TOWN OF AVON
INCORPORATED FEB. 21, 1888

TOWN OF
AVON
MASSACHUSETTS

Hazard Mitigation Plan and Municipal Vulnerability Report

(FINAL DRAFT)

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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. Amongst the communities of Norfolk County, hazard mitigation planning tends to focus on flooding, the most likely natural hazard to impact these communities. The Federal Disaster Mitigation Act of 2000 requires all municipalities to adopt a local multi-hazard mitigation plan (HMP) and update their plan every five years in order to be eligible for FEMA funding for hazard mitigation grants.

The Massachusetts Executive Office of Energy and Environmental Affairs, Municipal Vulnerability Preparedness (MVP) grant program helps communities plan and take action towards becoming more resilient to the impacts of climate change. The program provides MVP Planning Grants to assist municipalities in preparing for the impacts of climate change through participation in a community climate vulnerability workshop and development of a climate change action plan and MVP Action Grants to fund the implementation of priority climate change adaptation actions.

This plan provides for both a hazard mitigation planning approach, as well as incorporating MVP provisions for the Town of Avon that are related to increasing resiliency associated with climate change impacts. This provides the Town with a holistic assessment and implementation plan for both hazard mitigation and climate change resiliency.

Planning Process

Planning for the Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HMP-MVP Plan) was led by Avon's Municipal Vulnerability Preparedness/Hazard Mitigation Core Committee ("Core Committee"). This Core Committee was composed of staff from a number of different town departments. The Core Committee met on January 10, 2020, and a Municipal Vulnerability Preparedness Workshop was held on September 21, 2020. During these meetings, the group planned for the Workshop reviewed public comments, discussed where the impacts of natural hazards most affect the Town, the goals for addressing these impacts, developed the mitigation plan, and transitioned to implementation of the plan's mitigation strategies

The town's Core Committee held one public meetings on April 14, 2021. Additionally, the draft plan was posted on the Town's website for public review. Key town stakeholders and neighboring communities were notified of the public meetings and invited to submit comments.

Risk Assessment

The Avon HMP-MVP Plan assesses the potential impacts to the Town from a variety of natural disasters including flooding, high winds, winter storms, brush fire, geologic hazards, extreme temperatures, and drought. These are shown in the map series located in Appendix B.

Avon's Core Committee identified 42 Critical Facilities. These are also shown in the map series and listed in Table 2-6, identifying which facilities are located within the mapped hazard zones.

Hazard Mitigation Goals

The town's Core Committee reviewed and discussed the set of goals for the Town. The committee endorsed a total of seven goals. Many of these were similar to those included in the Old Colony Regional Hazard Mitigation Plan, with the addition of a new goal addressing climate change. These goals are presented in Section 5.

Hazard Mitigation Strategy

The Core Committee identified and discussed a number of mitigation measures that would serve to reduce the Town's vulnerability to natural hazard events. Overall, the hazard mitigation strategy recognizes that mitigating hazards for Avon will be an ongoing process as our understanding of natural hazards and the steps that can be taken to mitigate their damages change over time. Climate change and a variety of other factors impact the Town's vulnerability. In the future, local officials will need to work together across municipal lines, and with state and federal agencies, to understand and address these changes. The hazard mitigation strategy will be incorporated into the Town's other related plans and policies. This will ensure that all areas of planning and development within the Town will recognize and incorporate hazard mitigation measures.

Plan Development Process

In 2015, Avon adopted the Old Colony Regional Hazard Mitigation Plan. This plan provided hazard mitigation guidance for fifteen communities within the Old Colony region. This plan provides a starting point with respect to considering hazards, vulnerabilities, and mitigation strategies that were under consideration at that time.

Moving forward into the next five-year plan implementation period there will be many more opportunities to incorporate hazard mitigation into the Town's decision-making processes.

Using the 2015 regional plan, the Town will document actions taken, challenges met, and mitigation actions successfully adopted within this iteration of the HMP-MVP Plan. This will serve as part of the ongoing plan maintenance to be conducted by the Core Committee, as described in Section 8 Plan Adoption and Maintenance.

1.0 INTRODUCTION

1.1 What is a Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan?

Hazard mitigation is the effort to reduce the loss of life and property by lessening the impact of disasters. Mitigation is the phase of emergency management that is dedicated to breaking the cycle of damage, reconstruction and repeated damage through action and long-term strategies. These actions and long-term strategies can include planning, policy changes, education programs, infrastructure projects, and other activities. The Federal Emergency Management Agency (FEMA) currently has three mitigation grant programs: the Hazard Mitigation Grant Program (HGMP) (https://www.fema.gov/hazard-mitigation-grant-program), the Pre-Disaster Mitigation (PDM) program (https://www.fema.gov/pre-disaster-mitigation-grant-program), and the Flood Mitigation Assistance (FMA) program (https://www.fema.gov/flood-mitigation-assistance-grant-program).

