITH TEMPERATURES ABOVE 90°F

145	114	101
2005 OBSERVED ANNUAL AVERAGE	MID-CENTURY PROJECTED ANNUAL AVERAGE	END-OF-CENTURY PROJECTED ANNUAL AVERAGE

DAYS WITH TEMPERATURES BELOW 32°F

16



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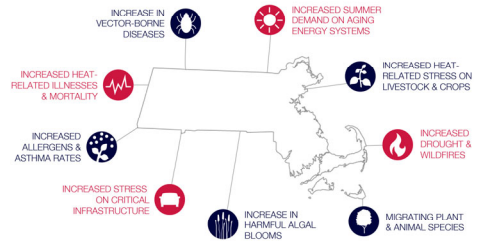
IMPACTS OF RISING TEMPERATURES

WARMER ANNUAL AIR TEMPERATURES
UP 0.5°F PER DECADE SINCE 1970, ON AVERAGE

WARMER WINTERS
UP 1.3°F PER DECADE SINCE 1970, ON AVERAGE



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CHANGES IN PRECIPITATION

MORE **INTENSE & FREQUENT** EXTREME RAIN EVENTS

PRECIPITATION DURING **HEAVY EVENTS** IN THE NORTHEAST

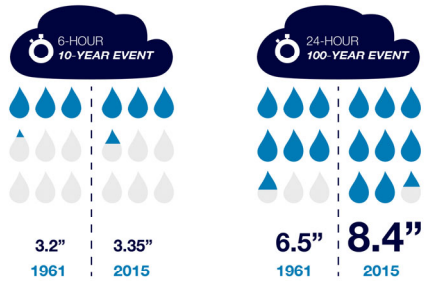
INCREASED BY MORE THAN

70%

BETWEEN 1958-2010

20

CHANGES IN PRECIPITATION



21

EXTREME PRECIPITATION

8%

Increase in extreme precipitation events by **midcentury**

13%

Increase in extreme precipitation events by **end of century**

22

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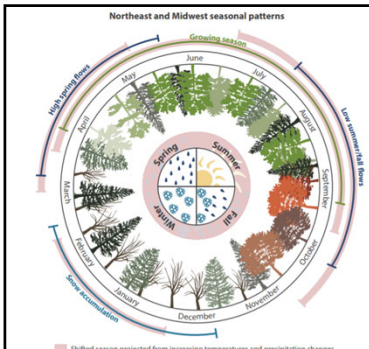

Shifted season projected from increasing temperatures and precipitation changes
Image credit: Northeast Climate Science Center, University of Maryland Center for Environmental Science

2016

The most notable recent drought event was in

The occurrence of droughts **lasting 1 to 3 months** could go up by as much as **75% over existing conditions** by the end of the century, under the high emissions scenario

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WINTER STORMS

The blizzard of 2013 left nearly **400,000 Massachusetts residents without power**

"Heavy blizzards are among the **most costly and disruptive** weather events for Massachusetts communities."

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FLOODING

ZONE	ANNUAL CHANCE	FLOODPLAIN
A, AE, A1-A30	1% ANNUAL CHANCE	100-YEAR FLOODPLAIN
X	0.2% ANNUAL CHANCE	500-YEAR FLOODPLAIN

"By 2050, Boston could experience the current 100- year riverine flood every two to three years on average"

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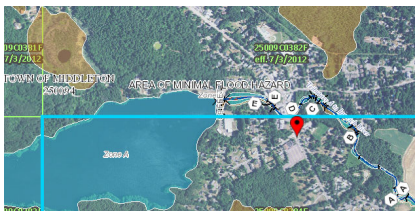
Where are the flood-prone areas in Town?



Above: a portion of the FEMA Flood Insurance Rate Map (FIRM) for Middleton

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STORMWATER FLOODING

Areas with:

- Poor drainage
- High amounts of impervious surface
- Undersized culverts

Where does stormwater flooding occur in Town?

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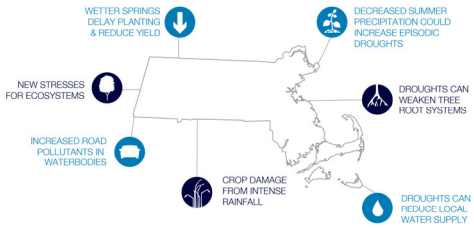
IMPACTS OF CHANGING PRECIPITATION

HIGHER AVERAGE ANNUAL PRECIPITATION
INCREASED BY ABOUT 10% IN THE NORTHEAST INTHE LAST 50 YEARS



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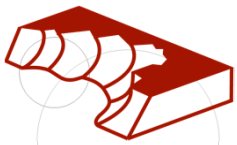
EROSION

Caused by riverine flow & stormwater

Increased precipitation, including winter rains, could increase erosion

Drier soils will reduce resistance to erosion



(Source: MA Climate Change Adaptation Report, 2011)

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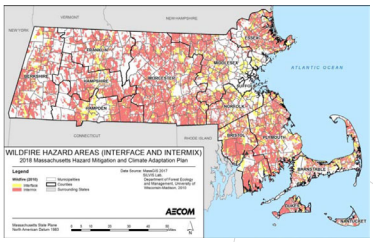
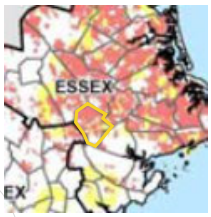
WILDFIRE





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HURRICANES AND EARTHQUAKES

HURRICANE

Sandy
was the most recent hurricane

Upward trend in North Atlantic hurricane activity since 1970

Nor'easters along the Atlantic coast are increasing in frequency and intensity

EARTHQUAKE

30-40
Earthquakes occur in New England each year, although most are not felt.

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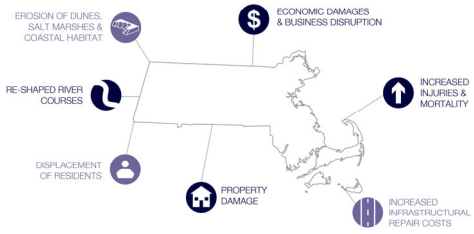
IMPACTS OF EXTREME WEATHER

STORMS ARE BECOMING MORE INTENSE AND DAMAGING



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HAZARD POTENTIAL OF DAMS

Name	Water Body	Ownership	Hazard Class
EMERSON BROOK DAM	EMERSON BROOK	TOWN OF DANVERS	LOW
MIDDLETON POND OUTLET DAM	TRIBUTARY OF IPSWICH RIVER	TOWN OF DANVERS	LOW
SOUTH MIDDLETON DAM	IPSWICH RIVER	PRIVATE	SIGNIFIGANT
CREIGHTON POND DAM	TRIBUTARY OF BOSTON BROOK	PRIVATE	LOW
MILL POND DAM	EMERSON BROOK	PRIVATE	SIGNIFIGANT

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As an FYI: Boston Sea Level Rise Projections (ft)

Increased coastal flooding

Permanently inundated low-lying coastal areas

Increased shoreline erosion

Emission Scenario	2030	2050	2070	2100
Intermediate	0.7	1.4	2.3	4.0
Intermediate-High	0.8	1.7	2.9	5.0
High	1.2	2.4	4.2	7.6
Extreme	1.4	3.1	5.4	10.2

(Source: Northeast Climate Adaption Science Center)

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WORKSHOP OUTLINE

PRESENTATION:
- Overview of Science & Data
- Characterization of Hazards

- BREAK -

INDIVIDUAL TABLES:
- Identify Community Features

- LUNCH -

INDIVIDUAL TABLES:
- Identify and Prioritize Actions

- BREAK -

LARGE GROUP DISCUSSION:
- Determine Overall Priority Actions

Photo: bostonbayarchitects.com

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RISK MATRIX

Photo: flintlibrary.org

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RISK MATRIX

Community Resilience Building Risk Matrix — www.CommunityResilienceBuilding.com

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership: V or S	Priority: H M L	Time: Short (S) Long (L) Ongoing
Infrastructural				
Societal				
Environmental				

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RISK MATRIX: HAZARDS

Community Resilience Building Risk Matrix — www.CommunityResilienceBuilding.com

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership: V or S	Priority: H M L	Time: Short (S) Long (L) Ongoing
Infrastructural				
Societal				
Environmental				

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IDENTIFY HAZARDS

Photo: Ipswich River Wildlife Sanctuary, Town of Middleton Website

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Natural Hazards in Middleton

CHOOSE 4 FOR THE MVP ACTION PLAN

Flooding

Wildfires, Urban Fires

Earthquakes

Severe Thunderstorms, Wind, Tornado

Dam Failure

Drought

Nor'easters, Ice Storm, Severe Snow Storm

Hurricanes

Extreme Temperatures

Landslide

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15 MINUTE BREAK!

Photo: Fuller Meadow School, CBI Consulting Inc.

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RISK MATRIX: HAZARDS

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)				Priority	Time
				H - M - L	Short Long Ongoing

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RISK MATRIX: FEATURES

Community Resilience Building Risk Matrix

www.CommunityResilienceBuilding.com

H-M-L priority for action over the Short or Long term (and Ongoing)
V = Vulnerability S = Strength

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S									Priority	Time
Infrastructural												H - M - L	Short Long Ongoing
Societal													
Environmental													

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RISK MATRIX: FEATURES

H-M-L priority for action over the Short or Long term (and Ongoing)
V = Vulnerability S = Strength

Features	Location	Ownership	V or S
Infrastructural			
Societal			
Environmental			

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RISK MATRIX: FEATURES

FEATURES	LOCATION	OWNERSHIP	VULNERABILITY OR STRENGTH
Infrastructural	Town wide	State	Vulnerability
Societal	Multi- vs. Single-neighborhood	Town	Strength
Environmental	Specific location	Private	Both
		Shared	

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FEATURES IN MIDDLETON

Photo: yelp.com

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INFRASTRUCTURAL FEATURES


Police Department


Fire Department


Wastewater Treatment & Collection


Dams

Transportation


Water Supply

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INFRASTRUCTURAL FEATURES

CRITICAL FACILITY EXAMPLES

Police and Fire Department
- Police Department
- Fire Department

Town Facilities
- Department of Public Works
- Electric Department
- Danvers Water Treatment Facility

Communication and Utilities Infrastructure
- Verizon Telephone Hut
- MIT Public Communication Tower

Emergency Shelters
- Fuller Meadow School
- Howe-Manning School

Primary Evacuation Routes
- Route 114
- Route 62

Critical Bridges, Intersections, and Sites

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INFRASTRUCTURAL FEATURES - DRINKING WATER

- Vernon C. Russel Water Treatment Plant (WTP) in Middleton
- The WTP treats water from:
  - Middleton Pond Reservoir which receives water from
    - Swan Pond Reservoir
    - Emerson Brook Reservoir
- Ground water supply located along the Ipswich River
  - Well 1 (Middleton)
  - Well 2 (Danvers)

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SOCIETAL FEATURES

Population
2010: 11,287 residents
2018: 12,418 residents

Age
Under 18 years: 21%
65+ years: 9.8%

Education
Bachelor's degree or higher: 45.8%

Additional Information
Median household income: $101,303
Persons in poverty: 7.1%
With a disability: 6.5%
Language other than English spoken at home: 11.6%

Source: U.S. Census Bureau, 2019

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SOCIETAL FEATURES

SCHOOL SYSTEM
- 703 students are enrolled in the public school system
- Public school system includes 2 elementary schools and 1 middle school and 1 high school (regional)
- Other schools include:
  - Essex North Shore Agricultural & Technical School (regional)

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SsocietAL FEATURES

60 public safety personnel, including:

23 uniformed police officers

37 on-call fire fighters

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ENVIRONMENTAL FEATURES

Rail Trail

Ponds

Water Bodies in Middleton

- Middleton Pond
- Emerson Brook Reservoir
- Ipswich River
- Aunt Betts Pond

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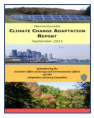
DATA RESOURCES



resilient MA

Climate Change Clearinghouse for the Commonwealth

Massachusetts Climate Change Projections, 2018)

Massachusetts State Hazard and Climate Adaptation Plan, 2018

Massachusetts Climate Change Adaptation Report, 2011

US Census, American Community Survey, 2013-2017

Interviews

Others?

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EXISTING HAZARD PROTECTION

For Example:

- Tree management plan
- Drainage improvements
- Floodplain bylaw
- Local wetlands bylaw

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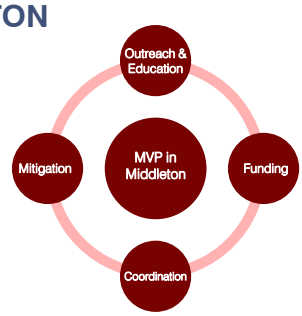
MVP GOALS IN MIDDLETON



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LUNCH

Photo: Middleton Pond. Wordpress.com

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ADAPTATION STRATEGIES

Photo: Aunt Betts Pond: Mapcarta.com

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15 MINUTE BREAK!

Photo: Howe-Manning Elementary School, CTA Construction Managers

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DEFINE COMMUNITY ACTIONS

Photo: familypedia.wikia.com:

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IDENTIFY PRIORITY ACTIONS

Photo: Town of Middleton Police Department: Wickedlocal.com

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WRAP-UP & CLOSING REMARKS

Photo: Middleton Fire Department: Essexcountyfire.com

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THANK YOU

Weston & Sampson

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APPENDIX B

Additional Hazard Data

Hazus: Hurricane Global Risk Report

Region Name: Middleton

Hurricane Scenario: Probabilistic 100-year Return Period

Print Date: Thursday, February 13, 2020

Disclaimer:
This version of Hazus utilizes 2010 Census Data.
Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific Hurricane. These results can be improved by using enhanced inventory data.

Table of Contents

General Description of the Region

Hazus is a regional multi-hazard loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery.

The hurricane loss estimates provided in this report are based on a region that includes 1 county(ies) from the following state(s):

- Massachusetts

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 14.48 square miles and contains 1 census tracts. There are over 2 thousand households in the region and a total population of 8,987 people (2010 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 2 thousand buildings in the region with a total building replacement value (excluding contents) of 1,294 million dollars (2014 dollars). Approximately 89% of the buildings (and 75% of the building value) are associated with residential housing.

Building Inventory

General Building Stock

Hazus estimates that there are 2,634 buildings in the region which have an aggregate total replacement value of 1,294 million (2014 dollars). Table 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

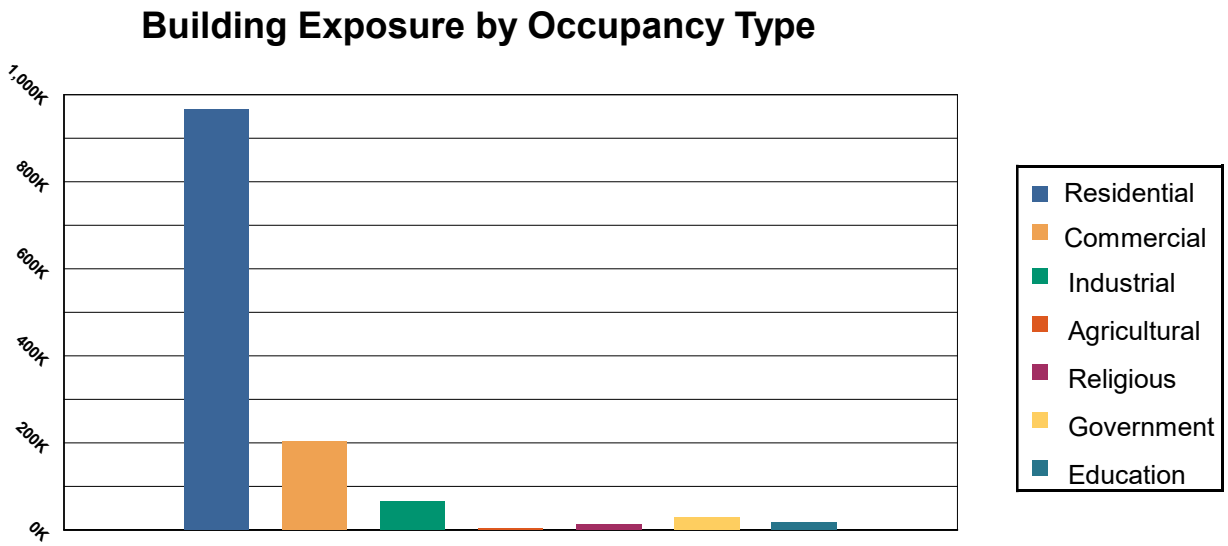


Table 1: Building Exposure by Occupancy Type

Occupancy	Exposure ($1000)	Percent of Tot
Residential	965,697	74.64 %
Commercial	204,538	15.81%
Industrial	64,952	5.02%
Agricultural	2,563	0.20%
Religious	11,812	0.91%
Government	28,025	2.17%
Education	16,214	1.25%
Total	**1,293,801**	**100.00%**

Essential Facility Inventory

For essential facilities, there are no hospitals in the region with a total bed capacity of no beds. There are 3 schools, 1 fire stations, 3 police stations and no emergency operation facilities.

Hurricane Scenario

Hazus used the following set of information to define the hurricane parameters for the hurricane loss estimate provided in this report.

Scenario Name:	Probabilistic
Type:	Probabilistic

Building Damage

General Building Stock Damage

Hazus estimates that about 6 buildings will be at least moderately damaged. This is over 0% of the total number of buildings in the region. There are an estimated 0 buildings that will be completely destroyed. The definition of the 'damage states' is provided in the Hazus Hurricane technical manual. Table 2 below summarizes the expected damage by general occupancy for the buildings in the region. Table 3 summarizes the expected damage by general building type.

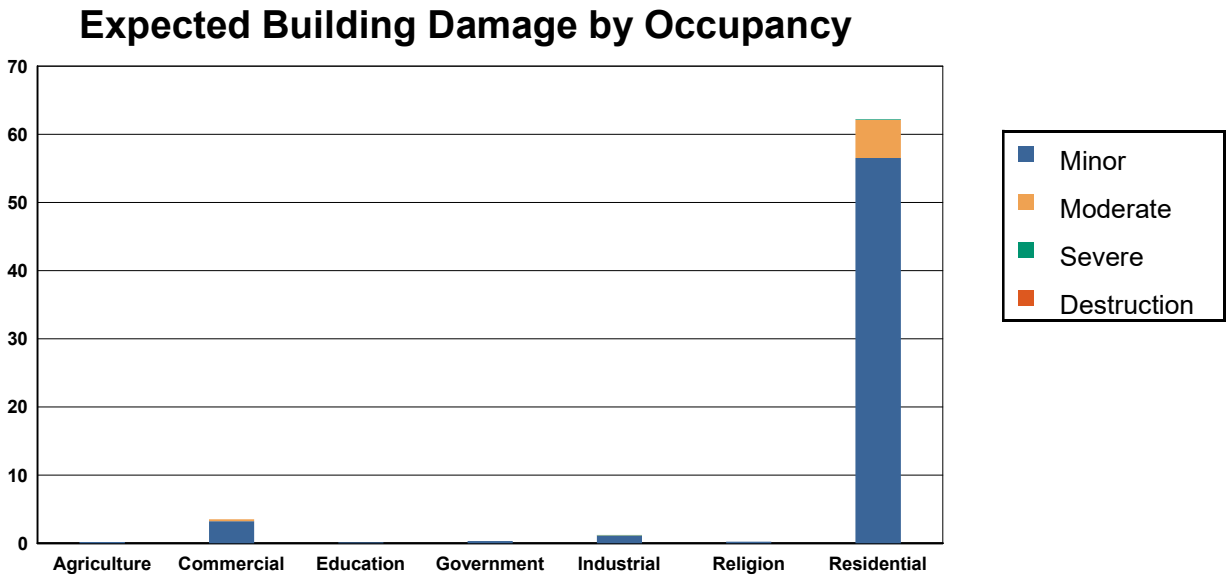


Table 2: Expected Building Damage by Occupancy : 100 - year Event

	None		Minor		Moderate		Severe		Destruction	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	7.83	97.85	0.15	1.88	0.02	0.22	0.00	0.06	0.00	0.00
Commercial	176.50	98.06	3.20	1.78	0.28	0.16	0.01	0.01	0.00	0.00
Education	7.87	98.33	0.13	1.63	0.00	0.04	0.00	0.00	0.00	0.00
Government	17.68	98.20	0.32	1.76	0.01	0.04	0.00	0.00	0.00	0.00
Industrial	60.81	98.08	1.12	1.81	0.05	0.09	0.01	0.02	0.00	0.00
Religion	11.80	98.32	0.20	1.63	0.01	0.06	0.00	0.00	0.00	0.00
Residential	2,283.79	97.35	56.50	2.41	5.60	0.24	0.11	0.00	0.00	0.00
Total	**2,566.28**		**61.62**		**5.97**		**0.14**		**0.00**	

Table 3: Expected Building Damage by Building Type : 100 - year Event

Building Type	None		Minor		Moderate		Severe		Destruction	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	24	97.74	1	2.21	0	0.05	0	0.00	0	0.00
Masonry	165	95.49	6	3.49	2	0.99	0	0.02	0	0.00
MH	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Steel	130	98.09	2	1.78	0	0.13	0	0.01	0	0.00
Wood	2,185	97.84	46	2.08	2	0.08	0	0.00	0	0.00

Essential Facility Damage

Before the hurricane, the region had no hospital beds available for use. On the day of the hurricane, the model estimates that 0 hospital beds (0%) are available for use by patients already in the hospital and those injured by the hurricane. After one week, none of the beds will be in service. By 30 days, none will be operational.