Developing hazard mitigation plans enables state, tribal, and local governments to:

- Increase education and awareness around threats, hazards, and vulnerabilities;
- Build partnerships for risk reduction involving government, organizations, businesses, and the public;
- Identify long-term, broadly supported strategies for risk reduction;
- Align risk reduction with other state, tribal, or community objectives;
- Identify implementation approaches that focus resources on the greatest risks and vulnerabilities; and
- Communicate priorities to potential sources of funding.

Hazard Mitigation Measures can be categorized by their different approaches to mitigating hazards. These approaches vary in terms of the types of actions taken and how those actions are administered at the local level. Measures are generally sorted into the following groups (Source: FEMA Local Multi-Hazard Mitigation Planning Guidance):

- *Prevention:* Government administrative or regulatory actions or processes that influence the way land and buildings are developed and built. These actions also include public activities to reduce hazard losses. Examples include planning and zoning, building codes, capital improvement programs, open space preservation, and stormwater management regulations.
- *Property Protection:* Actions that involve the modification of existing buildings or infrastructure to protect them from a hazard or removal from the hazard area. Examples include acquisition, elevation, relocation, structural retrofits, flood proofing, storm shutters, and shatter-resistant glass.
- *Public Education & Awareness:* Actions to inform and educate citizens, elected officials, and property owners about the potential risks from hazards and potential ways to mitigate them. Such actions include outreach projects, real estate disclosure, hazard information centers, and school-age and adult education programs.
- *Natural Resource Protection:* Actions that, in addition to minimizing hazard losses also preserve or restore the functions of natural systems. These actions include sediment and erosion control, stream corridor restoration, watershed management, forest and vegetation management, and wetland restoration and preservation.

- *Structural Projects:* Actions that involve the construction of structures to reduce the impact of a hazard. Such structures include stormwater controls (e.g., culverts), floodwalls, seawalls, retaining walls, and safe rooms.
- *Emergency Services Protection:* Actions that will protect emergency services before, during, and immediately after an occurrence. Examples of these actions include protection of warning system capability, protection of critical facilities, and protection of emergency response infrastructure.

Hazard mitigation planning uses a stepped process that includes an assessment of hazards, vulnerabilities and risks and the development of the policies, tools, and actions to mitigate those risks. This is accomplished through the participation of a wide range of stakeholders and the public, resulting in a plan for the community that will outline practical approaches to reduce long-term risks from natural hazards and disasters. Hazard mitigation is most effective when it is based on a comprehensive, long-term plan that is developed before a disaster occurs.

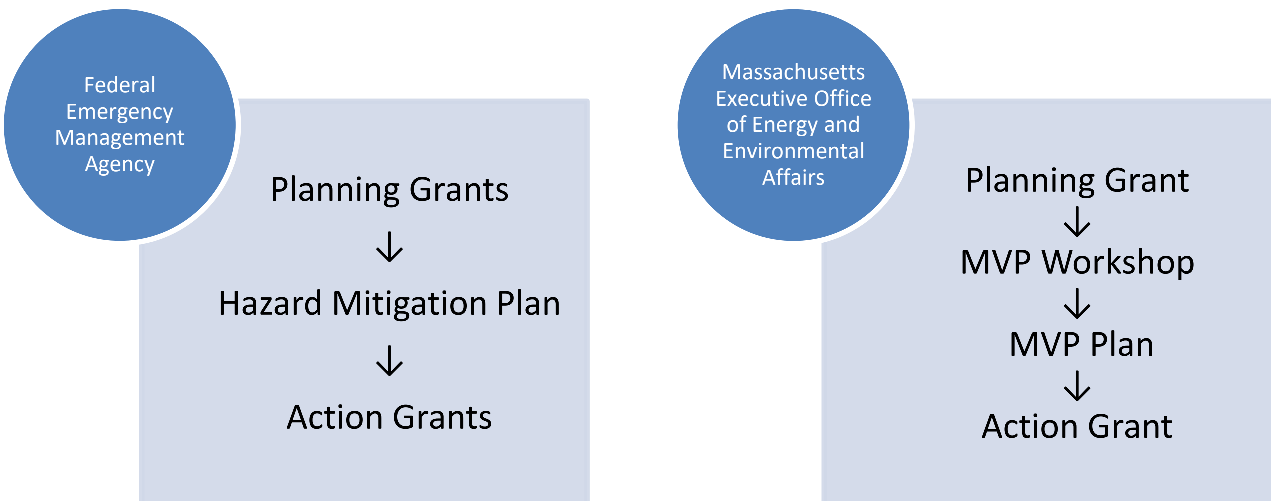
According to the Federal Emergency Management Agency (FEMA), the purpose of mitigation planning is to identify local policies and actions that can be implemented over the long-term to reduce risk and future losses from hazards. These mitigation policies and actions are identified based on an assessment of hazards, vulnerabilities, and risks. Stakeholders and the public are an integral part of the planning process. Benefits of mitigation planning include:

- Identifying actions for risk reduction that are agreed upon by stakeholders and the public.
- Focusing resources on the greatest risks and vulnerabilities.
- Building partnerships by involving citizens, organizations, and businesses.
- Increasing education and awareness of threats and hazards, as well as their risks.
- Communicating priorities to State and Federal officials.
- Aligning risk reduction with other community objectives.

Section 322 of the Federal Disaster Mitigation Act ("The Act") specifically addresses mitigation planning and requires state and local governments to prepare multi-hazard mitigation plans as a precondition for receiving FEMA mitigation project grants. The regulations set forth the basic criteria necessary for a state or local government to meet the mitigation plan requirement. The standard mitigation plan must include the following components:

- Description of the planning process.
- Risk assessment of natural hazards.
- Mitigation strategy.
- Process for coordination of local mitigation planning.
- Plan maintenance process.
- Plan adoption process; and.
- Compliance assurances.

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 plan and become more resilient to the impacts of climate change. The program provides Planning Grants to assist municipalities in preparing for the impacts of climate change through participation in a community climate vulnerability workshop and development of a climate change action plan. Communities that complete the planning grant program receive a designation of “Certified MVP Community”. This designation provides the community with an increased standing in other state grant programs, as well as eligibility for MVP Action Grants. MVP Action Grants fund the implementation of priority climate change adaptation actions that have been described in the municipality’s MVP plan. The Town of Avon 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 to follow the Community Resilience Building (CRB) Workshop Guidance, developed by The Nature Conservancy. This enabled Avon 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 (2018).



1.2 Previous Federal/State Disasters

Federal hazard mitigation assistance and well as statewide hazard mitigation assistance provides funding for both structural and non-structural activities. This could include physical changes to a facility or development of standards, as well as community planning initiatives such as developing land-use zoning plans. By participating in hazard mitigation initiatives, a community could minimize damages from a disaster, potentially saving lives, property, and money. To understand the importance of hazard mitigation, it is useful to know the types and frequencies of disasters that occur in Massachusetts. Since 1991, there have been 22 storms in Massachusetts that resulted in Federal or State Disaster Declarations. Seventeen of those disaster declarations occurred in Norfolk county, of which the Town of Avon is included. Many of these storms caused severe flooding. These disasters and the related assistance from FEMA are described in Table 1-1, and the disasters that affected Norfolk County are shown as bold, italicized font.

Table 1-1. Previous Federal/State Disaster Declarations

Disaster Name (Date of Event)	Disaster Number	Type of Assistance	Areas Under Declaration
Hurricane Bob August 19, 1991	*DR-914*	*FEMA Hazard Mitigation Grant Program*	*Counties of Barnstable, Bristol, Dukes, Essex, Hampden, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk*
Severe Coastal Storm October 30-November 2, 1991	*DR-920*	*FEMA Hazard Mitigation Grant Program*	*Counties of Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk*
Winter Coastal Storm December 11-13, 1992	DR-975	FEMA Hazard Mitigation Grant Program	Counties of Barnstable, Dukes, Essex, Plymouth, Suffolk
Blizzard January 7-13, 1996	*DR-1090*	*No funding reported*	*All 14 Massachusetts Counties*
Severe Storms/Flooding October 20-25, 1996	*DR-1142*	*FEMA Hazard Mitigation Grant Program*	*Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk*
Heavy Rain and Flooding June 13-July 6, 1998	*DR-1224*	*FEMA Hazard Mitigation Grant Program*	*Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester*
Severe Storms & Flooding March 5-April 16, 2001	*DR-1364*	*FEMA Hazard Mitigation Grant Program*	*Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester*
Flooding April 1-30, 2004	*DR-1512*	*FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program*	*Essex, Middlesex, Norfolk, Suffolk, Worcester*
Severe Storms and Flooding October 7-16, 2005	*DR-1614*	*FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program*	*All 14 Massachusetts Counties*
Severe Storms and Flooding May 12-23, 2006	DR-1642	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Middlesex, Essex, Suffolk
Severe Storms and Inland and Coastal Flooding April 15-25, 2007	DR-1701	FEMA Public Assistance; FEMA	Berkshire, Franklin, Hampshire, Hampden, Essex, Plymouth, Barnstable, Dukes