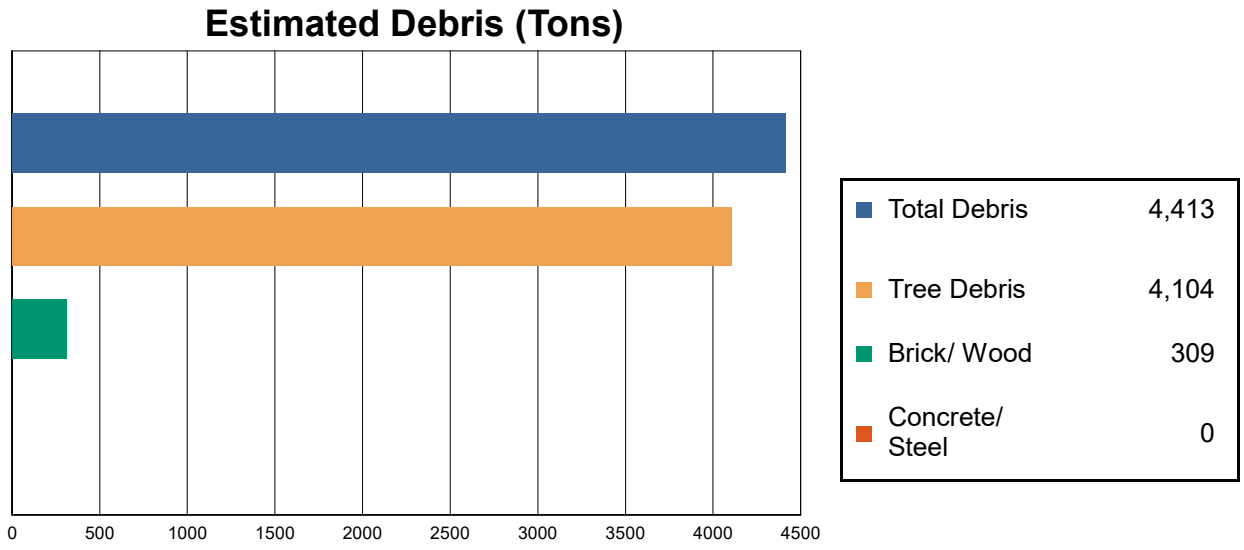
Thematic Map of Essential Facilities with greater than 50% moderate

Table 4: Expected Damage to Essential Facilities

		# Facilities		
Classification	**Total**	**Probability of at Least Moderate Damage > 50%**	**Probability of Complete Damage > 50%**	**Expected Loss of Use < 1 day**
Fire Stations	1	0	0	1
Police Stations	3	0	0	3
Schools	3	0	0	3

Induced Hurricane Damage

Debris Generation

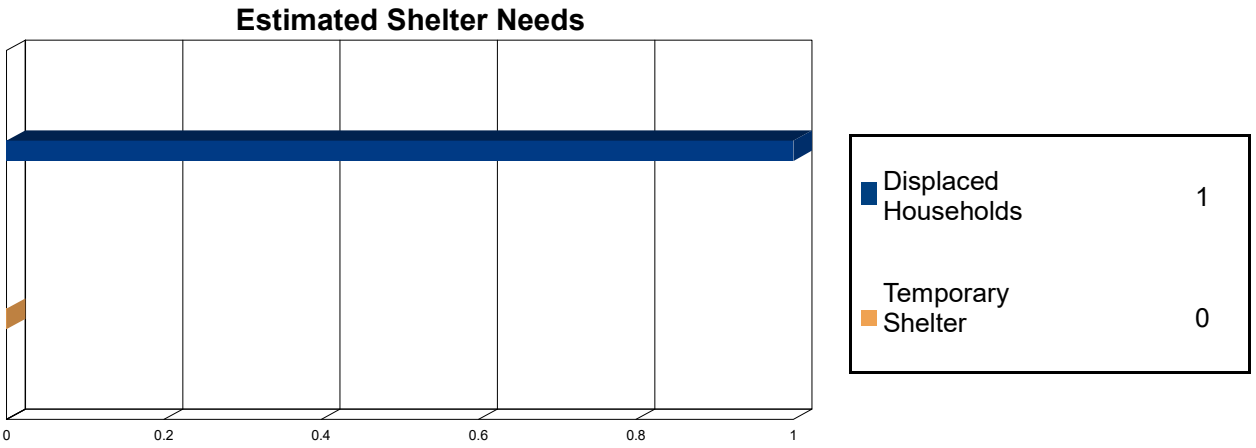


Hazus estimates the amount of debris that will be generated by the hurricane. The model breaks the debris into four general categories: a) Brick/Wood, b) Reinforced Concrete/Steel, c) Eligible Tree Debris, and d) Other Tree Debris. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 4,413 tons of debris will be generated. Of the total amount, 3,254 tons (74%) is Other Tree Debris. Of the remaining 1,159 tons, Brick/Wood comprises 27% of the total, Reinforced Concrete/Steel comprises of 0% of the total, with the remainder being Eligible Tree Debris. If the building debris tonnage is converted to an estimated number of truckloads, it will require 12 truckloads (@25 tons/truck) to remove the building debris generated by the hurricane. The number of Eligible Tree Debris truckloads will depend on how the 850 tons of Eligible Tree Debris are collected and processed. The volume of tree debris generally ranges from about 4 cubic yards per ton for chipped or compacted tree debris to about 10 cubic yards per ton for bulkier, uncompacted debris.

Social Impact

Shelter Requirement



Hazus estimates the number of households that are expected to be displaced from their homes due to the hurricane and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 1 households to be displaced due to the hurricane. Of these, 0 people (out of a total population of 8,987) will seek temporary shelter in public shelters.

Economic Loss

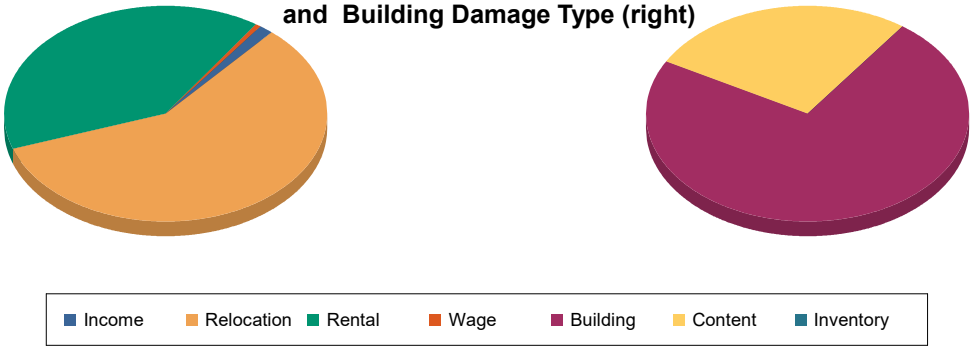
The total economic loss estimated for the hurricane is 7.0 million dollars, which represents 0.54 % of the total replacement value of the region's buildings.

Building-Related Losses

The building related losses are broken into two categories: direct property damage losses and business interruption losses. The direct property damage losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the hurricane. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the hurricane.

The total property damage losses were 7 million dollars. 3% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 97% of the total loss. Table 5 below provides a summary of the losses associated with the building damage.

Loss by Business Interruption Type (left) and Building Damage Type (right)



Loss Type by General Occupancy

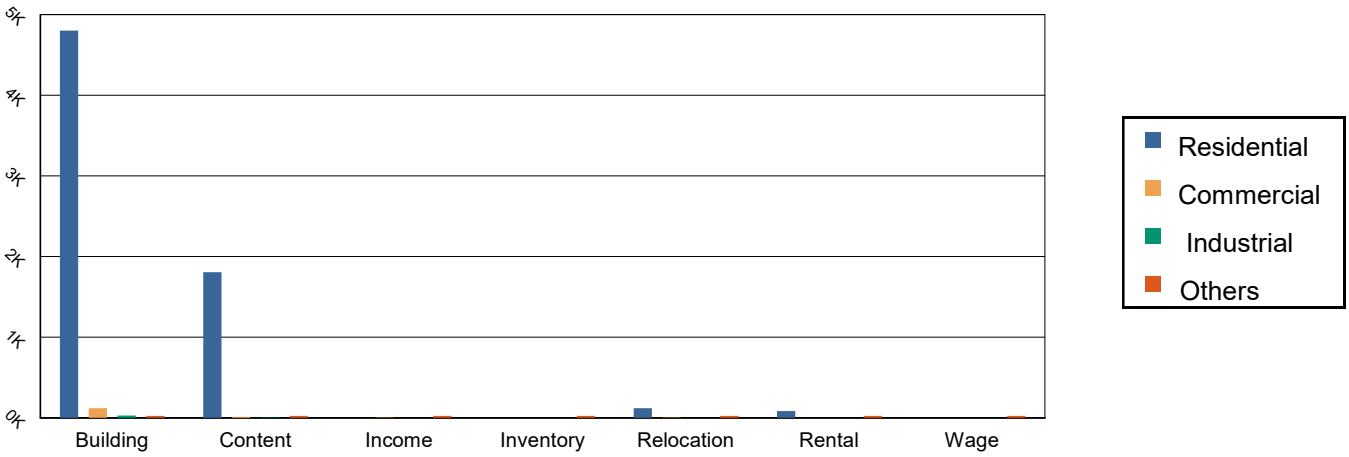


Table 5: Building-Related Economic Loss Estimates

(Thousands of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	4,799.54	119.59	30.04	24.15	4,973.31
	Content	1,806.68	12.55	5.96	0.58	1,825.77
	Inventory	0.00	0.33	0.99	0.04	1.36
	Subtotal	**6,606.22**	**132.46**	**37.00**	**24.77**	**6,800.45**
Business Interruption Loss						
	Income	0.00	3.26	0.00	0.00	3.26
	Relocation	121.15	4.38	0.13	0.19	125.85
	Rental	84.13	1.45	0.00	0.00	85.58
	Wage	0.00	1.16	0.00	0.00	1.16
	Subtotal	**205.28**	**10.24**	**0.13**	**0.19**	**215.84**

Total

Total	**6,811.50**	**142.70**	**37.13**	**24.96**	**7,016.29**

Appendix A: County Listing for the Region

Massachusetts
- Essex

Appendix B: Regional Population and Building Value Data

		Building Value (thousands of dollars)		
	Population	Residential	Non-Residential	Total
Massachusetts				
Essex	8,987	965,697	328,104	1,293,801
Total	**8,987**	**965,697**	**328,104**	**1,293,801**
Study Region Total	**8,987**	**965,697**	**328,104**	**1,293,801**

Hazus: Hurricane Global Risk Report

Region Name: Middleton

Hurricane Scenario: Probabilistic 500-year Return Period

Print Date: Thursday, February 13, 2020

Disclaimer:
This version of Hazus utilizes 2010 Census Data.
Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific Hurricane. These results can be improved by using enhanced inventory data.

Table of Contents

General Description of the Region

Hazus is a regional multi-hazard loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery.

The hurricane loss estimates provided in this report are based on a region that includes 1 county(ies) from the following state(s):

- Massachusetts

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 14.48 square miles and contains 1 census tracts. There are over 2 thousand households in the region and a total population of 8,987 people (2010 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 2 thousand buildings in the region with a total building replacement value (excluding contents) of 1,294 million dollars (2014 dollars). Approximately 89% of the buildings (and 75% of the building value) are associated with residential housing.

Building Inventory

General Building Stock

Hazus estimates that there are 2,634 buildings in the region which have an aggregate total replacement value of 1,294 million (2014 dollars). Table 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

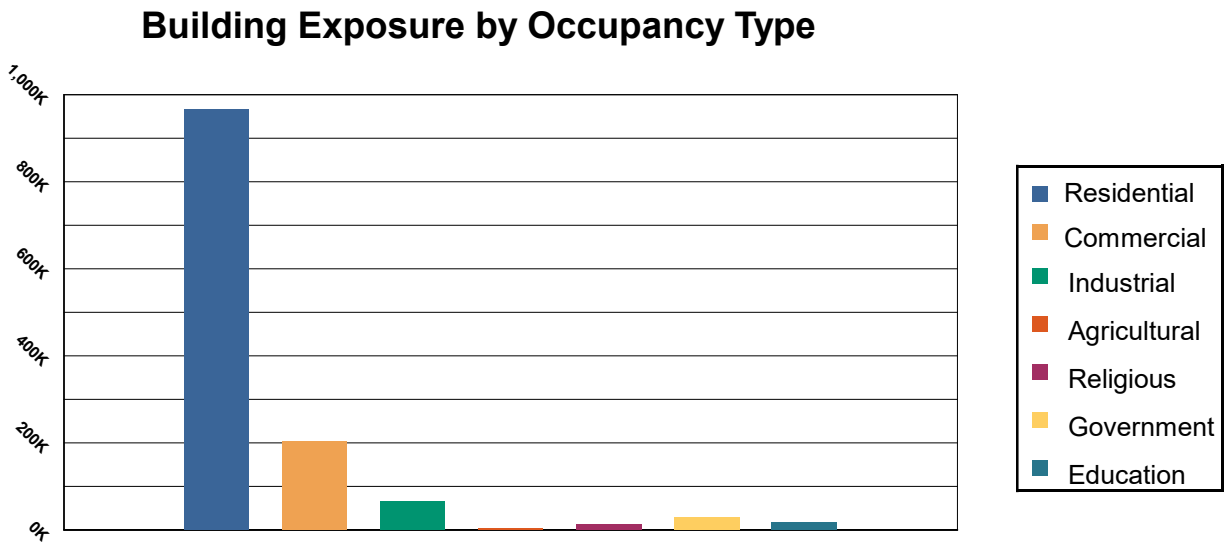


Table 1: Building Exposure by Occupancy Type

Occupancy	Exposure ($1000)	Percent of Tot
Residential	965,697	74.64 %
Commercial	204,538	15.81%
Industrial	64,952	5.02%
Agricultural	2,563	0.20%
Religious	11,812	0.91%
Government	28,025	2.17%
Education	16,214	1.25%
Total	**1,293,801**	**100.00%**

Essential Facility Inventory

For essential facilities, there are no hospitals in the region with a total bed capacity of no beds. There are 3 schools, 1 fire stations, 3 police stations and no emergency operation facilities.

Hurricane Scenario

Hazus used the following set of information to define the hurricane parameters for the hurricane loss estimate provided in this report.

Scenario Name:	Probabilistic
Type:	Probabilistic

Building Damage

General Building Stock Damage

Hazus estimates that about 67 buildings will be at least moderately damaged. This is over 3% of the total number of buildings in the region. There are an estimated 1 buildings that will be completely destroyed. The definition of the 'damage states' is provided in the Hazus Hurricane technical manual. Table 2 below summarizes the expected damage by general occupancy for the buildings in the region. Table 3 summarizes the expected damage by general building type.

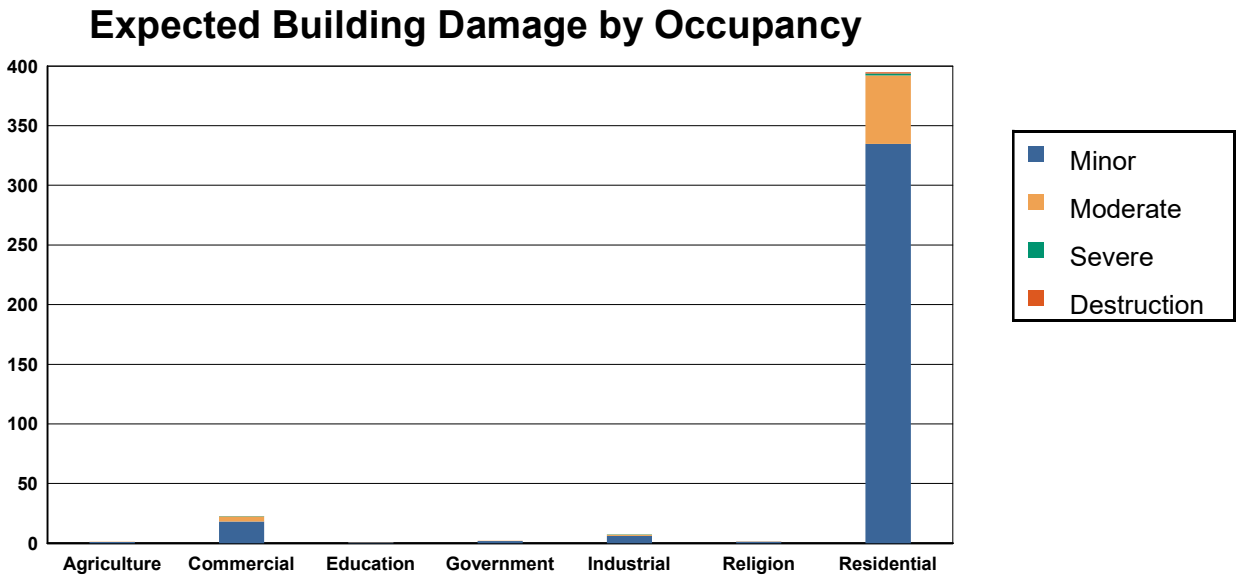


Table 2: Expected Building Damage by Occupancy : 500 - year Event

	None		Minor		Moderate		Severe		Destruction	
Occupancy	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	6.77	84.59	0.91	11.38	0.21	2.68	0.10	1.23	0.01	0.12
Commercial	157.17	87.32	18.19	10.11	4.11	2.28	0.53	0.29	0.00	0.00
Education	7.15	89.36	0.74	9.21	0.11	1.38	0.00	0.06	0.00	0.00
Government	15.92	88.46	1.75	9.73	0.31	1.74	0.01	0.07	0.00	0.00
Industrial	54.54	87.96	5.94	9.58	1.26	2.02	0.25	0.41	0.02	0.03
Religion	10.54	87.85	1.28	10.63	0.17	1.45	0.01	0.07	0.00	0.00
Residential	1,951.30	83.18	334.75	14.27	57.28	2.44	1.68	0.07	1.00	0.04
Total	**2,203.39**		**363.56**		**63.45**		**2.58**		**1.03**	

Table 3: Expected Building Damage by Building Type : 500 - year Event

Building Type	None		Minor		Moderate		Severe		Destruction	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	22	86.62	3	10.92	1	2.40	0	0.06	0	0.00
Masonry	139	80.28	22	12.48	12	6.87	1	0.33	0	0.03
MH	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Steel	117	88.12	12	9.25	3	2.30	0	0.32	0	0.00
Wood	1,883	84.34	314	14.08	33	1.47	2	0.07	1	0.04

Essential Facility Damage

Before the hurricane, the region had no hospital beds available for use. On the day of the hurricane, the model estimates that 0 hospital beds (0%) are available for use by patients already in the hospital and those injured by the hurricane. After one week, none of the beds will be in service. By 30 days, none will be operational.

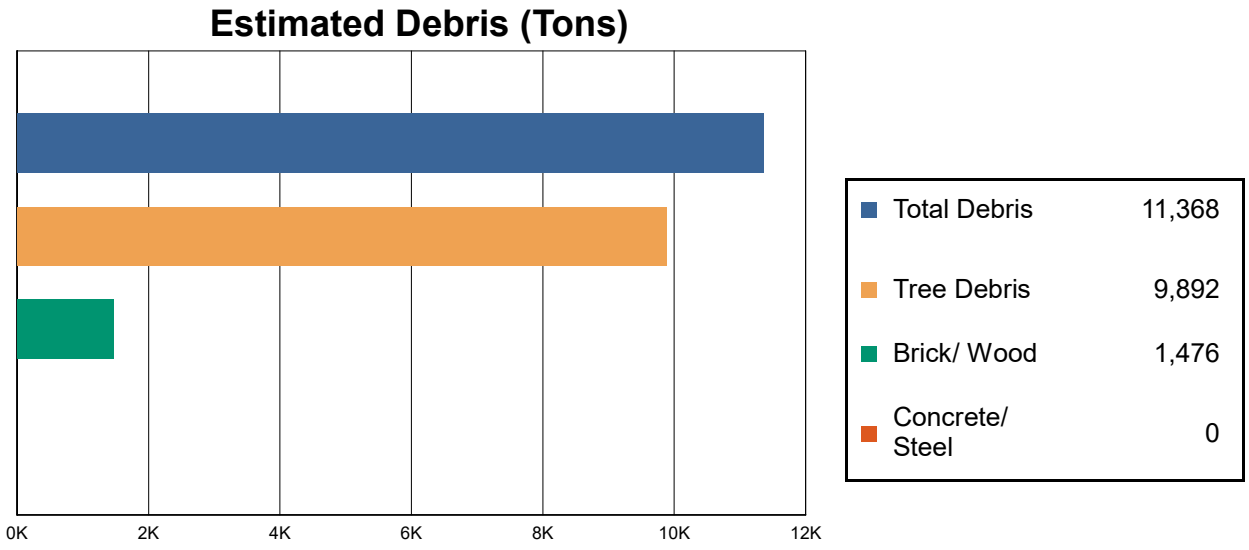
Thematic Map of Essential Facilities with greater than 50% moderate

Table 4: Expected Damage to Essential Facilities

		# Facilities		
Classification	Total	Probability of at Least Moderate Damage > 50%	Probability of Complete Damage > 50%	Expected Loss of Use < 1 day
Fire Stations	1	0	0	1
Police Stations	3	0	0	3
Schools	3	0	0	3

Induced Hurricane Damage

Debris Generation

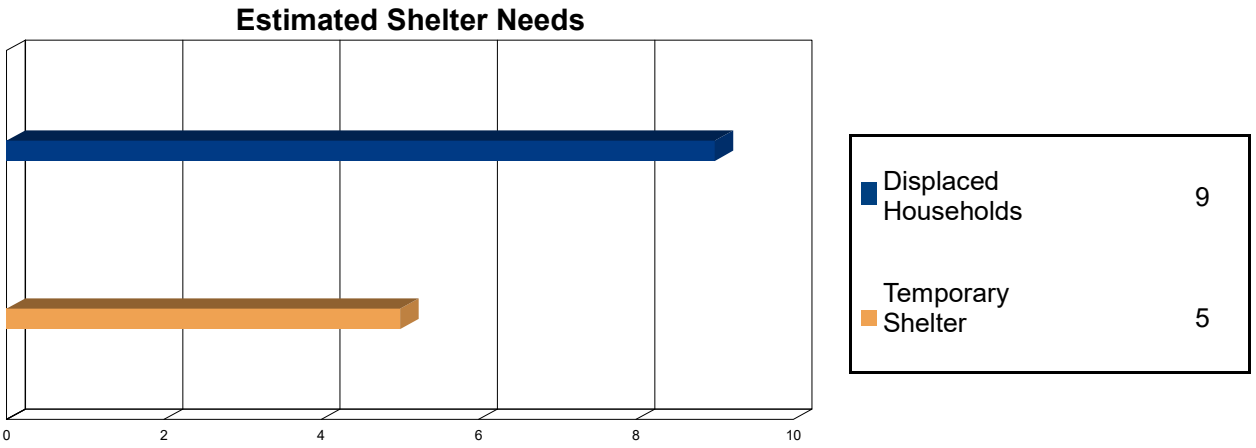


Hazus estimates the amount of debris that will be generated by the hurricane. The model breaks the debris into four general categories: a) Brick/Wood, b) Reinforced Concrete/Steel, c) Eligible Tree Debris, and d) Other Tree Debris. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 11,368 tons of debris will be generated. Of the total amount, 7,842 tons (69%) is Other Tree Debris. Of the remaining 3,526 tons, Brick/Wood comprises 42% of the total, Reinforced Concrete/Steel comprises of 0% of the total, with the remainder being Eligible Tree Debris. If the building debris tonnage is converted to an estimated number of truckloads, it will require 59 truckloads (@25 tons/truck) to remove the building debris generated by the hurricane. The number of Eligible Tree Debris truckloads will depend on how the 2,050 tons of Eligible Tree Debris are collected and processed. The volume of tree debris generally ranges from about 4 cubic yards per ton for chipped or compacted tree debris to about 10 cubic yards per ton for bulkier, uncompacted debris.

Social Impact

Shelter Requirement



Hazus estimates the number of households that are expected to be displaced from their homes due to the hurricane and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 9 households to be displaced due to the hurricane. Of these, 5 people (out of a total population of 8,987) will seek temporary shelter in public shelters.

Economic Loss

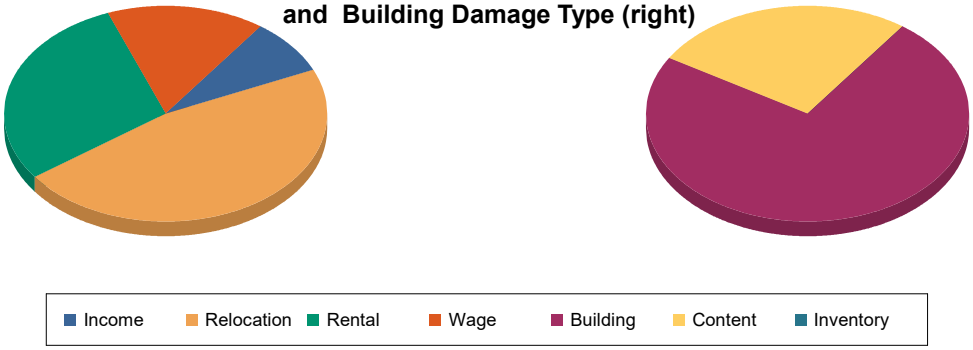
The total economic loss estimated for the hurricane is 25.6 million dollars, which represents 1.98 % of the total replacement value of the region's buildings.

Building-Related Losses

The building related losses are broken into two categories: direct property damage losses and business interruption losses. The direct property damage losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the hurricane. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the hurricane.

The total property damage losses were 26 million dollars. 5% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 91% of the total loss. Table 5 below provides a summary of the losses associated with the building damage.

Loss by Business Interruption Type (left) and Building Damage Type (right)



Loss Type by General Occupancy

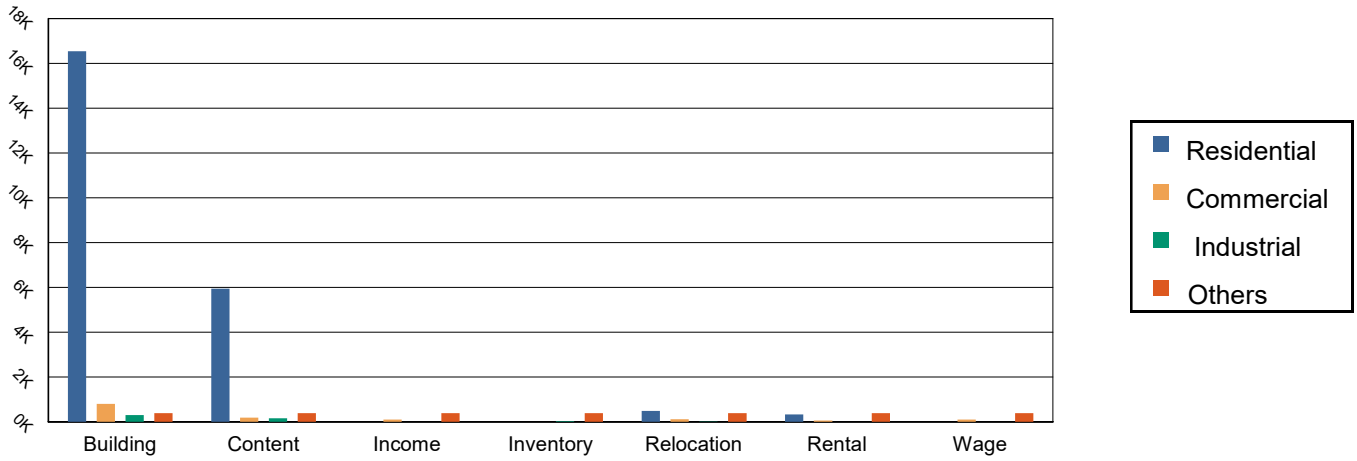


Table 5: Building-Related Economic Loss Estimates

(Thousands of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	16,545.13	803.26	300.54	187.75	17,836.67
	Content	5,945.60	191.96	159.09	38.49	6,335.14
	Inventory	0.00	5.25	25.19	0.75	31.19
	Subtotal	**22,490.73**	**1,000.47**	**484.81**	**226.99**	**24,203.01**
Business Interruption Loss						
	Income	0.00	96.86	3.19	13.42	113.46
	Relocation	490.09	118.60	13.64	25.20	647.54
	Rental	334.90	62.24	2.42	3.75	403.31
	Wage	0.00	101.32	5.30	112.93	219.56
	Subtotal	**824.99**	**379.02**	**24.55**	**155.31**	**1,383.87**

Total

Total	**23,315.73**	**1,379.49**	**509.36**	**382.30**	**25,586.88**

Appendix A: County Listing for the Region

Massachusetts
- Essex

Appendix B: Regional Population and Building Value Data

		Building Value (thousands of dollars)		
	Population	Residential	Non-Residential	Total
Massachusetts				
Essex	8,987	965,697	328,104	1,293,801
Total	**8,987**	**965,697**	**328,104**	**1,293,801**
Study Region Total	**8,987**	**965,697**	**328,104**	**1,293,801**

FIGURE 1

TOWN OF MIDDLETON, MASSACHUSETTS

MUNICIPAL VUNLERABILITY PREPARDNESS
HAZARD AND FEATURE MAP

APRIL 2020 SCALE: NOTED

Weston & Sampson

Hazus: Earthquake Global Risk Report

Region Name	Middleton
Earthquake Scenario:	Middleton mag 5 earthquake
Print Date:	February 13, 2020

Disclaimer:
This version of Hazus utilizes 2010 Census Data.
Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

Table of Contents

General Description of the Region

Hazus-MH is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

Massachusetts

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 14.48 square miles and contains 1 census tracts. There are over 2 thousand households in the region which has a total population of 8,987 people (2010 Census Bureau data). The distribution of population by Total Region and County is provided in Appendix B.

There are an estimated 2 thousand buildings in the region with a total building replacement value (excluding contents) of 1,293 (millions of dollars). Approximately 89.00 % of the buildings (and 75.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 506 and 46 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 2 thousand buildings in the region which have an aggregate total replacement value of 1,293 (millions of dollars) . Appendix B provides a general distribution of the building value by Total Region and County.

In terms of building construction types found in the region, wood frame construction makes up 85% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

Hazus breaks critical facilities into two (2) groups: essential facilities and high potential loss facilities (HPL). Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 0 hospitals in the region with a total bed capacity of beds. There are 3 schools, 1 fire stations, 3 police stations and 0 emergency operation facilities. With respect to high potential loss facilities (HPL), there are no dams identified within the inventory. The inventory also includes 10 hazardous material sites, no military installations and no nuclear power plants.

Transportation and Utility Lifeline Inventory

Within Hazus, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 552.00 (millions of dollars). This inventory includes over 39.77 miles of highways, 9 bridges, 249.79 miles of pipes.

Table 1: Transportation System Lifeline Inventory

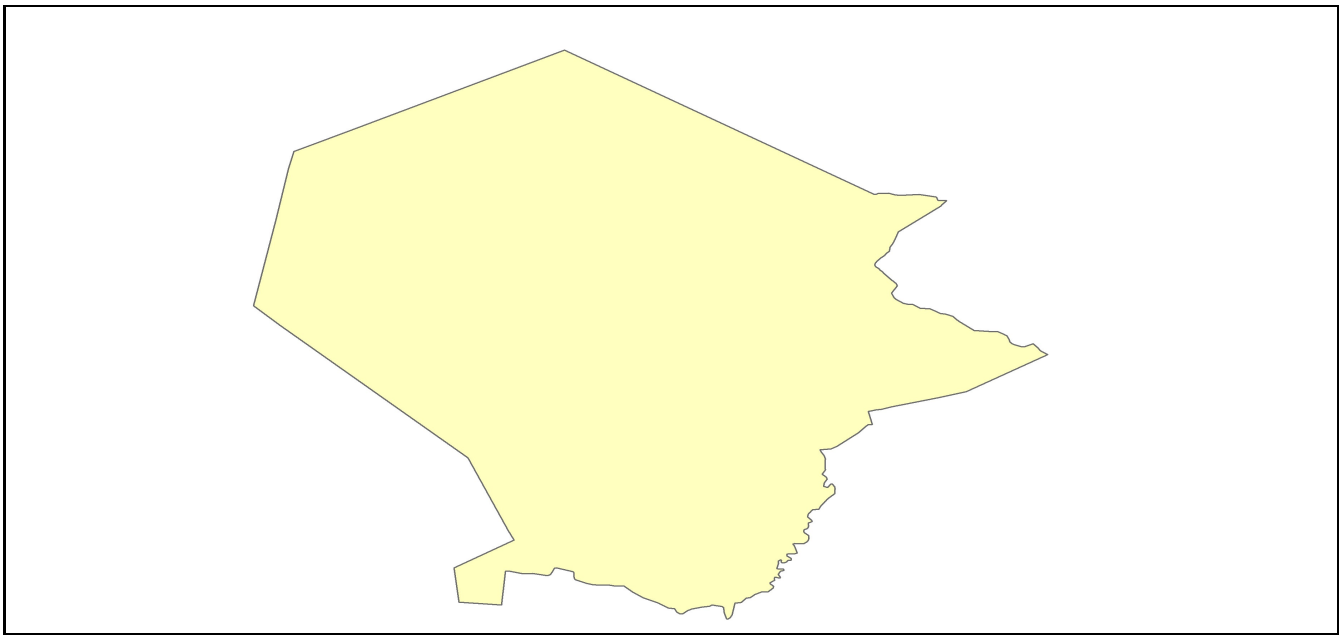
System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	9	35.9549
	Segments	44	459.4276
	Tunnels	0	0.0000
		Subtotal	**495.3825**
Railways	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	2	10.2611
	Tunnels	0	0.0000
		Subtotal	**10.2611**
Light Rail	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	0	0.0000
	Tunnels	0	0.0000
		Subtotal	**0.0000**
Bus	Facilities	1	1.2644
		Subtotal	**1.2644**
Ferry	Facilities	0	0.0000
		Subtotal	**0.0000**
Port	Facilities	0	0.0000
		Subtotal	**0.0000**
Airport	Facilities	0	0.0000
	Runways	0	0.0000
		Subtotal	**0.0000**
		Total	**506.90**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	4.0245
	Facilities	1	38.6280
	Pipelines	0	0.0000
		Subtotal	**42.6525**
Waste Water	Distribution Lines	NA	2.4147
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**2.4147**
Natural Gas	Distribution Lines	NA	1.6098
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**1.6098**
Oil Systems	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**0.0000**
Electrical Power	Facilities	0	0.0000
		Subtotal	**0.0000**
Communication	Facilities	0	0.0000
		Subtotal	**0.0000**
		Total	**46.70**

Earthquake Scenario

Hazus uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.



Scenario Name	Middleton mag 5 earthquake
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-71.02
Latitude of Epicenter	42.60
Earthquake Magnitude	5.00
Depth (km)	10.00
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	Central & East US (CEUS 2008)

Direct Earthquake Damage

Building Damage

Hazus estimates that about 568 buildings will be at least moderately damaged. This is over 22.00 % of the buildings in the region. There are an estimated 30 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Damage Categories by General Occupancy Type

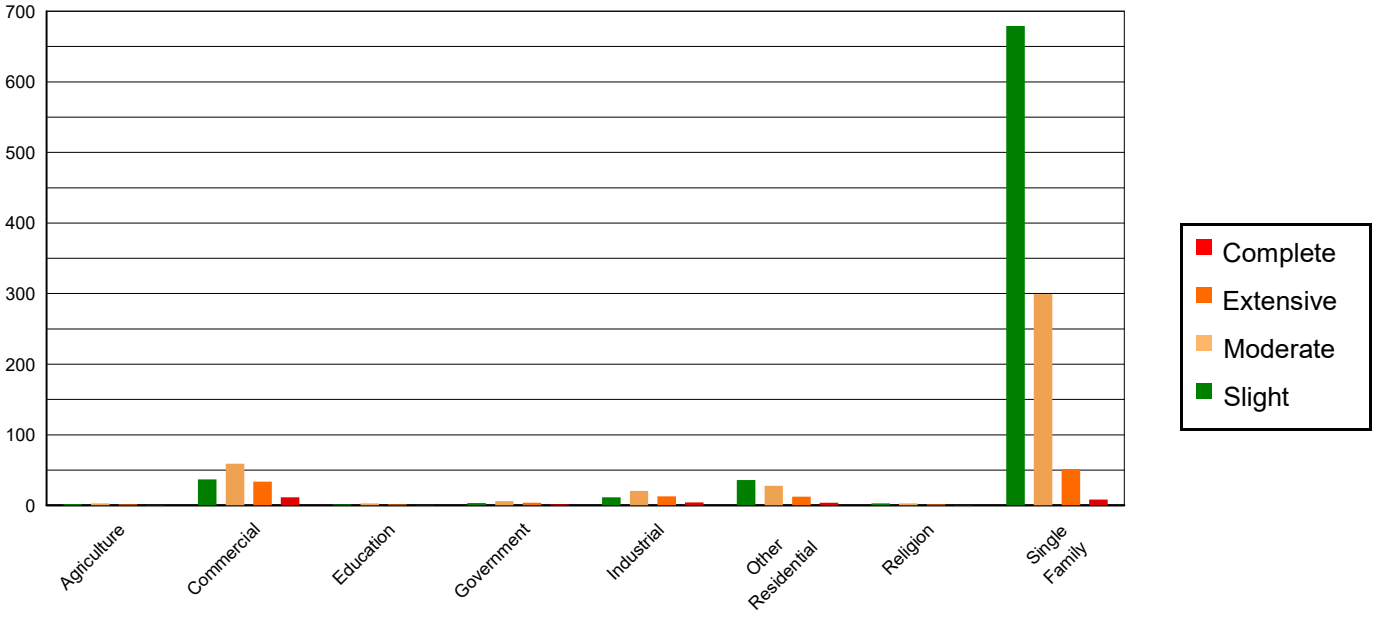


Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	1.73	0.13	1.94	0.25	2.67	0.64	1.24	1.05	0.42	1.38
Commercial	39.18	3.03	36.91	4.77	58.92	14.01	33.48	28.45	11.52	37.73
Education	1.86	0.14	1.62	0.21	2.61	0.62	1.43	1.21	0.48	1.56
Government	3.77	0.29	3.33	0.43	6.01	1.43	3.65	3.10	1.25	4.08
Industrial	12.87	1.00	11.45	1.48	20.63	4.91	12.68	10.78	4.36	14.29
Other Residential	57.76	4.47	35.90	4.64	27.58	6.56	12.14	10.31	3.63	11.89
Religion	4.22	0.33	2.84	0.37	2.88	0.68	1.56	1.32	0.51	1.68
Single Family	1170.90	90.61	679.00	87.84	299.25	71.16	51.49	43.76	8.36	27.39
Total	**1,292**		**773**		**421**		**118**		**31**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	1205.05	93.25	699.58	90.51	301.20	71.62	42.16	35.83	3.15	10.33
Steel	26.77	2.07	23.00	2.98	48.43	11.52	31.25	26.56	11.18	36.63
Concrete	4.33	0.33	3.86	0.50	9.09	2.16	5.89	5.00	1.79	5.88
Precast	1.60	0.12	1.18	0.15	3.08	0.73	3.12	2.65	0.98	3.20
RM	9.56	0.74	4.70	0.61	9.98	2.37	8.17	6.94	1.50	4.92
URM	44.98	3.48	40.66	5.26	48.77	11.60	27.08	23.01	11.92	39.04
MH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**1,292**		**773**		**421**		**118**		**31**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had hospital beds available for use. On the day of the earthquake, the model estimates that only hospital beds (%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, % of the beds will be back in service. By 30 days, % will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	0	0	0	0
Schools	3	3	0	0
EOCs	0	0	0	0
PoliceStations	3	2	0	1
FireStations	1	1	0	0

Transportation Lifeline Damage

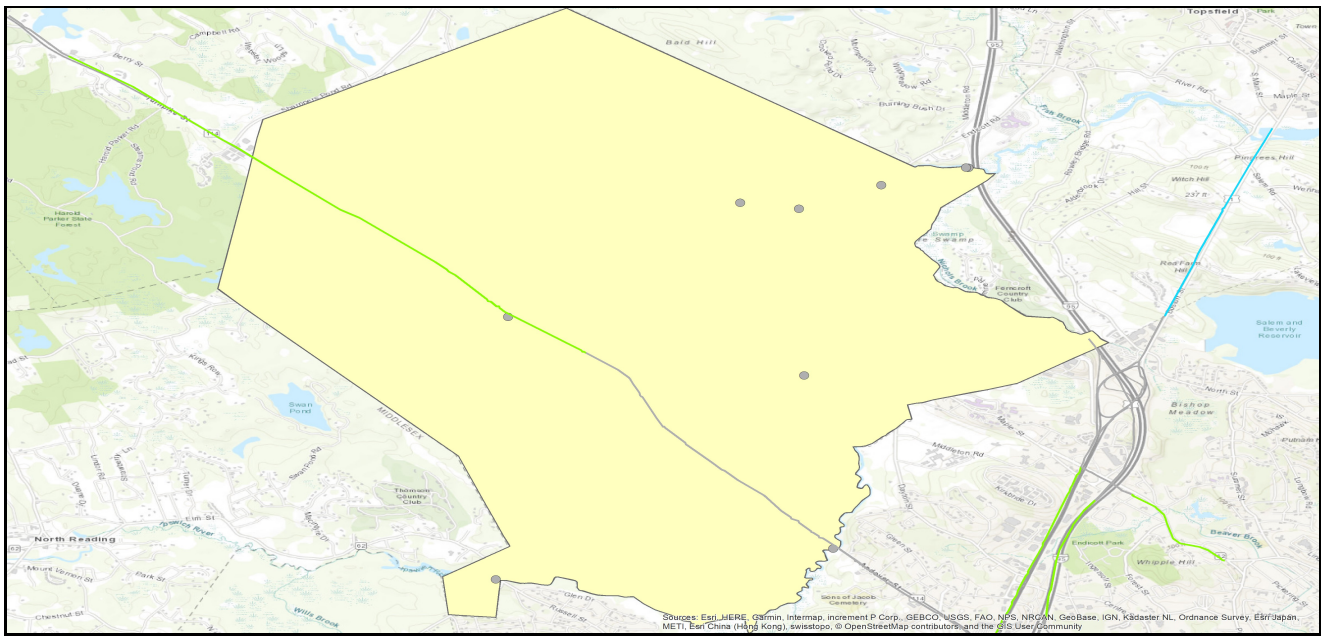


Table 6: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	44	0	0	35	35
	Bridges	9	0	0	9	9
	Tunnels	0	0	0	0	0
Railways	Segments	2	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	1	0	1	1
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	0	0	0	0	0
	Runways	0	0	0	0	0

Table 6 provides damage estimates for the transportation system.