Table 1-1. Previous Federal/State Disaster Declarations

Disaster Name (Date of Event)	Disaster Number	Type of Assistance	Areas Under Declaration
		Hazard Mitigation Grant Program	
Severe Winter Storm and Flooding December 11-18, 2008	*DR-1813*	*FEMA Public Assistance; FEMA Hazard Mitigation Grant Program*	*All 14 Massachusetts Counties*
Severe Storm and Flooding March 12-April 26, 2010	*DR-1895*	*FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program*	*Bristol, Essex, Middlesex, Suffolk, Norfolk, Plymouth, Worcester*
Severe Winter Storm and Snowstorm January 11-12, 2011	*DR-1959*	*FEMA Public Assistance; FEMA Hazard Mitigation Grant Program*	*Berkshire, Essex, Hampden, Hampshire, Middlesex, Norfolk, Suffolk*
Severe Storms and Tornadoes June 1, 2011	DR-1994	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Hampden, Sturbridge, Southbridge, Worcester
Tropical Storm Irene August 27-29, 2011	*DR-4028*	*FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program*	*Barnstable, Berkshire, Bristol, Dukes, Franklin, Hampden, Hampshire, Norfolk, Plymouth*
Severe Storm and Snowstorm October 29-30, 2011	DR-4051	FEMA Public Assistance; FEMA Public Assistance Snow Removal; FEMA Hazard Mitigation Grant Program	Berkshire, Franklin, Hampden, Hampshire, Middlesex, Worcester
Hurricane Sandy October 27-November 8, 2012	DR-4097	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	Barnstable, Bristol, Dukes, Nantucket, Plymouth, Suffolk

Table 1-1. Previous Federal/State Disaster Declarations

Disaster Name (Date of Event)	Disaster Number	Type of Assistance	Areas Under Declaration
Severe Winter Storm, Snowstorm, and Flooding February 8-9, 2013	*DR-4110*	*FEMA Public Assistance; FEMA Hazard Mitigation Grant Program*	*All 14 Massachusetts Counties*
Severe Winter Storm, Snowstorm, and Flooding January 26-28, 2015	*DR-4214*	*FEMA Public Assistance; FEMA Hazard Mitigation Grant Program*	*Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester*
Severe Winter Storm and Flooding March 2-3, 2018	*DR-4372*	*FEMA Public Assistance; FEMA Hazard Mitigation Grant Program*	*Essex, Suffolk, Norfolk, Bristol, Plymouth, Barnstable, Nantucket*
Severe Winter Storm and Snowstorm March 13-14, 2018	*DR-4379*	*FEMA Public Assistance; FEMA Hazard Mitigation Grant Program*	*Essex, Middlesex, Norfolk, Suffolk, Worcester*

Source: MEMA 2019; FEMA 2018b; EEA and EOPSS 2018, 6-24 and Appendix B

1.3 FEMA Funded Mitigation Projects

Avon participates in the National Flood Insurance Program (NFIP) (FEMA, 2018f). 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. NFIP offers flood insurance to communities that comply with the minimum standards for floodplain management.

NFIP uses a 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. Avon is not currently eligible to participate in the CRS Program.

2.0 COMMUNITY PROFILE, LAND USE AND DEVELOPMENT TRENDS

2.1 Community Profile

The Town of Avon was originally settled in 1700 and incorporated in 1888. The town has a total land area of 4.54 square miles (U.S. Census Bureau 2010). Avon has both the smallest land area and population of any community in the region. It has a compact density of over 1,000 persons per square mile and is a town of predominantly residential housing. The town has preserved its quiet, tranquil, suburban character, while maintaining its place as part of a metropolitan community with great advantages in terms of accessibility to cultural, educational and recreational resources.

To complement this handsome backdrop, the community is singularly fortunate to have been blessed with an active, involved citizenry, whose major goal has always been to protect what is precious from the past, while continuing to plan for future generations. Avon is justly proud of its historic past; its present responsible and responsive local government; a wealth of dedicated and able volunteers; as well as many parks, playgrounds and recreational lands; and its excellent school system. The town maintains a website at http://www.avon-ma.gov.

The town is governed by a Board of Selectman and a Town Administrator. The town operates under the open town meeting format. In 2017, the population was 4,468 people (U.S. Census Bureau 2017). Demographic characteristics in Avon that should be taken into consideration when planning for natural hazards are summarized in Table 2-1.