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, Hazus performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	1	1	0	0	1
Waste Water	0	0	0	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	0	0	0	0	0

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (miles)	Number of Leaks	Number of Breaks
Potable Water	125	33	8
Waste Water	75	17	4
Natural Gas	50	6	1
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	2,898	0	0	0	0	0
Electric Power		2,446	1,634	690	125	3

Induced Earthquake Damage

Fire Following Earthquake

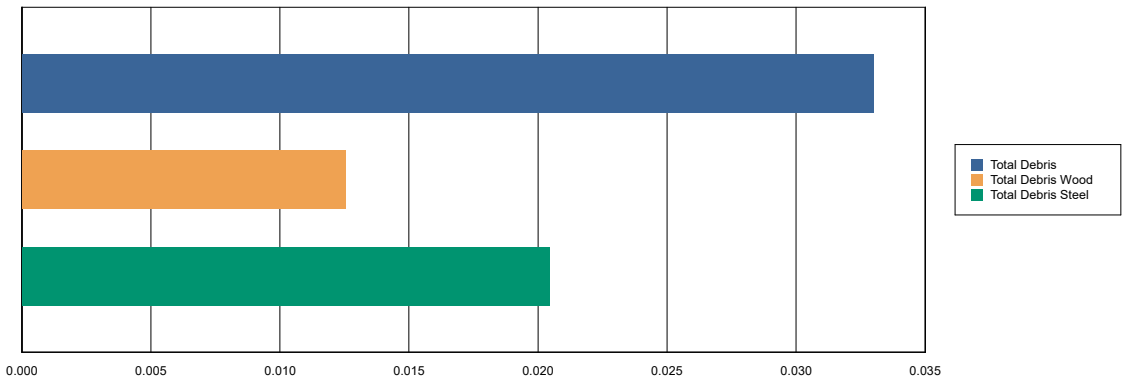
Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (millions of dollars) of building value.

Debris Generation

Hazus estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 33,000 tons of debris will be generated. Of the total amount, Brick/Wood comprises 38.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 1,320 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Earthquake Debris (millions of tons)



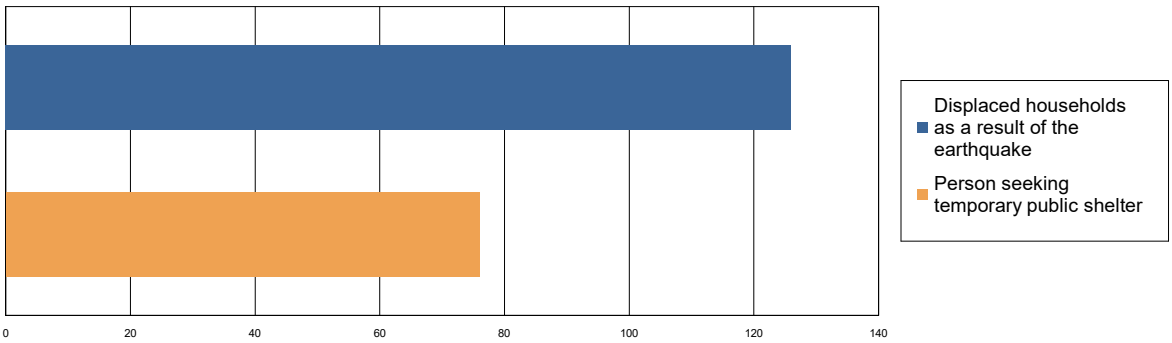
Brick/ Wood	Reinforced Concrete/Steel	Total Debris	Truck Load
0.01	0.02	0.03	1,320 (@25 tons/truck)

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 126 households to be displaced due to the earthquake. Of these, 76 people (out of a total population of 8,987) will seek temporary shelter in public shelters.

Displaced Households/ Persons Seeking Short Term Public Shelter



Displaced households as a result of the earthquake	Persons seeking temporary public shelter
126	76

Casualties

Hazus estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	0.62	0.15	0.02	0.04
	Commuting	0.00	0.00	0.00	0.00
	Educational	0.00	0.00	0.00	0.00
	Hotels	0.00	0.00	0.00	0.00
	Industrial	0.46	0.11	0.02	0.03
	Other-Residential	10.73	2.69	0.40	0.79
	Single Family	8.50	1.46	0.15	0.30
	Total	**20**	**4**	**1**	**1**
2 PM	Commercial	35.99	8.94	1.25	2.43
	Commuting	0.00	0.00	0.00	0.00
	Educational	12.03	3.07	0.46	0.89
	Hotels	0.00	0.00	0.00	0.00
	Industrial	3.37	0.85	0.12	0.24
	Other-Residential	2.24	0.57	0.09	0.16
	Single Family	1.76	0.32	0.04	0.06
	Total	**55**	**14**	**2**	**4**
5 PM	Commercial	25.44	6.34	0.89	1.71
	Commuting	0.02	0.08	0.07	0.02
	Educational	0.87	0.22	0.03	0.06
	Hotels	0.00	0.00	0.00	0.00
	Industrial	2.11	0.53	0.08	0.15
	Other-Residential	4.25	1.08	0.16	0.31
	Single Family	3.34	0.60	0.07	0.12
	Total	**36**	**9**	**1**	**2**

Economic Loss

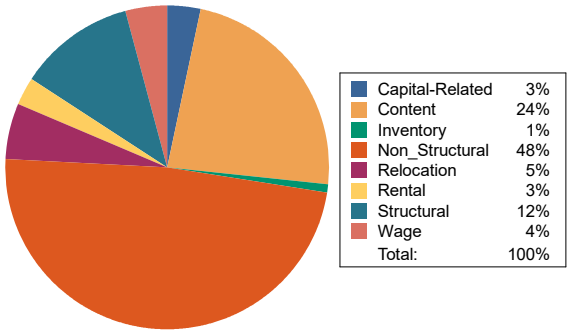
The total economic loss estimated for the earthquake is 202.06 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 187.43 (millions of dollars); 16 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 50 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Earthquake Losses by Loss Type ($ millions)



Earthquake Losses by Occupancy Type ($ millions)

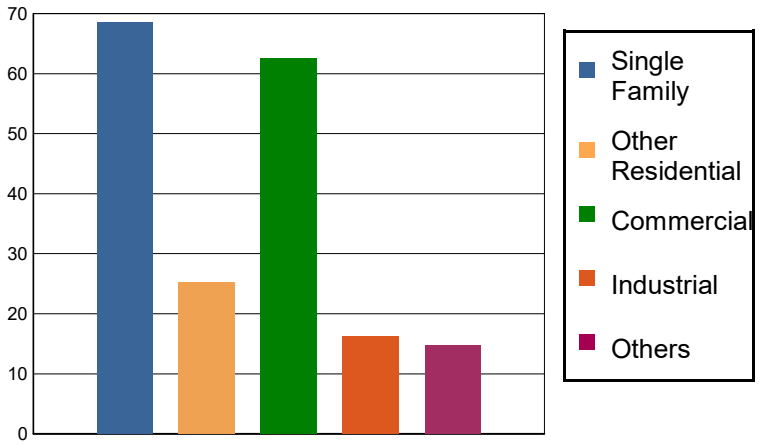


Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.0000	0.0845	6.5890	0.3373	0.7608	7.7716
	Capital-Related	0.0000	0.0358	5.8020	0.1977	0.0668	6.1023
	Rental	0.7462	1.3305	2.7974	0.0883	0.4117	5.3741
	Relocation	2.6735	0.8247	4.4460	0.5187	1.7159	10.1788
	Subtotal	**3.4197**	**2.2755**	**19.6344**	**1.1420**	**2.9552**	**29.4268**
Capital Stock Losses							
	Structural	6.5264	2.9263	8.1020	2.1478	2.1073	21.8098
	Non_Structural	39.5055	15.3313	22.3451	7.3510	6.3285	90.8614
	Content	19.0774	4.6638	12.1995	4.7796	3.4165	44.1368
	Inventory	0.0000	0.0000	0.3109	0.8719	0.0171	1.1999
	Subtotal	**65.1093**	**22.9214**	**42.9575**	**15.1503**	**11.8694**	**158.0079**
	Total	**68.53**	**25.20**	**62.59**	**16.29**	**14.82**	**187.43**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, Hazus computes the direct repair cost for each component only. There are no losses computed by Hazus for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

Table 12: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	459.4276	0.0000	0.00
	Bridges	35.9549	0.4248	1.18
	Tunnels	0.0000	0.0000	0.00
	Subtotal	**495.3825**	**0.4248**	
Railways	Segments	10.2611	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**10.2611**	**0.0000**	
Light Rail	Segments	0.0000	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Bus	Facilities	1.2644	0.5489	43.41
	Subtotal	**1.2644**	**0.5489**	
Ferry	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Port	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Airport	Facilities	0.0000	0.0000	0.00
	Runways	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**506.91**	**0.97**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0000	0.0000	0.00
	Facilities	38.6280	13.3960	34.68
	Distribution Line	4.0245	0.1487	3.69
	Subtotal	**42.6525**	**13.5447**	
Waste Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	2.4147	0.0747	3.09
	Subtotal	**2.4147**	**0.0747**	
Natural Gas	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	1.6098	0.0256	1.59
	Subtotal	**1.6098**	**0.0256**	
Oil Systems	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Electrical Power	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Communication	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**46.68**	**13.65**	

Appendix A: County Listing for the Region

Essex,MA

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Massachusetts					
	Essex	8,987	965	328	1,293
Total Region		**8,987**	**965**	**328**	**1,293**

Hazus: Earthquake Global Risk Report

Region Name	Middleton
Earthquake Scenario:	Middleton Magnitude 7 Earthquake
Print Date:	February 13, 2020

Disclaimer:
This version of Hazus utilizes 2010 Census Data.
Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

Table of Contents

General Description of the Region

Hazus-MH is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

Massachusetts

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 14.48 square miles and contains 1 census tracts. There are over 2 thousand households in the region which has a total population of 8,987 people (2010 Census Bureau data). The distribution of population by Total Region and County is provided in Appendix B.

There are an estimated 2 thousand buildings in the region with a total building replacement value (excluding contents) of 1,293 (millions of dollars). Approximately 89.00 % of the buildings (and 75.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 506 and 46 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 2 thousand buildings in the region which have an aggregate total replacement value of 1,293 (millions of dollars) . Appendix B provides a general distribution of the building value by Total Region and County.

In terms of building construction types found in the region, wood frame construction makes up 85% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

Hazus breaks critical facilities into two (2) groups: essential facilities and high potential loss facilities (HPL). Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 0 hospitals in the region with a total bed capacity of beds. There are 3 schools, 1 fire stations, 3 police stations and 0 emergency operation facilities. With respect to high potential loss facilities (HPL), there are no dams identified within the inventory. The inventory also includes 10 hazardous material sites, no military installations and no nuclear power plants.

Transportation and Utility Lifeline Inventory

Within Hazus, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 552.00 (millions of dollars). This inventory includes over 39.77 miles of highways, 9 bridges, 249.79 miles of pipes.

Table 1: Transportation System Lifeline Inventory

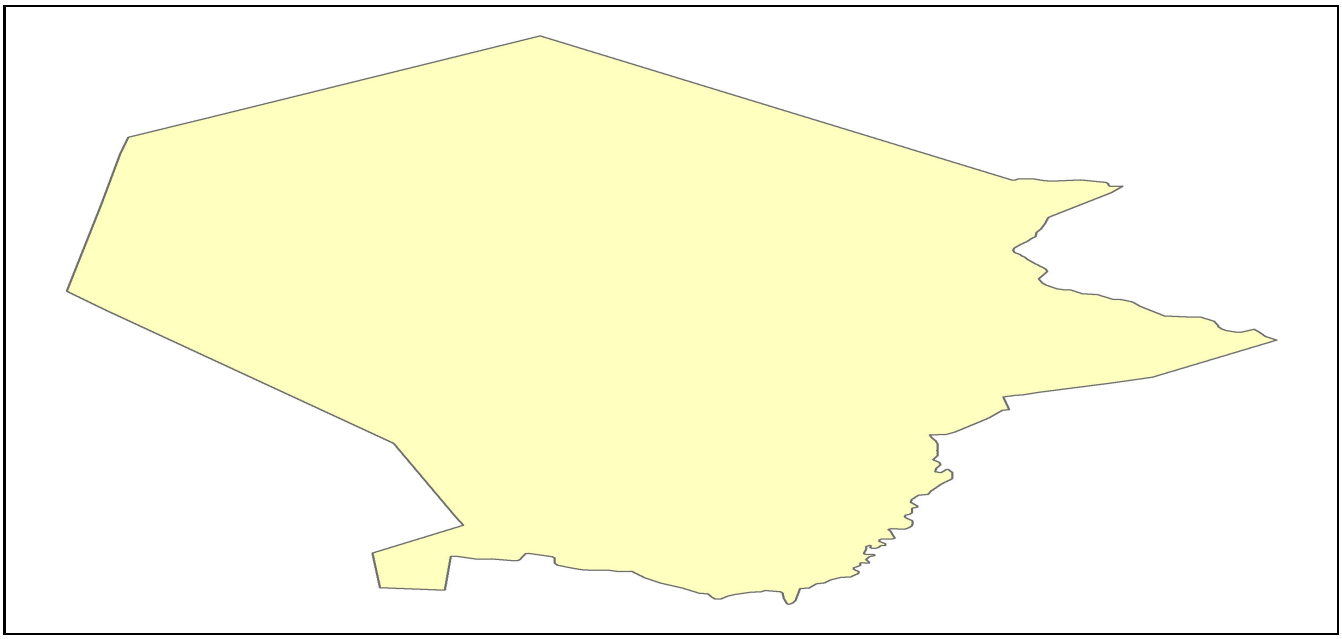
System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	9	35.9549
	Segments	44	459.4276
	Tunnels	0	0.0000
		Subtotal	**495.3825**
Railways	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	2	10.2611
	Tunnels	0	0.0000
		Subtotal	**10.2611**
Light Rail	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	0	0.0000
	Tunnels	0	0.0000
		Subtotal	**0.0000**
Bus	Facilities	1	1.2644
		Subtotal	**1.2644**
Ferry	Facilities	0	0.0000
		Subtotal	**0.0000**
Port	Facilities	0	0.0000
		Subtotal	**0.0000**
Airport	Facilities	0	0.0000
	Runways	0	0.0000
		Subtotal	**0.0000**
		Total	**506.90**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	4.0245
	Facilities	1	38.6280
	Pipelines	0	0.0000
		Subtotal	**42.6525**
Waste Water	Distribution Lines	NA	2.4147
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**2.4147**
Natural Gas	Distribution Lines	NA	1.6098
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**1.6098**
Oil Systems	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**0.0000**
Electrical Power	Facilities	0	0.0000
		Subtotal	**0.0000**
Communication	Facilities	0	0.0000
		Subtotal	**0.0000**
		Total	**46.70**

Earthquake Scenario

Hazus uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.



Scenario Name	Middleton Magnitude 7 Earthquake
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-71.02
Latitude of Epicenter	42.59
Earthquake Magnitude	7.00
Depth (km)	12.00
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	Central & East US (CEUS 2008)

Direct Earthquake Damage

Building Damage

Hazus estimates that about 2,548 buildings will be at least moderately damaged. This is over 97.00 % of the buildings in the region. There are an estimated 1,249 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Damage Categories by General Occupancy Type

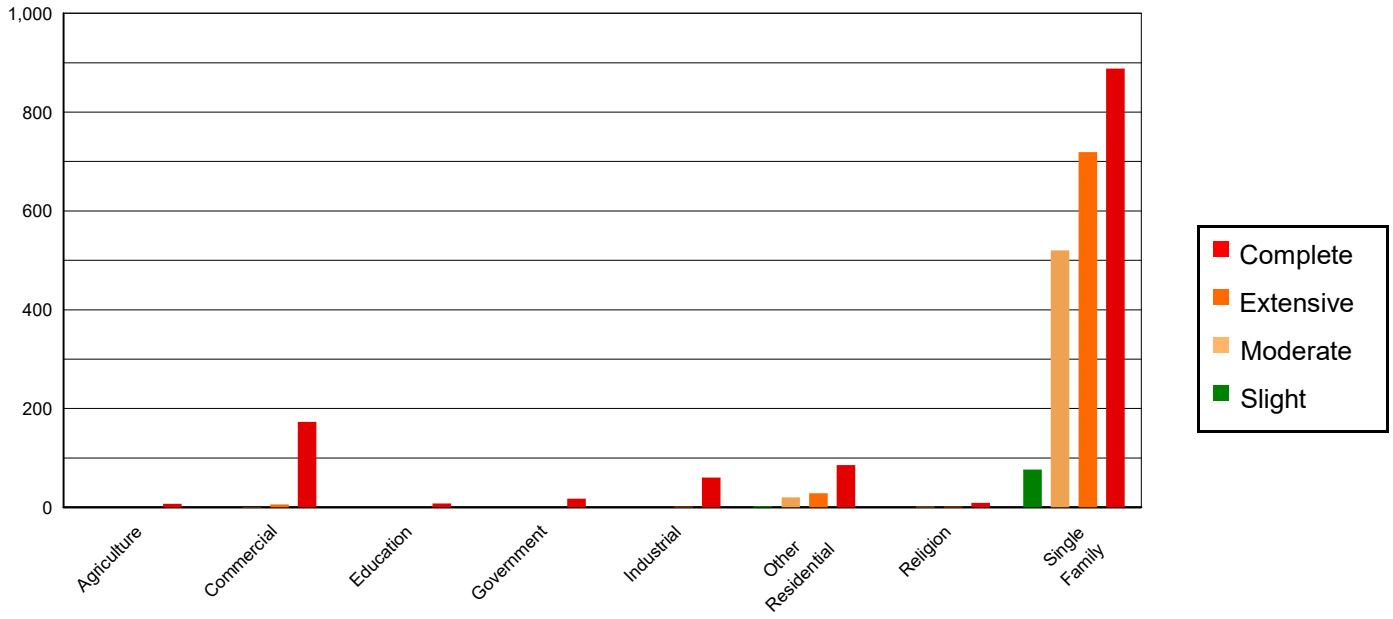


Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0.00	0.00	0.00	0.00	0.04	0.01	0.43	0.06	7.53	0.60
Commercial	0.01	0.14	0.04	0.05	0.65	0.12	6.05	0.80	173.24	13.87
Education	0.00	0.01	0.00	0.00	0.03	0.01	0.25	0.03	7.72	0.62
Government	0.00	0.02	0.00	0.00	0.04	0.01	0.43	0.06	17.52	1.40
Industrial	0.00	0.05	0.01	0.01	0.16	0.03	1.56	0.21	60.27	4.82
Other Residential	0.20	3.68	2.90	3.65	19.87	3.67	28.38	3.75	85.64	6.86
Religion	0.01	0.20	0.16	0.20	1.09	0.20	1.64	0.22	9.10	0.73
Single Family	5.30	95.90	76.40	96.07	520.32	95.96	718.76	94.89	888.22	71.10
Total	**6**		**80**		**542**		**758**		**1,249**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	5.51	99.71	79.40	99.85	540.81	99.74	748.75	98.84	876.67	70.18
Steel	0.01	0.13	0.01	0.01	0.12	0.02	2.38	0.31	138.11	11.06
Concrete	0.00	0.00	0.00	0.00	0.03	0.01	0.32	0.04	24.60	1.97
Precast	0.00	0.00	0.00	0.00	0.02	0.00	0.07	0.01	9.88	0.79
RM	0.01	0.16	0.01	0.01	0.14	0.03	0.44	0.06	33.30	2.67
URM	0.00	0.00	0.10	0.13	1.08	0.20	5.54	0.73	166.68	13.34
MH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**6**		**80**		**542**		**758**		**1,249**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had hospital beds available for use. On the day of the earthquake, the model estimates that only hospital beds (%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, % of the beds will be back in service. By 30 days, % will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	0	0	0	0
Schools	3	3	3	0
EOCs	0	0	0	0
PoliceStations	3	3	3	0
FireStations	1	1	1	0

Transportation Lifeline Damage

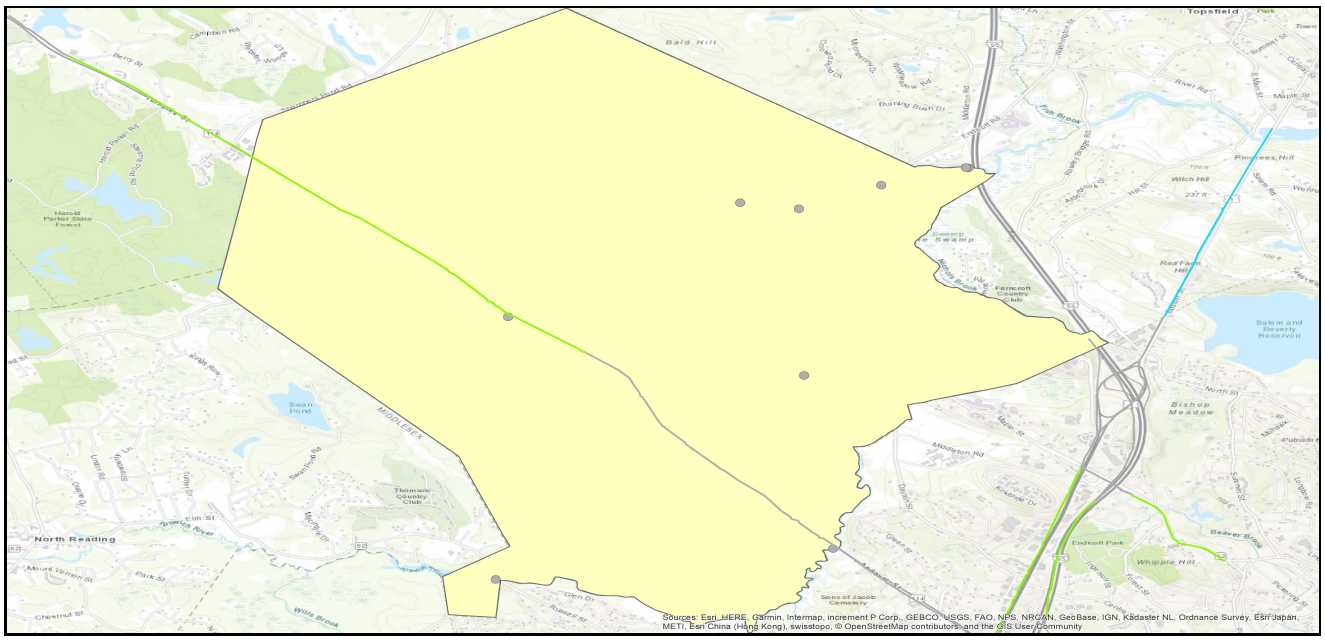


Table 6: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	44	0	0	35	35
	Bridges	9	9	9	0	0
	Tunnels	0	0	0	0	0
Railways	Segments	2	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	1	1	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	0	0	0	0	0
	Runways	0	0	0	0	0

Table 6 provides damage estimates for the transportation system.