Table 2-1. Avon Demographic Characteristics

4,468	Total Population
3.6%	Under Age 5
16.9%	Under Age 18
16.0%	Over Age 65
8.5%	Individuals Living Below the Poverty Level
1,766	Number of Housing Units
89.1%	Own Home
10.9%	Renters
2,510	Labor Force
2.8%	Unemployment Rate
36.3%	Employed in Top Employment Industry (Management, business, science, and arts)

Source: U.S. Census Bureau 2017

The Town of Avon has several unique characteristics to keep in mind while planning for natural hazards:

- It is only 4.54 square miles in size (U.S. Census Bureau 2017).
- It is home to the Brockton Reservoir and a large portion of Waldo Lake.
- Route 24 runs through the Town on its western edge.
- It has a population density of 990 people per square mile (U.S. Census Bureau 2017).

2.2 Economic Assets and Infrastructure

An important component of the hazard identification and mitigation process is understanding the way that people travel and reside throughout the Town, and the relationship with the surrounding cities and towns. As discussed in Section 4 of this Plan, certain areas of Avon may be more vulnerable to hazards than other areas of the Town. One must take into account whether these areas are highly populated, or whether there is a large commuter population that may need access to a specific road or train station within or near Avon either to enter or exit the Town.

As a 4.5 square mile suburb of Boston, Avon sees its fair share of commuters. Avon is 17 miles south of Boston, 27 miles northeast of Providence, and 211 miles from New York City. The Town of Avon is a historic Massachusetts town located in Norfolk County region of Massachusetts, bordered by Brockton on the south, Stoughton on the west, Randolph on the north, Holbrook on the east. Avon is considered to be a prestigious community located along Route 24. The combination of good highway access and a positive attitude toward economic growth and development in the community has enabled the Town to develop as a major employment center in the South Shore area. Avon is served by the Brockton Area Transit Authority and the Massachusetts Bay Transportation Authority (MBTA), which provide public transit services to Brockton and Boston.

Avon's municipal drinking water supply is drawn from seven wells within the Town. The wells are protected by Zone II wellhead protection areas and by Avon's Water Supply Protection District. Almost all of the Town's wastewater is handled by onsite wastewater systems, except for a small commercial area on Memorial Drive (Route 28) near the Brockton city line, which is connected to Brockton's municipal wastewater system. The combination of small size with a limited amount of land available to develop and a lack of municipal sewer service has kept Avon's population stagnant in recent years.

The town is home to two of the region's largest commercial and industrial parks. Taking advantage of its close proximity to Route 24, the Town has two major commercial and industrial centers, one just east of Exit 10 and one just west of Exit 19. The Avon Industrial Park located east of Exit 19, which has developed over the last 10 years, contains 127 firms who employ over 3,600 persons in a variety of occupations. A recent expansion of the industrial park has made more sites available for development. The industrial park's location is proximate to Route 24 and separate from nearby residential areas, making it an exceptional location for business development for the Town. Merchant's Park, located west of Exit 19 is a hub of retail stores anchored by a number of "big box" retailers. In addition, there are many local businesses within town, with a total employment of 2,510 people in 2017. There are 4,468 people living in the Town of Avon. The percentage of residents over the age of 65 is 16.0% and 16.9% of residents are under the age of 18 (U.S. Census Bureau 2017).

2.3 Land Use

The Town of Avon is about 4.5 square miles, ranking as one of the state's smallest communities, with much of its remaining land unsuitable for development. The Town's industrial areas have proven to be a regional asset. The industrial area contributes significantly to the Town's tax base and provide thousands of jobs in the area. Figure 2-1 displays the land use categories within Avon providing the percent cover of each category within the Town (See Appendix B, Map 2 of the Hazard Maps).