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, Hazus performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	1	1	1	0	0
Waste Water	0	0	0	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	0	0	0	0	0

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (miles)	Number of Leaks	Number of Breaks
Potable Water	125	1053	263
Waste Water	75	529	132
Natural Gas	50	181	45
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	2,898	2,892	2,885	2,779	0	0
Electric Power		2,794	2,634	2,176	922	3

Induced Earthquake Damage

Fire Following Earthquake

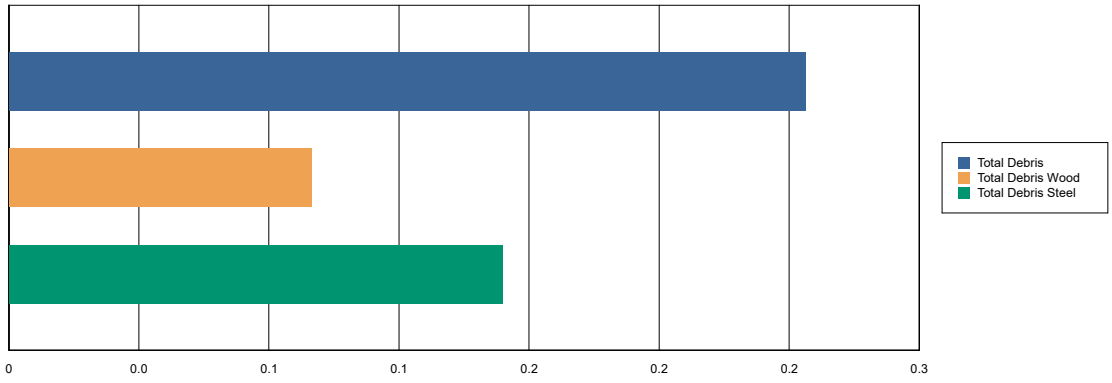
Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (millions of dollars) of building value.

Debris Generation

Hazus estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 245,000 tons of debris will be generated. Of the total amount, Brick/Wood comprises 38.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 9,800 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Earthquake Debris (millions of tons)



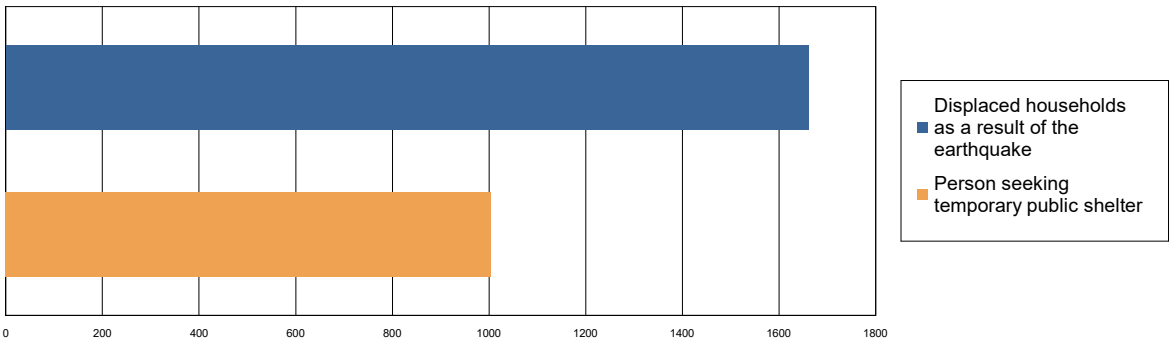
Brick/ Wood	Reinforced Concrete/Steel	Total Debris	Truck Load
0.09	0.15	0.25	9,800 (@25 tons/truck)

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 1,661 households to be displaced due to the earthquake. Of these, 1,004 people (out of a total population of 8,987) will seek temporary shelter in public shelters.

Displaced Households/ Persons Seeking Short Term Public Shelter



Displaced households as a result of the earthquake	Persons seeking temporary public shelter
1,661	1,004

Casualties

Hazus estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	6.14	1.97	0.31	0.62
	Commuting	0.02	0.06	0.06	0.01
	Educational	0.00	0.00	0.00	0.00
	Hotels	0.00	0.00	0.00	0.00
	Industrial	4.24	1.38	0.23	0.45
	Other-Residential	127.90	40.27	6.22	12.17
	Single Family	211.64	53.26	4.45	7.86
	Total	**350**	**97**	**11**	**21**
2 PM	Commercial	355.31	113.81	18.22	35.67
	Commuting	0.14	0.56	0.50	0.12
	Educational	122.45	40.08	6.71	13.07
	Hotels	0.00	0.00	0.00	0.00
	Industrial	31.51	10.26	1.69	3.29
	Other-Residential	26.98	8.53	1.36	2.53
	Single Family	45.09	11.40	1.11	1.69
	Total	**581**	**185**	**30**	**56**
5 PM	Commercial	252.27	80.84	13.05	25.17
	Commuting	2.41	9.37	8.37	2.00
	Educational	8.84	2.90	0.48	0.95
	Hotels	0.00	0.00	0.00	0.00
	Industrial	19.69	6.41	1.06	2.06
	Other-Residential	51.09	16.16	2.58	4.78
	Single Family	85.38	21.59	2.10	3.20
	Total	**420**	**137**	**28**	**38**

Economic Loss

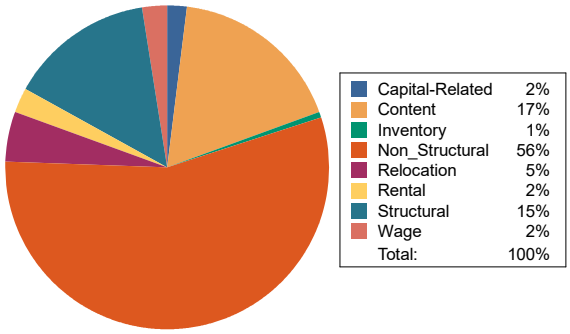
The total economic loss estimated for the earthquake is 1,369.72 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 1,308.01 (millions of dollars); 12 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 60 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Earthquake Losses by Loss Type ($ millions)



Earthquake Losses by Occupancy Type ($ millions)

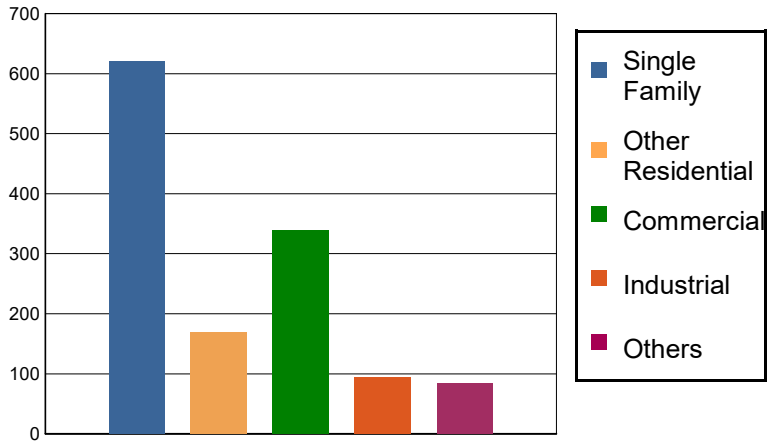


Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.0000	0.4847	27.6274	1.4488	2.8618	32.4227
	Capital-Related	0.0000	0.2055	24.9567	0.8400	0.3087	26.3109
	Rental	11.2303	9.0348	10.1405	0.3136	1.5041	32.2233
	Relocation	36.9588	5.0804	15.0908	1.5273	6.5119	65.1692
	Subtotal	**48.1891**	**14.8054**	**77.8154**	**4.1297**	**11.1865**	**156.1261**
Capital Stock Losses							
	Structural	108.7626	20.0993	40.8710	10.0474	10.9507	190.7310
	Non_Structural	378.3054	111.2434	146.9716	47.8495	41.8267	726.1966
	Content	85.1095	23.7522	71.5511	27.8034	19.7386	227.9548
	Inventory	0.0000	0.0000	1.8239	5.0758	0.1049	7.0046
	Subtotal	**572.1775**	**155.0949**	**261.2176**	**90.7761**	**72.6209**	**1151.8870**
	Total	**620.37**	**169.90**	**339.03**	**94.91**	**83.81**	**1308.01**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, Hazus computes the direct repair cost for each component only. There are no losses computed by Hazus for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

Table 12: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	459.4276	0.0000	0.00
	Bridges	35.9549	22.4948	62.56
	Tunnels	0.0000	0.0000	0.00
	Subtotal	**495.3825**	**22.4948**	
Railways	Segments	10.2611	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**10.2611**	**0.0000**	
Light Rail	Segments	0.0000	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Bus	Facilities	1.2644	1.0981	86.85
	Subtotal	**1.2644**	**1.0981**	
Ferry	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Port	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Airport	Facilities	0.0000	0.0000	0.00
	Runways	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**506.91**	**23.59**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0000	0.0000	0.00
	Facilities	38.6280	30.1814	78.13
	Distribution Line	4.0245	4.7369	117.70
	Subtotal	**42.6525**	**34.9183**	
Waste Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	2.4147	2.3795	98.54
	Subtotal	**2.4147**	**2.3795**	
Natural Gas	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	1.6098	0.8152	50.64
	Subtotal	**1.6098**	**0.8152**	
Oil Systems	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Electrical Power	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Communication	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**46.68**	**38.11**	

Appendix A: County Listing for the Region

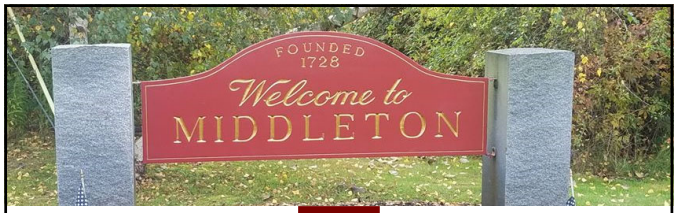
Essex,MA

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Massachusetts					
	Essex	8,987	965	328	1,293
Total Region		**8,987**	**965**	**328**	**1,293**

APPENDIX C

CRB Workshop



TOWN OF MIDDLETON

Community Resilience Building Workshop
Thursday, November 9th, 2019

Photo: Welcome to Middleton, Photo by the Town of Middleton, Facebook, 2018

1

WELCOME CORE TEAM

Andrew Sheehan
Katrina O'Leary
Ken Gibbons
Thomas J. Martinuk
James DiGianvittorio
Kristin Kent
Derek Fullerton
Jillian Smith

Photo: The Board of Selectmen, Finance Committee, and Staff Reviewing FY19 Budget Requests with Departments, Photo by the Town of Middleton, Facebook, 2018

2

WELCOME W&S

Amanda Kohn
Steve Roy
Lindsey Adams
Dana Martin

3

WELCOME PARTICIPANTS

Your name
Organization/Relationship to Middleton
Favorite thing about Middleton

4

WORKSHOP OUTLINE

PRESENTATION:
- Overview of Science & Data
- Characterization of Hazards

- BREAK -

INDIVIDUAL TABLES:
- Identify Community Features

- LUNCH -

INDIVIDUAL TABLES:
- Identify and Prioritize Actions

- BREAK -

LARGE GROUP DISCUSSION:
- Determine Overall Priority Actions

Photo: middleton.wickedlocal.com

5

MVP COMPONENTS

PHASE 1 - PLANNING
- Receive Planning Grant
- Prioritize Action Items
- Complete MVP Program
- Submit Final Report for Approval
- Become Certified

PHASE 2 - ACTION
- Select an Action Item from Planning Phase
- Apply for Action Grant Funding
- Implement Action Item

6

MVP PLANNING GRANT COMPONENT

HAZARD MITIGATION PLAN UPDATE

- Aligns with MVP Process
- Extended hazard profiles and vulnerability assessment
- Update to previous mitigation measures table

7

7

Top 5 Hazard Mitigation Project Types in 2019

1. FLOOD CONTROL $148M
2. ACQUISITIONS $132M
3. UTILITY AND INFRASTRUCTURE PROTECTION $112M
4. GENERATORS $73M
5. SAFE ROOMS/WIND SHELTERS $67M

8

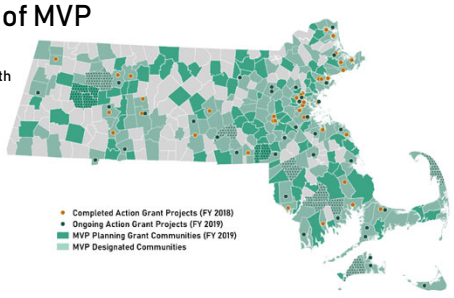
8

Three Years of MVP

MVP Designations
71% of the Commonwealth
249 communities

Action Grant Projects
FY18: 37
FY19: 36

Total Awards
$17M+ in planning and action grants to date



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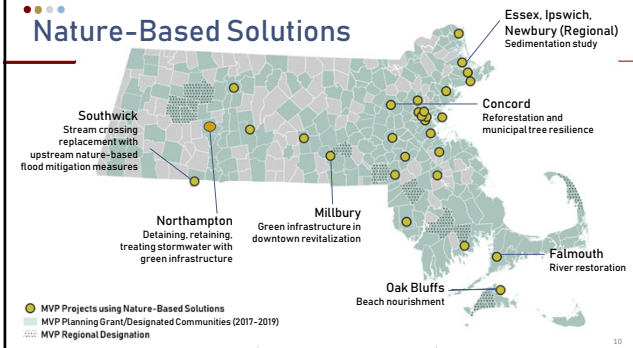
Nature-Based Solutions



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10

ELIGIBLE MVP ACTION GRANT PROJECTS

- Detailed Vulnerability and Risk Assessment
- Public Education and Communication
- Local Bylaws, Ordinances, Plans, and Other Management Measures
- Redesigns and Retrofits
- Energy Resilience Strategies
- Chemical Safety
- Nature-Based Storm-Damage Protection, Drought Prevention, Water Quality, and Water Infiltration Techniques
- Nature-Based, Infrastructure and Technology Solutions to Reduce Vulnerability to Extreme Heat and Poor Air Quality
- Nature-Based Solutions to Reduce Vulnerability to other Climate Change Impacts
- Acquisition of Land to Achieve a Resiliency Objective
- Ecological Restoration and Habitat Management to Increase Resiliency

Weston & Sampson

11

11

Example MVP Action Grant Projects

Nature-Based Flood Protection, Drought Prevention, Water Quality, and Water Infiltration Techniques

Millbury

Utilizing green infrastructure like stormwater planters, bioretention bump outs, rain gardens, and other measures like porous pavers and pervious pavement to reduce heat island effects and stormwater runoff into the Blackstone River.

12

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Example MVP Action Grant Projects

Local Bylaws, Ordinances, Plans, and Other Management Measures
Redesigns and Retrofits

Boston

Developing its first ever resilient building code so that development in the future floodplain is prepared for at least three feet of sea level rise, the likely scenario by late century.

Proactive

Pilot potential

Retrofitting a major waterfront park into a legacy park that uses nature-based solutions to address climate vulnerabilities while providing important access to recreation for residents.

Nature-based solutions

Community co-benefits

13

Example MVP Action Grant Projects

Redesigns and Retrofits

Salisbury

Increasing the resilience of the neighborhood of Ring's Island by raising its access/egress roads and by improving tidal flushing through culvert replacements

Vulnerable communities

14

14

Example MVP Action Grant Projects

Nature-Based Flood Protection, Drought Mitigation, Water Quality, and Water Infiltration Techniques

Belchertown

Designing and permitting for a replacement water storage tank that would increase storage capacity and resiliency to drought, and completing a feasibility/ concept design of a rainwater harvesting system at Belchertown High School to irrigate the athletic fields.

Nature-based solutions

Pilot potential

15

15

RESOURCES

resilient MA
Climate Change Clearinghouse for the Commonwealth

Massachusetts Climate Change Projections, 2018)

Massachusetts State Hazard and Climate Adaptation Plan, 2018

Massachusetts Climate Change Adaptation Report, 2011

US Census, American Community Survey, 2013-2017

Input from Municipal Officials

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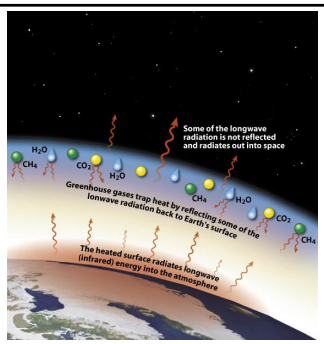
16

GREENHOUSE GASES (GHG)

- Naturally occurring
- Act as a blanket
- Examples: carbon dioxide and methane

Climate mitigation ensures there is less to adapt to and is a key component of our community's resilience



Smithsonian Environmental Research Center. "Too Much of a Good Thing." http://forces.si.edu/atmosphere/02_04_07.html

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17

17

MASSACHUSETTS GHG GOALS

- Established by the Global Warming Solutions Act (GWSA) of 2008
- 25% reduction in GHG emissions by 2020
- 80% reduction in GHG emissions by 2050
- 1990 is the baseline year

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Source: Commonwealth of Massachusetts. 2019. "Global Warming Solutions Act 10-year Progress Report," 10.