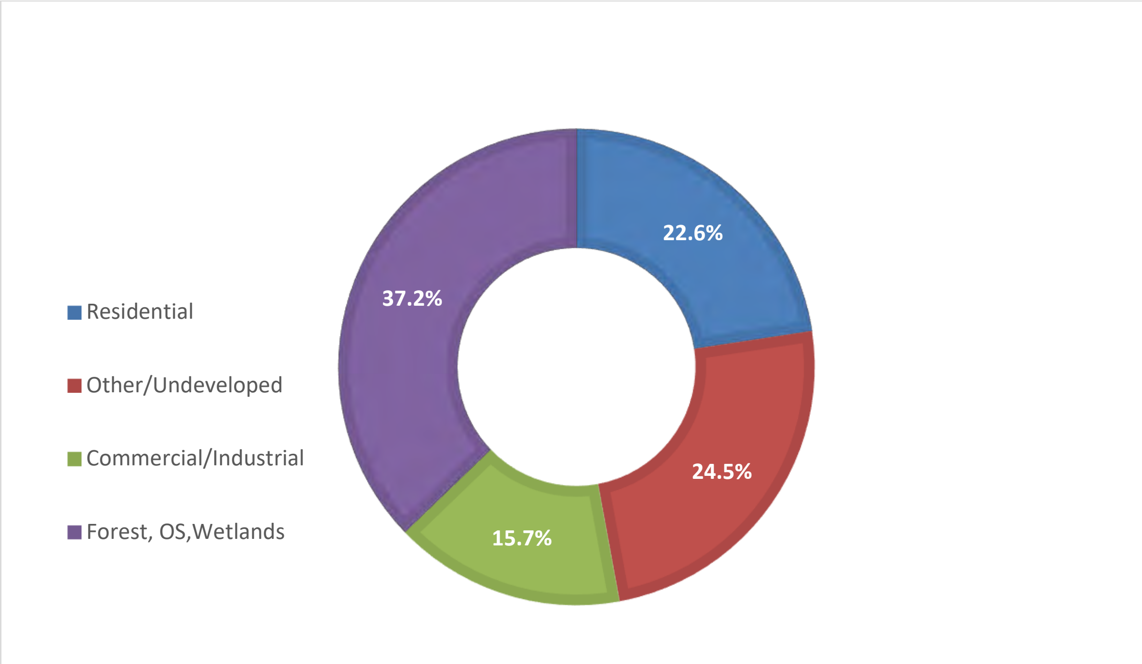


Figure 2-1. Land Use in Avon

Total residential land use makes up 22.6% of the Town's land. Commercial and industrial uses make up 15.7% of the Town land. Several categories of open space combined (forest, wetlands, crop land, open land, and water) make up 37.2% of the Town. The areas that make up a majority of the forested and wetland areas in Avon are the 737-acre D.W. Field Park that Avon shares with Brockton. The soil in this area of town is mapped as Freetown Muck, which is a very deep, nearly level, poorly drained soil that limits development due to its severe limitation for on-site wastewater disposal.

Land use in Avon is managed by the Planning Board and regulated by the Town's Zoning Ordinances and Subdivision of Land Regulations. Avon has seven zoning districts: Residence-Suburban A, Residence-Suburban B, General Business, Industrial, Mixed-Use – Low Density, Residential-High Density, Commercial, Floodplain, Water Supply District, Business Overlay District, and Village Overlay District.

More information on how the land use statistics were developed and the definitions of the categories can be found at: https://docs.digital.mass.gov/dataset/massgis-data-land-use-2005.

2.4 Critical Facilities & Infrastructure

Critical infrastructure is extremely important to a town during a natural hazard. They can be used for disaster response, shelter, and evacuation (for example, emergency shelters, fire stations, hospitals, etc.). Critical infrastructure can also be facilities where additional assistance might be needed during an emergency (nursing homes, elderly housing, schools or daycare centers). Critical infrastructure can also include infrastructure that could be dangerous if it is compromised during a natural disaster, such as a sewage treatment plant or a site with chemical storage. There are 42 critical facilities identified in Avon. These facilities are shown on the map series and corresponding tables in Appendix B and identified below in Table 2-2.

Table 2-2. Avon Critical Facilities

ID #	Facility	Name	Address
1	Bridge	Pond Street Bridge (Route 24)	N/A
2	Bridge	Route 24 Bridge (South Street)	N/A
3	State-Owned Bridges	Harrison Interchange	N/A
4	Dam	Brockton Reservoir Dam (Brockton Reservoir)	South St.
5	Fuel Station	Sunoco	284 East Main St.
6	Fuel Station	Super Petroleum	273 East Main St.
7	Fuel Storage, Tier II Site	Estes Express Lines	215 Bodwell St.
8	Fuel Storage Tier II Site	RoadSafe Traffic Systems	55 Bodwell St.
9	Fuel Storage Tier II Site	T.L. Edwards, Inc.	100R Wales Ave.
10	Tier II Site	National Grid Substation 28	Old Pond St.
11	Tier II Site	National Grid Substation 68	283 East Main St.
12	Library	Avon Public Library	280 West Main St.
13	Public Works	DPW (Water, Highway)	1 Avon Place
14	School, Mass Care Shelter	Avon Middle-High School	285 West Main St.
15	School, Mass Care Shelter, Childcare	Ralph D. Butler Elementary School	1 Patrick Clark Dr.
16	Town Hall, Senior Center	Town Hall & Council on Aging	65 East Main St.
17	Fire & Emergency Operations Center	Fire Station	150 Main St.
18	Police Station	Avon Police Station	86 Fagan Drive
19	Childcare	Avon Nursery School	119 North Main St.
20	Cultural Resource, Mass Care Shelter	Avon Baptist Church	119 North Main St.
21	Culture Resource	Blanchard H.L. Museum	188 Main St.
22	Cultural Resource	Blanchard's Tavern	98 North Main St.
23	Cultural Resource, Tier II Site	Costco Wholesale	120 Stockwell Dr.
24	Cultural Resource, Tier II Site	Home Depot	60 Stockwell Dr.
25	Cultural Resource, Mass Care Shelter	St. Michael's Church	87 North Main St.
26	Cultural Resource	Walmart	30 Memorial Dr.
27	Housing Authority	Avon Housing Authority	1 Fellowship Cir.
28	Postal & Shipping	USPS Avon Office	8 East Main St.
29	Special Needs	Grace Baptist Church	101 Wales Ave.
30	Waste Management, Tier II Site	Waste Management Inc.	40 Ledin Dr.
31	Cable Television	Avon Community Access & Media	2 East Main St.
32	Cellular Phone Facility, Tier II Site	AT&T Cellular Switching Center	155 Bodwell St.