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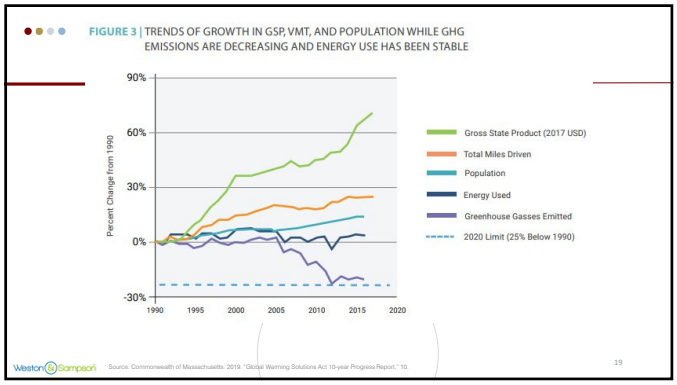

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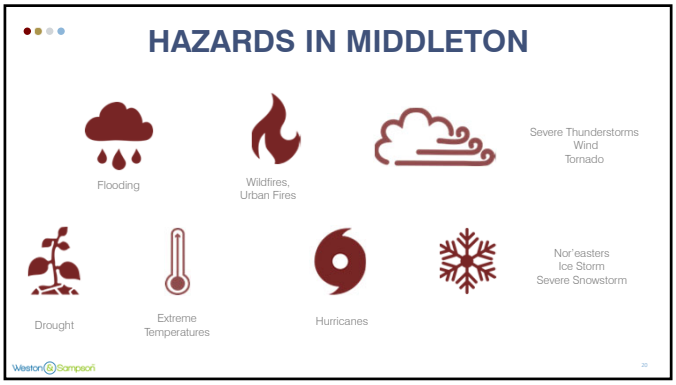

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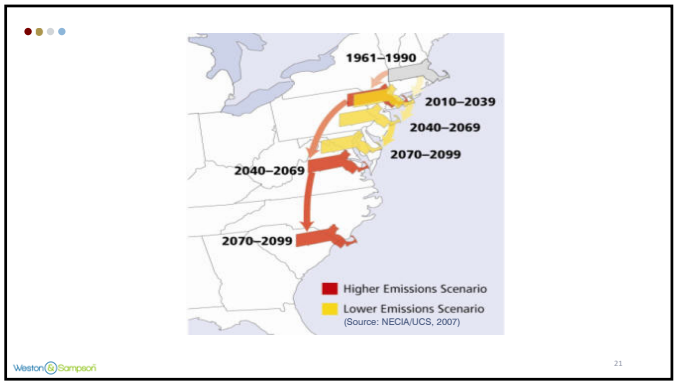

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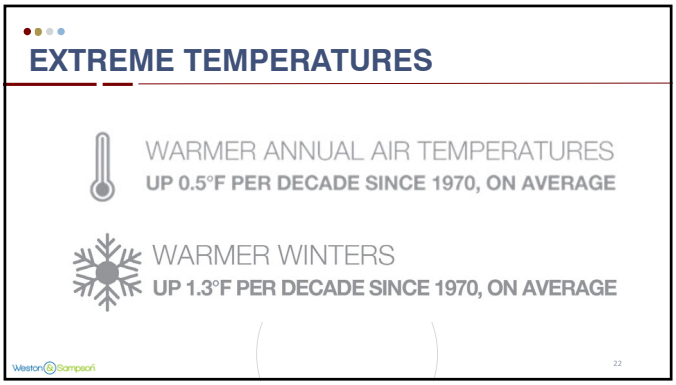

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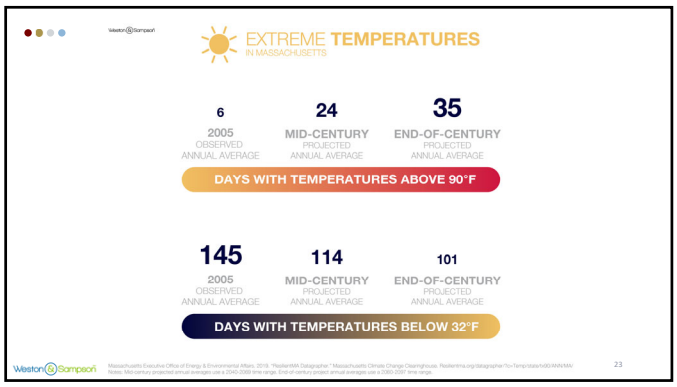

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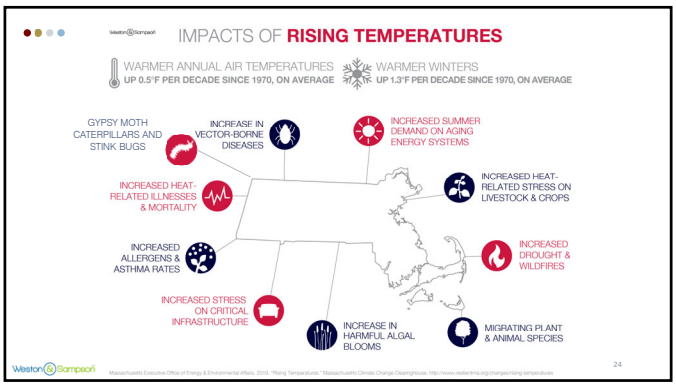


24

CHANGES IN PRECIPITATION

MORE **INTENSE & FREQUENT** EXTREME RAIN EVENTS

PRECIPITATION DURING **HEAVY EVENTS** IN THE NORTHEAST **INCREASED BY MORE THAN**

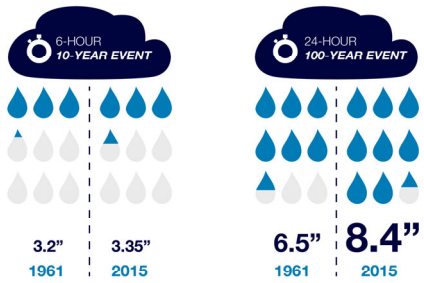
70%

BETWEEN 1958-2010

Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Changes in Precipitation." Massachusetts Climate Change Clearinghouse. Resilientma.org/changes/changes-in-precipitation

25

CHANGES IN PRECIPITATION



Sources: NOAA TP-40 (1961) and NOAA Atlas Volume 10 (2015)

26

EXTREME PRECIPITATION

8%

Increase in extreme precipitation events by **midcentury**

13%

Increase in extreme precipitation events by **end of century**

27

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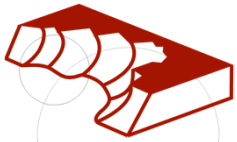
EROSION

Caused by riverine flow & stormwater

Increased precipitation, including winter rains, could increase erosion

Drier soils will reduce resistance to erosion



(Source: MA Climate Change Adaptation Report, 2011)

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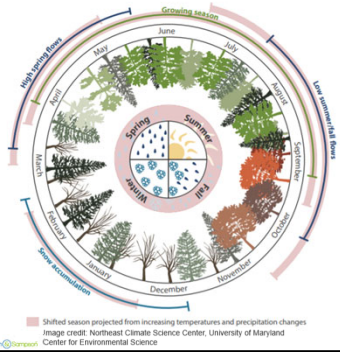


Drought in Middleton

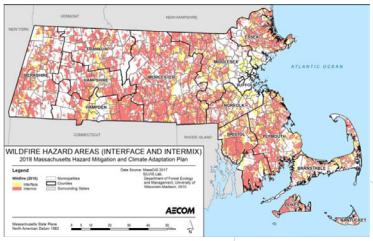
- Domestic wells have dried up
- Water bans
- Ipswich River was very low

The occurrence of droughts **lasting 1 to 3 months** could go up by as much as **75% over existing conditions** by the end of the century, under the high emissions scenario

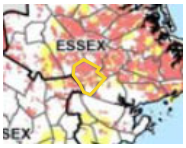
30

30

WILDFIRE



Bald Hill
North Area of Town
Liberty Street
Pinnacle Road
Mulch Fires



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WINTER STORMS

The blizzard of 2013 left nearly **400,000 Massachusetts residents without power**

"Heavy blizzards are among the **most costly and disruptive** weather events for Massachusetts communities."

32

FLOODING

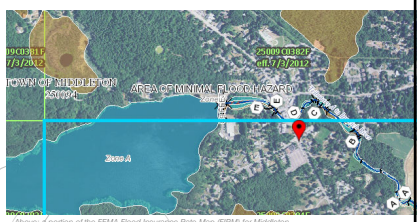
ZONE	ANNUAL CHANCE	FLOODPLAIN
A, AE, A1-A30	1% ANNUAL CHANCE	100-YEAR FLOODPLAIN
X	0.2% ANNUAL CHANCE	500-YEAR FLOODPLAIN

"By 2050, Boston could experience the current 100- year riverine flood every two to three years on average"

33

RIVERINE FLOODING

- Essex Street (beaver dams)
- Mill Pond at Liberty Street
- Thunder Bridge
- Boston Street



Above: A portion of the FEMA Flood Insurance Rate Map (FIRM) for Middleton

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STORMWATER FLOODING

Areas with:

- Poor drainage
- High amounts of impervious surface
- Undersized culverts
- Urbanization

Areas Prone to Stormwater Flooding:

- South Main Street
- Peabody Street and School Street
- River Street (fixed, obstructions removed)

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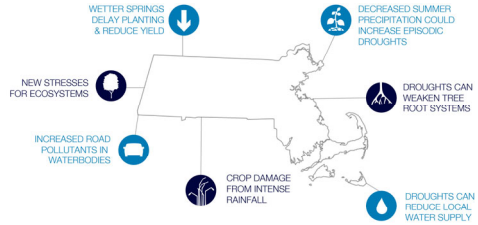
IMPACTS OF CHANGING **PRECIPITATION**

HIGHER AVERAGE ANNUAL PRECIPITATION
INCREASED BY ABOUT 10% IN THE NORTHEAST INTHE LAST 50 YEARS



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HURRICANES AND EXTREME WIND

HURRICANE Sandy was the most recent hurricane

Upward trend in North Atlantic **hurricane** activity since 1970

Nor'easters along the Atlantic coast are increasing in frequency and intensity

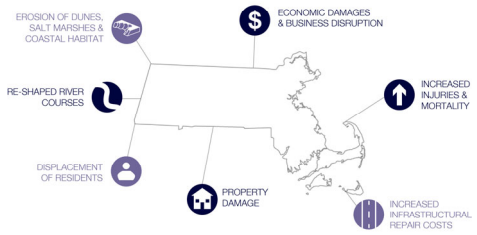
Microbursts have been previously experienced twice in the last 20 years Middleton

36 hours of power outage a few years ago from wind

37

IMPACTS OF EXTREME WEATHER

STORMS ARE BECOMING MORE INTENSE AND DAMAGING



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As an FYI: Boston Sea Level Rise Projections (ft)

Increased coastal flooding

Permanently inundated low-lying coastal areas

Increased shoreline erosion

Emission Scenario	2030	2050	2070	2100
Intermediate	0.7	1.4	2.3	4.0
Intermediate-High	0.8	1.7	2.9	5.0
High	1.2	2.4	4.2	7.6
Extreme	1.4	3.1	5.4	10.2

(Source: Northeast Climate Adaption Science Center)

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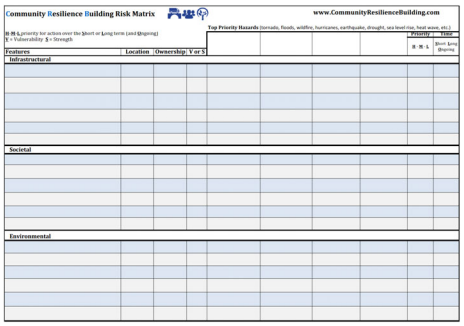
RISK MATRIX

40

RISK MATRIX



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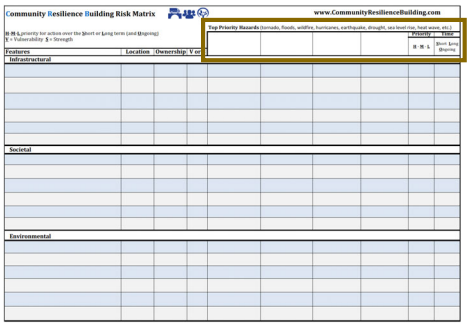
RISK MATRIX: HAZARDS



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IDENTIFY HAZARDS

Photo: wickedlocal.com

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HAZARDS IN MIDDLETON

CHOOSE 4 FOR THE RISK MATRIX

Flooding

Severe Thunderstorms, Wind, Tornado, Hurricanes

Drought
Extreme Heat
Wildfires

Nor'easters, Ice Storm, Severe Snowstorm, Extreme Cold

Weston & Sampson

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RISK MATRIX: HAZARDS

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)				Priority	Time
				H - M - L	Short Long Ongoing

45

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15 MINUTE BREAK!

Photo: Fuller Meadow School, CBI Consulting Inc.

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RISK MATRIX: FEATURES

Community Resilience Building Risk Matrix — www.CommunityResilienceBuilding.com

H-M-L priority for action over the Short or Long term (and Ongoing)
V = Vulnerability S = Strength

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Priority H - M - L	Time Short Long Ongoing
Infrastructural					
Societal					
Environmental					

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RISK MATRIX: FEATURES

H-M-L priority for action over the Short or Long term (and Ongoing)
V = Vulnerability S = Strength

Features	Location	Ownership	V or S
Infrastructural			
Societal			
Environmental			

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FEATURES IN MIDDLETON

Photo: yelp.com

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INFRASTRUCTURAL FEATURES


Police Department


Fire Department


Wastewater Treatment & Collection


Dams

Transportation


Water Supply

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HAZARD POTENTIAL OF DAMS

Name	Water Body	Ownership	Hazard Class
EMERSON BROOK DAM	EMERSON BROOK	TOWN OF DANVERS	LOW
MIDDLETON POND OUTLET DAM	TRIBUTARY OF IPSWICH RIVER	TOWN OF DANVERS	LOW
SOUTH MIDDLETON DAM	IPSWICH RIVER	PRIVATE	SIGNIFIGANT (TO BE REMOVED IN 2020)
CREIGHTON POND DAM	TRIBUTARY OF BOSTON BROOK	PRIVATE	LOW
MILL POND DAM	EMERSON BROOK	PRIVATE	SIGNIFIGANT

Weston & Sampson

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INFRASTRUCTURAL FEATURES

CRITICAL FACILITY EXAMPLES

Police and Fire Department
- Police Department
- Fire Department

Town Facilities
- Department of Public Works
- Electric Department
- Danvers Water Treatment Facility

Communication and Utilities Infrastructure
- Verizon Telephone Hut
- MIT Public Communication Tower

Emergency Shelters
- Fuller Meadow School
- Howe-Manning School

Primary Evacuation Routes
- Route 114
- Route 62

Critical Bridges, Intersections, and Sites

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INFRASTRUCTURAL FEATURES - DRINKING WATER

- Vernon C. Russel Water Treatment Plant (WTP) in Middleton
- The WTP treats water from:
  - Middleton Pond Reservoir which receives water from
    - Swan Pond Reservoir
    - Emerson Brook Reservoir
- Ground water supply located along the Ipswich River
  - Well 1 (Middleton)
  - Well 2 (Danvers)

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SOCIETAL FEATURES

Population	Middleton	Massachusetts
2010	8,987 residents	6,547,790
2018	10,050 residents	6,902,149
Age		
Under 18 years:	19%	20%
65+ years:	18%	17%
Additional Information		
Median household income:	$107,727	$74,167
Persons in poverty:	4%	10%
With a disability:	9%	8%
Language other than English spoken at home:	18%	23%
Hispanic/Latino	10%	18%
People of Color	11%	20%

Source: U.S. Census Bureau, 2013-2017 ACS Estimates

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SOCIETAL FEATURES

SCHOOL SYSTEM

- 703 students are enrolled in the public school system
- Public school system includes 2 elementary schools and 1 middle school and 1 high school (regional)
- Other schools include:
  - Essex North Shore Agricultural & Technical School (regional)

55

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SOCIETAL FEATURES

60 public safety personnel, including:

23 uniformed police officers

37 on-call fire fighters

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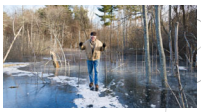
ENVIRONMENTAL FEATURES

Rail Trail



Ponds

Water Bodies in Middleton

- Middleton Pond
- Emerson Brook Reservoir
- Ipswich River
- Aunt Betts Pond
- Creighton Pond

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RISK MATRIX: FEATURES

FEATURES	LOCATION	OWNERSHIP	VULNERABILITY OR STRENGTH
Infrastructural	Town wide	State	Vulnerability
Societal	Multi- vs. Single-neighborhood	Town	Strength
Environmental	Specific location	Private	Both
		Shared	

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LUNCH

Photo: Middleton Pond. Wordpress.com

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ADAPTATION STRATEGIES

Photo: Aunt Betts Pond. Mapcarta.com

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EXISTING HAZARD PROTECTION

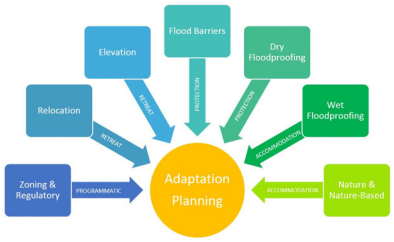
- Stormwater Bylaw
- Wetlands Bylaw
- Tree clearing
- Danvers Public Water Supply Emergency Response
- Emergency Shelter Plan with Fire Department

Source:

62

62

COMMUNITY ACTIONS



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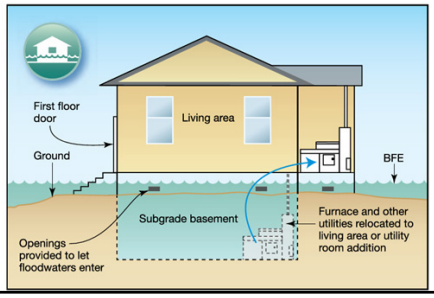
WET FLOODPROOFING



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RAISED BUILDINGS

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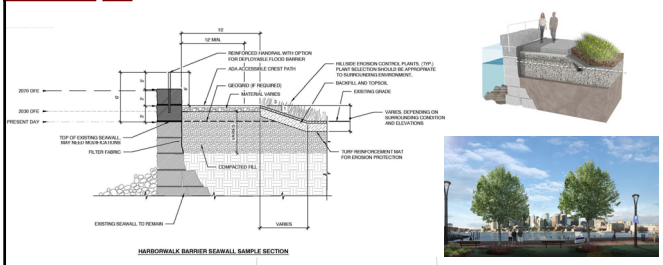
FLOOD WALLS



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DEPLOYABLE FLOOD BARRIER

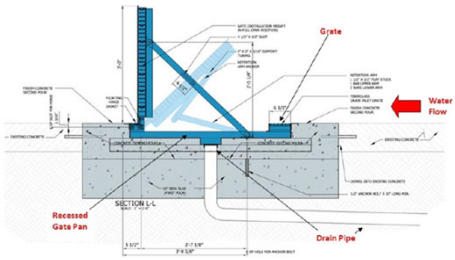

FIGURE 1 | A FloodBreak barrier gate diagram

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PREVENTING SEWER BACKFLOW

Photo: Weston & Sampson

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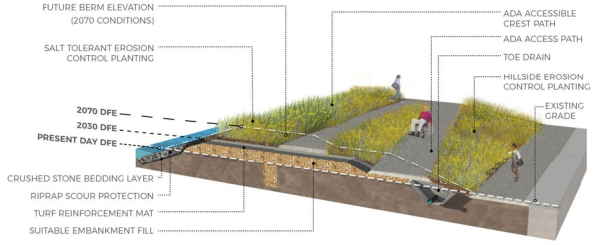
VEGETATED BERM



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MULTI-PURPOSE FLOOD STORAGE

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LOW IMPACT DEVELOPMENT (LID)

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POROUS ASPHALT & PERMEABLE PAVERS

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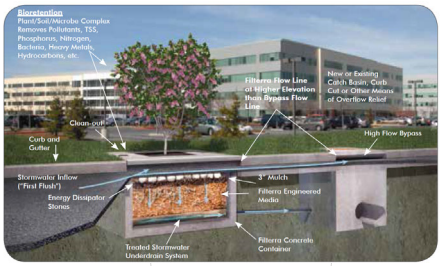
STREET TREES & TREE BOX FILTERS



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STREET TREES & TREE BOX FILTERS

Rain Garden in a median strip of a townhouse project. Please note the depressed curb and grate inlet structure

74

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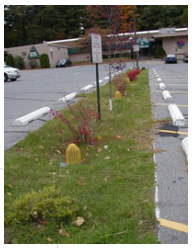
STORMWATER DETENTION & RETENTION



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CULVERT WIDENING TO IMPROVE HABITAT & FLOW

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CLOUDBURST STREETS

77

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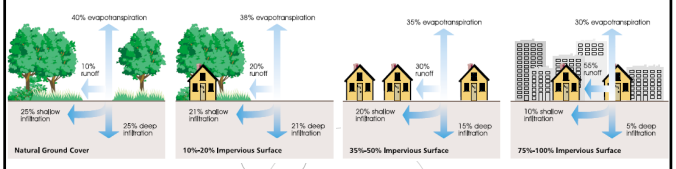
REDUCE IMPERVIOUS AREAS



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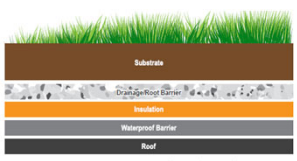
GREEN ROOFS



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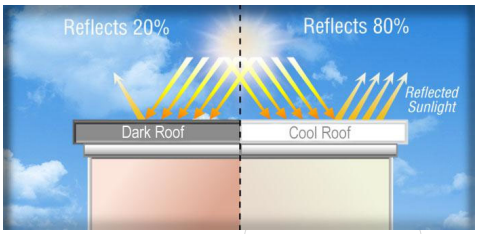
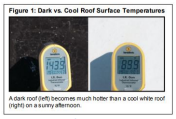
COOL ROOFS



Source: Heat Island Group at Lawrence Berkeley National Laboratory



Source: U.S. Department of Energy Guidelines for Selecting Cool Roofs

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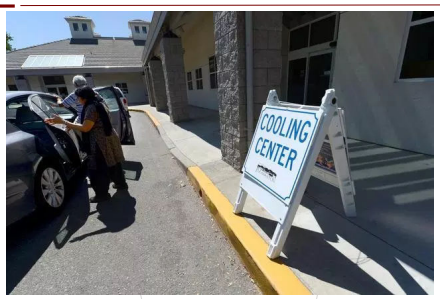
COOLING CENTERS



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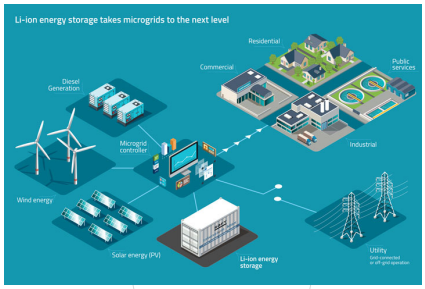
RENEWABLE MICRO-GRIDS



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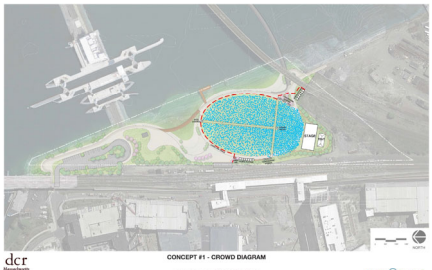
LANDSCAPE DESIGN TO ACCOMMODATE WATER



CONCEPT #1 - CROWD DIAGRAM

DRAW SEVEN PARK

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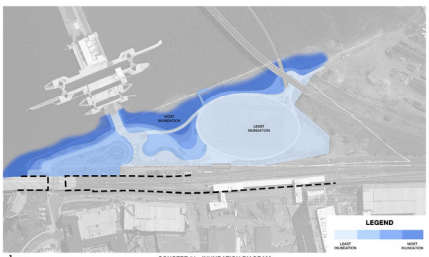
83

LANDSCAPE DESIGN TO ACCOMMODATE WATER



CONCEPT #1 - INUNDATION DIAGRAM

DRAW SEVEN PARK

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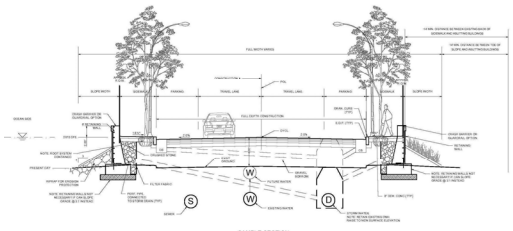
RAISED ROADWAYS



SAMPLE SECTION

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RETROFITTED FLOODPROOF DOORWAYS

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RE-EVALUATE LOCAL REGULATIONS & POLICIES

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15 MINUTE BREAK!