ID #	Facility	Name	Address
33	Water Well & Pumping Station, Water Treatment Facility, Water Filtration Plant	Memorial Drive Water Well #1, Pumping Station, Corrosion Control Facility, Filtration Plant	140 Memorial Dr.
34	Water Supply Tank	Central Street Water Storage Tank	Antone Rd/Central St.
35	Water Supply Tank, Public Safety Repeater Site	Page Street Water Storage Tank	212 Page St.
36	Water Well & Pumping Stations	Trout Brook Wellfield and Pump Station; Theater #3 Well and Pump Station, Satellite Well #3 Wellfield and Pump Station	Argyle Ave.
37	Water Wells, Water Treatment Plant	Trout Brook and Corrosion Control Facility	15 Argyle Ave.
38	Water Well & Pumping Station	Connolly Road Well #4 & Pumping Station	Connolly Rd.
39	Water Well, Pumping Station and Treatment Plant	Porter Well, Pumping Station and Corrosion Control Facility	Avon Pl.
40	Cell Phone/Microwave Tower	N/A	15 Grant Dr.
41	Cell Phone/Microwave Tower	N/A	21 Parker Dr.
42	Defense Contractor and Microwave Tenant	PPG Aerospace	1 Ledin Ave., 244 Bodwell St., and 264 Bodwell St.

3.0 PLANNING PROCESS & PUBLIC PARTICIPATION

This section presents the process that the Town undertook to develop the HMP-MVP for both hazard mitigation and climate resiliency, and how stakeholders and members of the general public were engaged throughout the process.

3.1 Planning Process Summary

To prepare for the development of this MVP-HMP Plan, the Town of Avon followed the process described in the Community Resilience Building Workshop Guidebook, which was developed by The Nature Conservancy (TNC, 2019). 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 natural hazard and climate change impact mitigation planning process is the discussion it promotes among community members about creating a safer, more resilient community. Developing a plan that reflects the Town of Avon's values and priorities is likely to produce greater community support and result in greater success in implementing mitigation strategies that reduce risk.

Community Resilience Building Workshop Guidebook

The Community Resilience Building 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 Community Resilience Building Workshop Guidebook's central objectives are to:

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

Federal regulation for HMP approval requires that stakeholders and the general public are provided opportunities to be involved during the planning process and in the plan's maintenance and implementation. Community members can therefore provide input that can affect the content and outcomes of the mitigation plan. The planning and outreach strategy used to develop this MVP-HMP Plan had three tiers: 1) the Core Committee, with representation from municipal leadership at the Town of Avon, 2) stakeholders who could be vulnerable to, or provide strength against, natural hazards and/or climate change, and 3) the public, who live and work in the Town.

3.2 The Local Multiple Hazard Planning / Municipal Vulnerability Preparedness Core Committee

The Town of Avon, with support from the Public Works Director and leadership from the Town Administrator's office, convened the Core Committee to act as a steering committee for the development of the HMP-MVP Plan. The Core Committee met on January 10, 2020 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 Committee 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 Committee are listed in Table 3-1.