Photo: Howe-Manning Elementary School, CTA Construction Managers

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DEFINE COMMUNITY ACTIONS

Photo: familypedia.wikia.com

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IDENTIFY PRIORITY ACTIONS

Photo: Town of Middleton Police Department. Wickedlocal.com

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WRAP-UP & CLOSING REMARKS

Photo: Middleton Police Department Facebook page.

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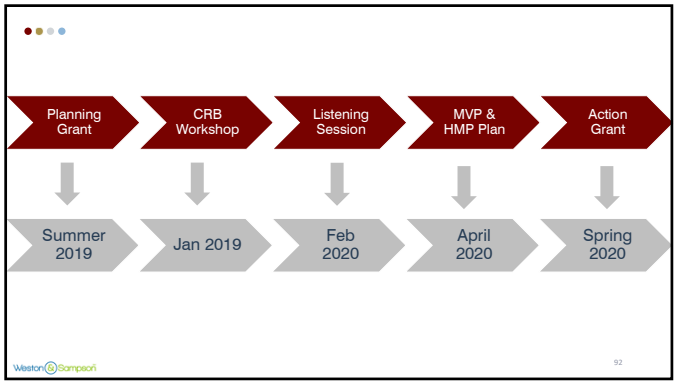
Planning Grant
CRB Workshop
Listening Session
MVP & HMP Plan
Action Grant
Summer 2019
Jan 2019
Feb 2020
April 2020
Spring 2020
Weston & Sampson
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THANK YOU
Weston & Sampson

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Middleton CRB Workshop / January 9, 2020

Attendees: 22 participants, including 3 elected official representatives

What do you like about Middleton?

- Responsive government/staff
- Open space
- Small town/rural feel
- Old historic Middleton
- Safe and friendly
- Richardsons
- Welcoming people
- Open, accessible public trails and bikeways
- School system
- Rivers and tributaries

Top Hazards in Middleton:

- Flooding
- Severe Thunderstorms, Wind, Tornadoes, Hurricanes
- Drought, Extreme Heat, Wildfire
- Nor'easters, Ice storms, snow storms, extreme cold

<u>Features</u>

Infrastructural:

- Infrastructure Priorities (from Amanda's notes):
    - Water storage tank → potable water
    - Campaign on reducing water use and conservation
    - PPW – show displays of best management practices to show residents/new developments
    - Elevate roadways: 62, 114. Raise pipes as well
    - Ipswich River cleanup
        - Stream team does a little, Town could do more
    - Route 62 is narrow and in bad shape. 114. Both are main points out of town and are bridges
- Rail trail may get its own bridge
- Municipal buildings (police/fire, town hall/senior/community) – geothermal
- Water storage – need another tank
- Bridges – 62 & 114 → water main under bridge
- Town is only on septic, no sewer → flooding?
- 114 flooding
- Power Lines
- Dam Removal – what will the impact be?

- Bridge → 114 (south Main Street) Mass DOT. Low area – electric light, man hole, and always has walkers on it
- Mill Street Dam
- Thunder Bridge – need to be able to access high school East Street (Middleton)
- Culverts → just completed study on priority/risk for most of town. There was just a culvert blowout (location?)
- Electric – MELD
- Water Treatment Plant → Middleton and Danvers
- Beverly – Peabody – Andover interconnections for water
- Variance sought after for septic system near well → public health system
- No sewage at all

Societal:

- Jail skews EJ data: is the population data that we are using including the jail
- Reverse 911 – emergency response
- County jail
- DYS – youth/juvenile. 70 residents
- Elderly – not a place to gather – isolation
- Federal housing – seniors
- 1 senior citizens van
- Hogan – in Danvers
- Seniors
    - Mental Health
    - Nursing Homes
    - Rehab after Surgery
- 3 daycares:
    - River
    - Maple x2

Environmental

- Brush fires on north side of town
- Working on rail trail
- Post office doesn't have sidewalk
- Bald Hill: Fire hazard. No maintenance
- Liberty – dangerous on curve
- Rail Trail
- Middleton in Motion
- Parks:
    - East street park at Thunder Bridge on old landfill
- Groundwater: wells
- Sediment and salinity from road runoff and chemistry of water
- Bathing beach: frequently shut for bacteria on Ipswich
- Traffic → air quality

- Large developments:
    - Mill street – many large driveways/impervious surfaces
    - Could implement bylaws on clearing currently predevelopment environment
    - Mass clearing
- *NAME* Creek Condos – success stories → kept natural landscape
- Contamination – water quality including temperature. Ipswich testing and bacteria

Action Items discussed during large and small group conversations:

- Safe streets & green infrastructure downtown
- Solar fields
- Geothermal at new buildings
- Green community – Ipswich and Rowley have worked to become green infrastructure: Middleton can't do this because of the municipal Light?
- Update subdivision regulations, including adding LID
- Solar fields at landfill?
- Update regulations to keep substances (oil, coolant) above a certain elevation
- Automated calls to check in on elderly
- Porous pavement proposal on subdivision roads
- The Town is currently building a new municipal center. There is the possibility to incorporate green infrastructure

Priorities:

- Zoning
- Town hall – basement flooding – some fixes

Community Resilience Building Risk Matrix

www.CommunityResilienceBuilding.org

H-**M**-**L** priority for action over the **S**hort or **L**ong term (and **O**ngoing)
V = Vulnerability **S** = Strength

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Flooding	Severe Thunderstorms, Wind, Tornadoes, Hurricanes	Drought, Extreme Heat, Wildfires	Nor'easters, Ice, Snowstorms, Extreme Cold	Priority H - M - L	Time S Long O ngoing
Infrastructural									
Roads/Drainage	Townwide	Town/State	V	Culvert Improvements Beaver Control Bridges - work with State	New stormwater drainage		Raise Road - School St Drainage Improvement	H	O
Water Supply - Public & Private	Townwide	Town/Private	V	Assess water conservation private wells - regs +repair existing		Well management from private wells - restrictions rain water harvesting	salt - roadway design rt 114 - north main street	H	O
Municipal Light	Townwide	Town	S		vegetation trimming/maintenance		vegetation trimming/maintenance	M	O
Dams - Mill Pond	Site Specific	Private	V	study - feasibility - ownership/maintenance				M	O
Police/Fire Facilities/Town	Townwide	Town	V/S	Emergency power backup - police and fire				H	O
Transportation - Emergencies	Townwide		V	ER Communication Plan - swift 911				H	O
Societal									
Schools: Howe-Manning -> shelter Fuller Meadow	School	Town	V/S	backup power / cooling - Fuller Meadow				H	O
Senior Center/Elderly	Center	Town	V/S	solved by future community center				L	O
Community Center (New)	Route 114	Town	S	incorporate climate resilience into design				H	O
+ 55 housing		Private	V	planning - require backup power				L	L
Transportation - no public	Townwide		V	pre-planning for transportation for seniors (like youth) Design transportation corridor for multi-model Transportation plan partnership with TNCs				H	O
Jail - Essex county facility juvenile facility -DYS		State/DYS	V	Coordination - HMP Issues - water Usage, emergency response				M	O
Environmental									
Ipswich River		State	V/S	manure management/coordination/ AG Explore MassDOT 114 - Salt discharge		Develop regs for new development beaver management implement stormwater MS4 permit organize trail committee		H	O
Conservation / AG Preservation		Town/Private/State	V/S	same as above	conservation land management plan future land use conservation			H	O
Watershed - Reservoir	Middleton/Emerson	Town	V	GW Protection bylaw	Assess Water Quality Threats - Auto Repair/storage			H	O
Groundwater - res wells commercial	Townwide	Private	V	promote water conservation revisit water restriction bylaw				H	O
Water Quality - temperatures, equipment, sediment, salt/chemistry, bacteria	Developments	Private	V	Ipswich WS Protection District Collect/Assess WQ Threats				H	O
Bike Lakes/Sidewalks/Bald Hill - Fire	Townwide	Town	V	Build connectivity - like developing rail trail - land acquisition/partnership east st 3/4 to 1 mile near Ipswich River Easement - could do riverwalk				H	O

Community Resilience Building Risk Matrix

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Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Flooding	Severe Thunder, Wind, Tornadoes, Hurricane	Drought, Extreme Heat, Wildfire	Nor'easter, Ice Storms, Snow, Extreme Cold	Priority H - M - L	Time Short Long Ongoing
Infrastructural									
Development	Townwide	Town/Private	V	Update regulations - add LID, green infrastructure, subdivision regs				H	S/O
New municipal building and existing library	Middleton Golf Course	Town	S	green infrastructure detention basin			geothermal energy	H	S/L
Water Treatment Plant	Lake St	Danvers	V/S	raising roadway leading to plant		backup water sources / additional water storage		H	S/O
Bridges	Route 62, Route 114	State	V	raise bridges, widen abutments	design to withstand hazards			H	S
Culverts/Drainage	Townwide	Town	V	update culverts for greater rainfall public education on catch basin cleaning				M	O
Dams	multiple	multiple	V	Publicize EAP of build town staff knowledge of potential impact Dams info on dam rehab and removal - need to know impact				L	O
Power and Electric (substation, powerlines)/communications	Townwide	Town	V/S		build communication redundancies		update regulations to include solar	H	O
Societal									
Elderly, Children (Vulnerable Populations)	Townwide		V	busses/how to get vulnerable populations to emergency shelters knowing where the elderly are located - education within neighborhoods to check on neighbors				H	O
Essex County Jail		State	V	raise bridge on Route 62		redundancy/protection of pumps		L	S
High rises (businesses and residential)	eastern corner of town	Private	V	raise bridge	backup power for sewer pump?	additional water storage	improve access (raise bridge)	M	S
Residents in north end of town	North		V	subdivision reg updates open space acquisition in north end of Town				H	S/O
Pedestrians and commuters	Townwide		V/S	safe streets and green infrastructure, stormwater management and street trees, rail trail funding				M	L/O
emergency response	Townwide	Town	V/S	raise bridges, widen abutments	communication redundancies	vehicle maintenance		H	O
Environmental									
Green Space at Route 114	114	Town	S	Flood management incorporate LID				H	O
Beavers	multiple		V	beaver management, beaver deceiver				L	O
Ipswich River			V/S	raise roadways, increase culvert size update regulations for a greater buffer. Land acquisition for stormwater retention		public outreach to conserve water & keep river for recreation		H	O
Ponds (Drinking Water)		Danvers, Middleton	V/S			backup water sources and additional water storage, outreach for water conservation, green infrastructure, rain barrels		H	L/O
Open Space/Forest/Trails	Townwide		V/S	open space acquisition in north end of town. Trail system around reservoir.		forest management around reservoir to reduce fire		H	S/O
Air Quality (cars)(pollen)(Fires)	Route 62, Route 114		V			public education and outreach on health impacts		M	O

Community Resilience Building Risk Matrix

www.CommunityResilienceBuilding.org

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

H-**M**-**L** priority for action over the **S**hort or **L**ong term (and **O**ngoing)
V = Vulnerability **S** = Strength

Features	Location	Ownership	V or S	Flooding	Severe Thunderstorms, Wind, Tornadoes, Hurricanes	Drought, Extreme Heat, Wildfires	Ice, Nor'easters, Extreme Cold	Priority H - M - L	Time S Long O
Infrastructural									
Route 114/Streets susceptible to flooding (South Main Street, Ipswich River Crossing, East Street)	South Main Street	MassDOT + Middleton	V	low lying, floods often, flooding businesses, communication and evacuation route street sweeper, raise roadways/add culvert/flood	flash flooding		Nor'easter creates flooding	H	O
Municipal Buildings	Townwide	Middleton	B	basement flooding, flood proofing town hall		install air conditioning shade building		L	S
High Risk Culverts		Town, State, Private	V	study existing, upgrade culverts				H	S
MELD	Townwide	Middleton	S		continue proactive tree trimming/ pole replacement proactive/maintaining independence			L	O
Water Supply/Wastewater	Middleton & neighboring communities		B	affecting septic and rising groundwater table zoning and bylaw review and revisions/agricultural runoff		surface water supply, river over allocated water conservation measures and fixture replacements		water - H wastewater - M	O
Mill pond and South Middleton Dams		Private	V	flooding and overtopping Mill Pond dam = privately owned. Assessment of dam	flash flooding			M	S/O
Societal									
Emergency shelters (currently	2 schools	Middleton	S	study to evaluate pond at park street to use as flood detention	generators exist education and informational response	install dedicated cooling station		M	L
vulnerable populations: Residential homes residential youth services (DVS) disabled home and jail			V		keep open communication	keep open communication		L	L
isolated elderly	Townwide		V		check on communication system (CodeRED)/wellness check calls database of isolated elderly - cooling station			M	O
emergency response	Fire & Police Department	Middleton	S	need additional street sweeper	fire, police, and emergency response facility upgrade	investment in local TV for education		L	L
youth population and day care	Townwide		B	river street - brand new but never a problem protect land adjacent - proper flood storage -		AC required in certain parts of schools, cooling station (gymnasium)		L	O
board of trade/local economy	Townwide		**B**	market basket / 114 / zoning / bylaws preventing future development				L	L
Environmental									
Stream Team			S	increase education programs, outreach programs, recruitment program, internship program, camp program, pike hikes, social media campaign				H	S/O
Open Space and Protected Forest			B	land acquisition and moratorium open land study to prioritize space for		potential brush fire edication campaign		H	O
Water Bodies: ipswich river/emerson pond/middleton brook			B	implement rec. of existing stidies increase edication		implement recs for studies to restore water balance edication water		H	O
Wildlife			B	protecting open space beaver management program and assessment catch basin cleanout program and prevent mosquitos			tick & vector borne disease edication	M	O
Hazardous Waste Management			V	all dumps in floodplain study to evaluate berm solutions				M	L/O

MIDDLETON CRB WORKSHOP ACTION ITEMS

"Highest High" Priorities

A. Roads and Drainage
   - Update culverts for greater rainfall capacity, raise roads (especially School Street) and bridges (Route 62), improve drainage along roadways, and
   - public education on catch basin cleaning.

B. Protect open space by updating bylaws and acquiring land.

C. Protect the water quality of the Ipswich River and tributaries:
   - Add an Ipswich River Watershed Protection District to restrict development surrounding these water bodies;
   - Collect and assess water quality threats, including controlling salt discharge, especially by the DOT
   -
   - Coordinate agricultural and manure management practices to reduce runoff into waterbodies;
   - Implement MS4 stormwater permit.

D. Implement a nature based complete streets plan which includes adding bike lanes and sidewalks to increase safety and connectivity throughout the town. The plan would also provide stormwater detention and treatment, and low impact development would be incorporated wherever possible.

E. Create a Riverwalk from East Street to the Ipswich River Easement and develop the rail trail to increase connectivity through the Town. Develop partnerships and acquire land to comp This would include land acquisitions and partnerships with landowners.

F. Leverage and support the stream team to improve water quality and to keep the rivers and streams clear to reduce flooding and allow for water activities. This can include increasing education programs, outreach programs, recruitment programs ,internship programs, camp programs, pike hikes, and social media campaigns.

G. Add stormwater treatment and geothermal to municipal buildings.

High Priorities

- Promote water conservation through. providing rain barrels for the community and promoting replacing fixtures, shorter showers, watering lawn/garden in morning or evening.
- Repair existing wells that are not in use and look at regulations surrounding wells
- Add additional emergency power backups at Fire and Police Stations
- Implement an ER Communication Plan – swift 911. Build communications redundancies so that these systems have greater reliability.
- Ensure that backup power at schools are sufficient for use as shelters. Add cooling to schools, at minimum in certain parts of school such as the gym
- Incorporate climate resilience into design of the new community center, including green infrastructure, a detention basin, and geothermal energy.
- Develop a transportation plan, which includes adding public transportation to Middleton and designing a transportation corridor for multi-model. There is also the potential for partnership with TNCs.
- Develop a conservation land management plan for future land use

- Create a groundwater protection bylaw
- Assess water quality threats from auto repair facilities and storage
- Update development regulations to include LID, green infrastructure, and additional climate resiliency items to subdivision regulations.
- Update regulations to remove barriers and encourage the installation of solar panels
- Develop a database of elderly or disabled residents
- Identify neighborhood volunteers to support outreach and public safety efforts, such as checking on elderly neighbors
- Acquire land to preserve forested/open space and potentially for flood mitigation.
- Ongoing maintenance of emergency response vehicles
- Increase forest management efforts in the north side of town to reduce brush fire.
- To reduce flooding in low-lying areas, additional street sweeping should be conducted, roads should be raised, culverts added or increased in size, add detention basins and other stormwater treatment such as tree box filters.
- Implement beaver control to reduce flooding.

Medium Priority

- Develop a robust tree management plan to aid Municipal Light in reducing power outages.
- Work with owners of dams that have a hazard rating of moderate or low, which do not currently have an emergency action plan, so that they can develop a plan.
- Coordinate with the Essex County Jail and juvenile facility (DYS) to discuss water usage and emergency response.
- Increase the amount of water storage
- Conduct public education and outreach on the impacts of poor air quality on public health, including from cars, pollen, and fires.
- Install a dedicated cooling station and awareness campaign.
- Evaluate the effectiveness of the existing communications systems, like codeRED and wellness calls, to ensure vulnerable populations are receiving these services
- Educate the public on ticks and other vector-borne diseases and how to reduce exposure.
- Draft a Climate Resiliency Plan
- Evaluate the risk associated with landfills located in the floodplain and identify solutions.

Other Priority

- Require back-up power at new 55+ housing that is in planning
- Add redundancies and protection to pump stations
- Flood proof the Town Hall to reduce flooding in the basement.
- Install air conditioning in public buildings and increase shade around to aid cooling.
- Address septic system failure.
- Purchase an additional street sweeper
- Upgrade the fire/police/emergency response facility
- Invest in a local TV station for outreach and education
- Protect land adjacent to River Street and add proper flood storage

TOWN OF MIDDLETON

Municipal Vulnerability Preparedness Planning Grant Project

Community Resilience Building Workshop

Flint Public Library Conference Room, 1 South Main Street
Thursday, January 9, 2020
9:00 am – 5:00 pm

9:00 am – 9:15 am	Registration and Refreshments
9:15 am – 9:30 am	Welcome and Introductions
9:30 am – 9:45 am	MVP Workshop Purpose and Overview
9:45 am – 10:30 am	Data Resources and Overview of Science
	Risk Matrix
10:30 am – 10:45 am	Large Group Exercise #1 – Identify Top Hazards
10:45 am – 11:00 am	BREAK
11:00 am – 11:20 am	Small Group Exercise #1 – Infrastructure Features
11:20 am – 11:40 am	Small Group Exercise #2 – Societal Features
11:40 am – 12:00 am	Small Group Exercise #3 – Environmental Features
12:00 am – 1:00 pm	Lunch
1:00 pm – 1:30 pm	MVP Community Actions Presentation
1:30 pm – 2:15 pm	Small Group Exercise #4 – Infrastructure Actions
2:15 pm – 3:00 pm	Small Group Exercise #5 – Societal Actions
3:00 pm – 3:30 pm	Small Group Exercise #6 – Environmental Features
3:30 pm – 3:45 pm	BREAK
3:45 pm – 4:45 pm	Large Group Exercise #2 – Prioritization Process
4:45 pm – 5:00 pm	Wrap-up and Closing Remarks

Stakeholders Invited to Attend Middleton's CRB Workshop

	Name	Title	Affiliation
✓	Kristin Kent	Conservation Agent	Town of Middleton
✓	Andrew Sheehan	Town Administrator	Town of Middleton
✓	Katrina O'Leary	Town Planner	Town of Middleton
✓	Ken Gibbons	DPW Superintendent	Town of Middleton
✓	James DiGianvittorio	Police Chief	Middleton Police Department
✓	Thomas J. Martinuk	Fire Chief	Middleton Fire Department
✓	Derek Fullerton	Director of Public Health	Town of Middleton
✓	Jillian Smith	Director of Council on Aging	Town of Middleton
	Scott Fitzpatrick	Building Commissioner	Town of Middleton
		Recreation Department	Town of Middleton
	Tony Bertone	Water Operator	Town of Middleton
	Paul Goodwin	DPW Deputy Superintendent	Town of Middleton
	Tanya Stepasiuk	Assistant Town Administrator	Town of Middleton
	Gary Bent	Director of Veterans Services	Town of Middleton
✓	Melissa Gaspar	Flint Public Library Director	Flint Public Library
✓	Michael Cloutier	Manager	Middleton Electric Light Department
	Tim Houten	Chair	Board of Selectmen
	Kristin Richardson	Chair	School Committee
	Anthony Tierno	Planning Board Chair	Town of Middleton
		Cultural Council Chair	Town of Middleton
✓	Judy Schneider	Cultural Council Co-Chair	Town of Middleton
	Maria Paikos	Chair	Middleton Housing Authority
	Anthony Pesce	Chair	Conservation Commission
	Laurie York	Member	Conservation Commission
✓	Jerry Gove	Member	Conservation Commission
	Paul LeBlanc	Chair	Board of Health
✓	Ray Cryan	Member	Board of Health
	George Demeritt	Member	Board of Health
	Richard Gregorio	Co-Chair	Finance Committee
	John Erickson	Co-Chair	Finance Committee
	Sarah George		Historical Commission
	Hayato Tsiramaki	Chair	Recreation Commission
	Richard Nazzaro	Chair	Zoning Board of Appeals
	Rosemary Turgeon	Development Director	Community Giving Tree
	Dr. David A. Jordan	President	Seven Hills Foundation
	Frank Leary	Board of Director	Middleton Food Pantry
			Camp Creighton
✓	Sandy Rubchinuk	President	Stream Team

✓	Pike Messenger	Member	Stream Team
✓	Wayne Castonguay	Director	Ipswich River Watershed Association
✓	Maggie Brown		Essex County Greenbelt
✓	Maryann Nay for Bruce Tarr	State Senator, 1st District	Massachusetts Senate
	Seth Moulton	Congressman, 6th District	US House of Representatives
✓	Michael Searles for Ted Speliotis	State Representative, 13th Essex District	Massachusetts House of Representatives
✓	Chris Stewart for Bradley Jones, Jr.	State Representative, 13th Essex District	Massachusetts House of Representatives
	Eileen Duff	Governor's Councilor, 5th District	MA Governor's Council
	Martin Pillsbury	Environmental Planning Director	MAPC
	Elise Simons	Environmental Protection Specialist	U.S. Environmental Protection Agency
	Mark Voorhees		U.S. Environmental Protection Agencies
	Eric Worrall	Northeast Regional Director	MA Department of Environmental Protection
	Priscilla Geigis or Dan Driscoll	Deputy Commissioner for Conservation and Resource Stewardship	DCR
	Allison/Chris		State 911
	Jeff Zukowski	Hazard Mitigation Unit Supervisor	MEMA
			National Grid – Natural Gas
	Christine Berry	Land Protection Specialist	Department of Conservation and Recreation
	Michelle Rowden	MVP Northeast Regional Coordinator	MA Executive Office of Energy and Environmental Affairs
	Ross Povenmore	Planning Agent	Town of Boxford
	Chris Olbrot	DPW Superintendent	Town of Boxford
	Martha A. Morrison	Planning Board Chairman	Town of Topsfield
✓	Jason McCarthy	Water Treatment Plant Operator	Town of Danvers
✓	Rich Souza	DPW Operations Director	Town of Danvers
	Robert Labossiere	Director of Department of Public Services	Town of Peabody
	Michael Velez	Water Department	Town of Peabody
	John Tomasz	Director of Public Works	Lynnfield
	Christopher Demin	DPW Operations Manager	Town of North Reading
	John Borgesi	Assistant DPW Director/ Town Engineer	Town of North Andover

✓ indicates invitee also attended the Workshop

APPENDIX D

Listening Session

55 Walkers Brook Drive, Suite 100, Reading, MA 01867
Tel: 978.532.1900

Middleton HMP-MVP Plan

Summary of Public Input

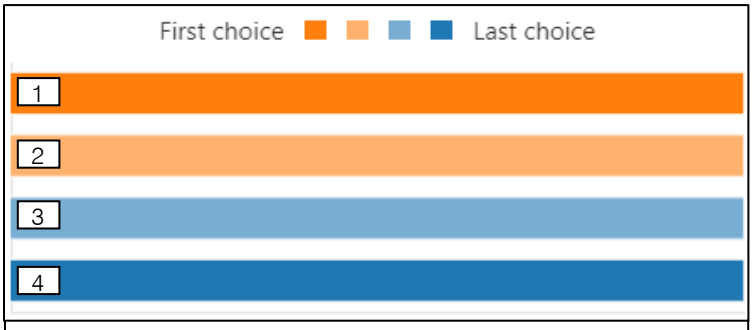
Introduction

The Town of Middleton was awarded a Municipal Vulnerability Preparedness (MVP) Planning Grant to improve the Town's resilience to climate change and to mitigate natural hazards. The MVP Program aims to provide technical and financial support for cities and towns across the Commonwealth to plan for, and mitigate the impacts from, climate change. As part of the virtual Public Listening Session and public comment period, the project team shared a survey to collect feedback related to climate hazards, strengths, vulnerabilities, and priority adaptation action items. Key information related to the results of this survey are summarized below:

- The survey was accessible on the Microsoft Forms website from May 8-May 29, 2020 with a video summary of the report and copy of the draft report.
- A link to the online survey was shared with the list of the stakeholders and was also available on Town's website. The Town also shared a post about the survey on their Social Media page.
- The project team received three online responses.

The following summary provides an overview of the survey responses, along with key findings and recommendations for using this information. A spreadsheet of short-answer responses from survey participants, along with a copy of the original survey, are included as attachments to this document.

Survey Results

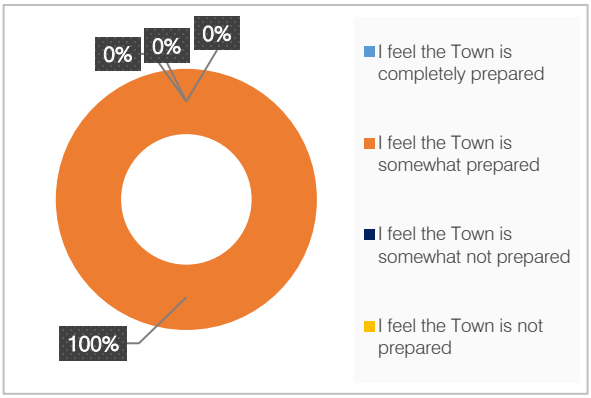


1. Ice, Nor'easters, and Extreme Cold
2. Drought, Extreme Heat, and Wildfires
3. Severe Thunderstorms, Wind, Tornadoes, and Hurricanes
4. Flooding

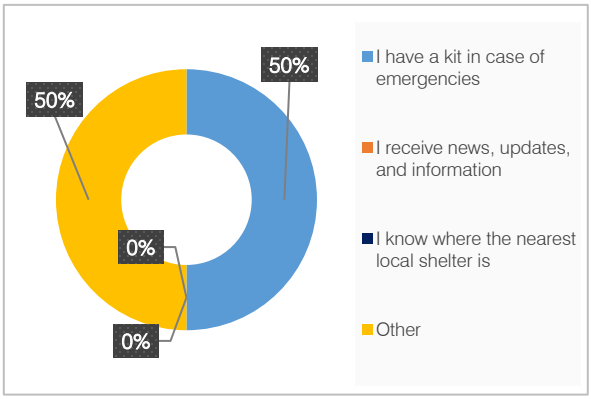
What hazard most concerns you?

- Survey results suggest that Ice, Nor'easters, and Extreme Cold are the hazards of most concern.
- After Nor'easters and Extreme Cold, residents were more concern about Drought, Extreme Heat, and Wildfires than Severe Thunderstorms, Wind, Tornadoes, and Hurricanes.
- Flooding was the least concern out of the four options.

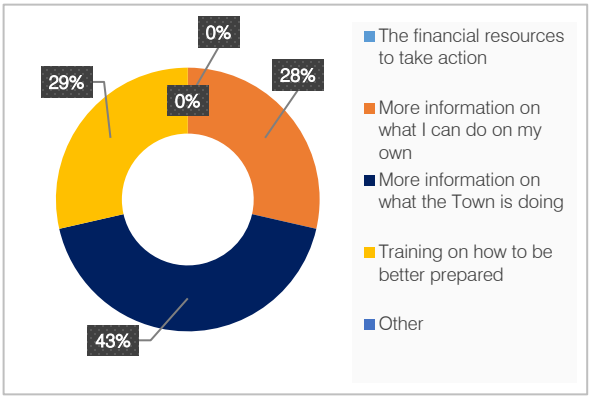
How prepared do you feel the Town is for future extreme events?



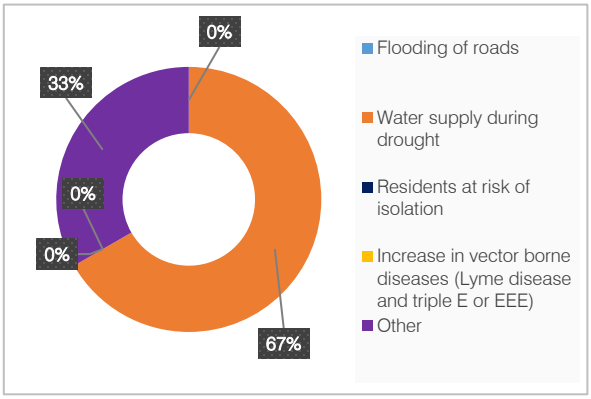
What steps have you already taken to prepare for extreme events?



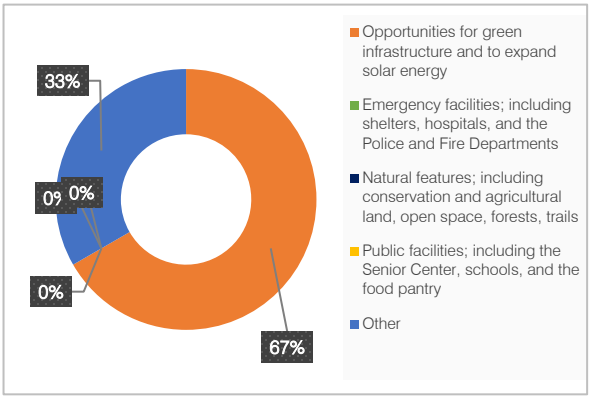
What resources do you need to feel more prepared?



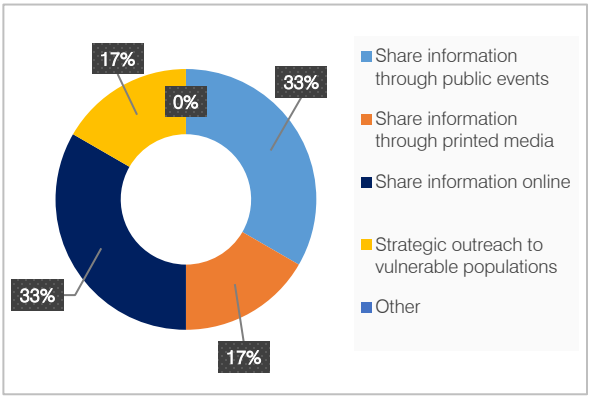
What would you consider one of Middleton's greatest vulnerabilities?



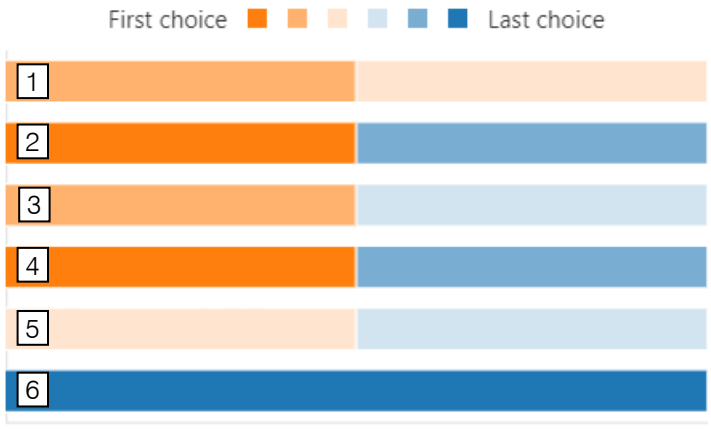
What would you consider as one Middleton's greatest strengths?



How can the Town improve its public education and outreach to better share information about existing resiliency projects and actions?



Please rank the following action items from highest to lowest priority.



1. Upgrade culverts for greater rainfall capacity.
2. Raise roads (especially School Street) and bridges (Route 62).
3. Create a Riverwalk from East Street to the Ipswich River Easement and develop the rail trail to increase connectivity through
4. Update development regulations to include LID, green infrastructure, and additional climate resiliency items to subdivision regulations.
5. Identify neighborhood volunteers to support outreach and public safety efforts, such as checking on elderly neighbors
6. Upgrade the fire/police/emergency response facility.

Based on responses on prioritizing actions, raising roads (especially School Street) and bridges (Route 62), and updating development regulations to include LID, green infrastructure, and additional climate resiliency items to subdivision regulations appear to be the top two priority actions whereas upgrading the fire/police/emergency response facility got the lowest vote.

Summary of short-answer responses:

What memories of climate hazards do you have? These could include impacts from:

- Recent heatwaves
- Four Nor'easters in four weeks in March 2018
- Drought in 2016
- Extreme winds or microbursts

Winter events are the most memorable climate hazard according to the survey responses (2 out of 3). Nor'easters (1969, 1978, 2018), 2008 ice storms, Drought, Gypsy Moths, 2005 flood, and recent heatwaves are mentioned as some of the memorable hazards.

Please explain your reason for selecting your answer in Question 3 (How prepared do you feel the Town is for future extreme events?).

While one of the respondents said that the Town might be prepared, the other two mentioned that the Town has more to do in order to be prepared for future extreme events and that the larger and more persistent threats need to be planned, rehearsed, and exercised.

Are there any other comments or questions that you would like to share with the project team?

As additional comment one of the surveyors has emphasized the fact that people need to have access to information, and it is important to build their trust.

Key Findings & Next Steps

As the pie charts and bar graphs indicate, Nor'easters and extreme cold, along with extreme heat and drought are the main concerns for residents. The responses suggest a need for raising roads at some places and more green infrastructure projects, along with a more efficient emergency communication system.

The project team should use the findings of this survey to:

- Pursue funding for climate adaptation projects related to flooding and green infrastructure.
- Share more information with the public related to areas and infrastructure in Town vulnerable to climate hazards, as well as more information on evacuation routes and shelters.
- Share more information with the Town residents, through public events and through the Town's website and social media platforms.

Attachments

- Attachment A: Short Answer Responses
- Attachment B: Middleton Community Feedback Survey

TOWN OF MIDDLETON SHORT ANSWER RESPONSES		
What memories of climate hazards do you have? These could include impacts from: - Recent heatwaves - Four Nor'easters in four weeks in March 2018 - Drought in 2016 - Extreme winds or microbursts	**Please explain your reason for selecting your answer in Question 3.**	**Are there any other comments or questions that you would like to share with the project team?**
Actually the 2008 December Ice storm is the one I have in memory many times. I had only lived in town 4 years and was concerned about power. Thankfully MELD is great.	I think there is all kinds of issues that can occur based on the PDF/video. Seems the FD can do initial response to emergencies, but the larger and more persistent threats appear not planed, rehearsed or exercised. Eg. what happens if	This seems like a great and timely project to do in this Pandemic time.
Nor-easters (1969, 1978, 2018), Drought, Gypsy Moths, Mother's Day Floor 2005	I haven't heard of any specific plans, but I assume they are prepared	
recent heatwaves	I feel the town has more it can do.	inform people as much as possible. tell the truth we need their trust

Middleton Hazard Mitigation and Municipal Vulnerability Preparedness Survey

The Town of Middleton is seeking community input as part of their hazard mitigation and climate adaptation planning process. This survey captures public feedback related to the Town's draft MVP-HMP report and summary webinar, available at the links below. The survey will be open until May 22nd.

Report: https://tinyurl.com/MiddletonHMP-MVP
Video: https://tinyurl.com/MiddletonVideoMVP

If you have additional questions or barriers to participating, please contact Kristin Kent, Middleton Conservation Agent at kristin.kent@middletonma.gov or (978) 777-1869.

Questions from the survey

1. What hazard most concerns you?

- Drought, Extreme Heat, and Wildfires
- Ice, Nor'easters, and Extreme Cold
- Severe Thunderstorms, Wind, Tornadoes, and Hurricanes
- Flooding

2.What memories of climate hazards do you have? These could include impacts from: - Recent heatwaves - Four Nor'easters in four weeks in March 2018 - Drought in 2016 - Extreme winds or microbursts

3.How prepared do you feel the Town is for future extreme events?

- ○ I feel the Town is completely prepared
- ○ I feel the Town is somewhat prepared
- ○ I feel the Town is somewhat not prepared
- ○ I feel the Town is not prepared

4.Please explain your reason for selecting your answer in Question 3.

5.What steps have you already taken to prepare for extreme events?

- [ ] I have a kit in case of emergencies (which may include food, water, flashlights, batteries, and other supplies)
- [ ] I receive news, updates, and information about emergency preparedness in Middleton
- [ ] I know where the nearest local shelter is
- [ ]

6.What resources do you need to feel more prepared?

- [ ] The financial resources to take action
- [ ] More information on what I can do on my own
- [ ] More information on what the Town is doing
- [ ] Training on how to be better prepared
- [ ]

7.What would you consider one of Middleton's greatest vulnerabilities?

- ○ Flooding of roads
- ○ Water supply during drought
- ○ Residents at risk of isolation
- ○ Increase in vector borne diseases (Lyme disease and triple E or EEE)
- ○

8.What would you consider as one Middleton’s greatest strengths?

- ○ Opportunities for green infrastructure and to expand solar energy
- ○ Emergency facilities; including shelters, hospitals, and the Police and Fire Departments
- ○ Natural features; including conservation land, agricultural land, open space, forests, and trails
- ○ Public facilities; including the Senior Center, schools, and the food pantry

9.Please rank the following action items from highest to lowest priority.

- Upgrade culverts for greater rainfall capacity.
- Raise roads (especially School Street) and bridges (Route 62).
- Create a Riverwalk from East Street to the Ipswich River Easement and develop the rail trail to increase connectivity through
- Update development regulations to include LID, green infrastructure, and additional climate resiliency items to subdivision regulations.
- Identify neighborhood volunteers to support outreach and public safety efforts, such as checking on elderly neighbors
- Upgrade the fire/police/emergency response facility.

10.How can the Town improve its public education and outreach to better share information about existing resiliency projects and actions?

☐ Share information through public events, including virtual webinars

☐ Share information through printed media; including reports, fact sheets, or brochures

☐ Share information online, including through the Town of Middleton website, Twitter, and Facebook pages

☐ Strategic outreach to vulnerable populations, such as elderly residents or other groups

☐

11.Are there any other comments or questions that you would like to share with the project team?

12.If you are interested in receiving additional updates related to climate initiatives in Middleton, please enter your email below.

APPENDIX E

Town Approval

CERTIFICATE OF ADOPTION

BOARD OF SELECTMEN

TOWN OF MIDDLETON, MASSACHUSETTS

A RESOLUTION ADOPTING THE
TOWN OF MIDDLETON
HAZARD MITIGATION PLAN - MUNICIPAL VULNERABILITY PREPAREDNESS PLAN 2020

WHEREAS, the Town of Middleton established a Core Team to prepare the *Town of Middleton Hazard Mitigation Plan - Municipal Vulnerability Preparedness Plan 2020*; and

WHEREAS, the *Town of Middleton Hazard Mitigation Plan- Municipal Vulnerability Preparedness Plan 2020* contains several potential future projects to mitigate potential impacts from natural hazards as well as climate change in the Town of Middleton, and

WHEREAS, the public was engaged through a meeting that was held by the local Conservation Department in coordination with the Master Planning Committee on January 9, 2020, and

WHEREAS, the Town of Middleton authorizes responsible departments and/or agencies to execute their responsibilities demonstrated in the plan, and

NOW, THEREFORE BE IT RESOLVED that the Town of Middleton Board of Selectmen adopts the *Town of Middleton Hazard Mitigation Plan- Municipal Vulnerability Preparedness Plan 2020,* in accordance with M.G.L. 40 §4 or the charter and bylaws of the Town of Middleton.

ADOPTED AND SIGNED May 4, 2021.

Richard Kassiotis, Chair

Timothy Houten, Clerk

Kosta Prentakis, Member

Brian Cresta, Member

Jeff Garber Member

APPENDIX F

FEMA Approval

U.S. Department of Homeland Security
FEMA Region I
99 High Street, Sixth Floor
Boston, MA 02110-2132

FEMA

July 1, 2021

Samantha C. Phillips, Director
Massachusetts Emergency Management Agency
400 Worcester Road
Framingham, Massachusetts 01702-5399

Dear Director Phillips:

The U.S. Department of Homeland Security, Federal Emergency Management Agency (FEMA) Region I Mitigation Division has approved the Town of Middleton 2020 Hazard Mitigation and Municipal Vulnerability Preparedness Plan effective **June 29, 2021** through **June 28, 2026** in accordance with the planning requirements of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), as amended, the National Flood Insurance Act of 1968, as amended, and Title 44 Code of Federal Regulations (CFR) Part 201.

With this plan approval, the jurisdiction is eligible to apply to the Massachusetts Emergency Management Agency for mitigation grants administered by FEMA. Requests for funding will be evaluated according to the eligibility requirements identified for each of these programs. A specific mitigation activity or project identified in this community's plan may not meet the eligibility requirements for FEMA funding; even eligible mitigation activities or projects are not automatically approved.

The plan must be updated and resubmitted to the FEMA Region I Mitigation Division for approval every five years to remain eligible for FEMA mitigation grant funding.

Thank you for your continued commitment and dedication to risk reduction demonstrated by preparing and adopting a strategy for reducing future disaster losses. Should you have any questions, please contact Brigitte Ndikum-Nyada at (617) 378-7951 or brigitte.ndikum-nyada@fema.dhs.gov.

Sincerely,

PAUL F FORD Digitally signed by PAUL F FORD
Date: 2021.07.01 13:23:09 -04'00'

Paul F. Ford
Acting Regional Administrator
DHS, FEMA Region I

PFF:bnn

cc: Jeffrey Zukowski, Hazard Mitigation Planner, MEMA
Marybeth Groff, CFM, Hazard Mitigation & Climate Adaptation Coordinator
Beth Dubrawski, Hazard Mitigation Contract Specialist, MEMA