Table 3-1. Avon's Core Committee

Member	Department/Affiliation
William Fitzgerald, Director	Public Works
Brian Martin	Traffic Engineering
Robert Spurr, Chief	Fire Department
Jeffrey J. Bukunt, Chief	Police Department
Gregory Enos	Town Administrator
Kathleen Waldren	Health Agent
Patricia Bessette	Town Clerk

The Core Committee developed the invitation list for the Community Resilience Building Workshop at which key stakeholders were invited to help town identify hazards, vulnerabilities, strengths, and proposed actions to mitigate the impacts of natural hazards and climate change. The Core Committee sought to include municipal leaders as well as politicians, representatives from local nonprofit organizations, local universities, other local jurisdictions, regional organizations, and state government. The Core Committee also suggested or made available reports, maps, and other pertinent information related to natural hazards and climate change impacts in Avon. These included:

- Old Colony Hazard Mitigation Plan, Adopted 2015
- Town of Avon, Stormwater Management Plan, June 2019
- Town of Avon, Zoning By-laws
- Town of Avon, Stormwater Ordinance
- Town of Avon Floodplain Zone
- 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 for Norfolk County, MA, (FEMA, 2010)
- National Center for Environmental Information (NOAA)
- National Water Information System (USGS)
- US Census, 2010 and American Community Survey, 2017

3.3 Stakeholder Involvement: Community Resilience Building Workshop

Key Town staff were invited to engage in a CRB Workshop, held on September 21, 2020. During the 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. Once identified participants prioritized key actions that would improve the Town's resiliency to natural and climate-related hazards. Materials from the Workshop are included in Appendix C.

Regulating development in the Town of Avon is a team effort. The Town has a small municipal staff, requiring that individuals often wear several hats when it comes to municipal responsibilities. Several key municipal officials provided input into the plan as participants in the CRB Workshop on September

21, 2020. The Planning Board plays an important role in land development within the Town, as does the Old Colony Planning Council, the state-designated regional planning authority for Avon. Although they were not able to participate in the CRB Workshop, they did provide comments as part of a draft review. 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.

Discussions of Natural Hazards and Climate Change Impacts

During the CRB, participants were asked to discuss natural hazards and climate change impact in Avon. Discussion centered around several major natural hazards in the Town: flooding, extreme temperatures, hurricanes, winter storms, wind, and drought. Discussion centered around Avon's small physical size, diverse population, and engaged citizenry and how these characteristics affect the Town's ability to respond to natural hazards.

Identification of Top Hazards

Workshop participants were then asked to identify the four top hazards/climate change impacts that Avon faces. They were:

1. Flooding, such as:
   - Flooding of wellfields and limitation on access.
   - Spot flooding of streams and ditches with impact on properties and septic systems.
   - Short-term flooding of roads.

2) High winds, such as:
   - Loss of power, communications, water, and other utilities.
   - Limited road access with downed trees.

3) Winter storms, such as:
   - Loss of power, communications, water, and other utilities.
   - Road access.

4) Drought and heat waves, such as:
   - Impact on well drawdowns.
   - Lack of AC for vulnerable populations.
   - Increased water demand.
   - Brushfires.

Discussion of Existing Infrastructure

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

Table 3-2. Infrastructure Features and Natural Hazards/Climate Change in Avon

Vulnerabilities	Strengths
• Water supply • Septic system flooding, leaching • Repeater site antenna for public safety • Stormwater drainage • Water storage and treatment	• Road network • Water treatment • Stormwater drainage • Water distribution system

Vulnerabilities	Strengths
• Roadside trees falling • Limited staff for technical operations, including due to increase in novel diseases (including linked to climate change and habitat loss) • Snow storage	• Information technology systems (fiber and redundancy)

Discussion of Society and Vulnerable Populations

Workshop participants identified those key societal aspects of Avon that are most vulnerable to, or provide protection against, natural hazards and climate change impacts (see Table 3-3).

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

Vulnerabilities	Strengths
• Aging population • Daytime population increase • Loss of services to vulnerable populations • Difficulty communication to entire population without local media • Communication to vulnerable non-English speaking population	• Daytime population increase • Diversity of residents

Discussion of the Environment

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

Table 3-4. Environmental Features and Natural Hazards/Climate Change in Avon

Vulnerabilities	Strengths
• Stormwater pollution • Impervious surface • Stormwater system mapping • Mosquito habitat • High groundwater/ledge	• Open space • D.W. Field Park • Wetlands

Identification of Hazard/Climate Change Mitigation Strategies

Workshop participants focused time and attention on identifying priority actions for addressing natural hazard and climate change impacts. The priority actions were then ranked as high priority, medium priority, additional priority actions as shown below. The input from the workshops was integrated throughout the HMP-MVP plan.

High Priority Actions

- Interconnects with neighboring towns for emergency and potential long term water supply for purchase of water
- Central Street Tank - repeater site antenna bracket repair or replacement
- Increase production capacity from town wells – redevelopment, replacement, groundwater recharge

- Implement green infrastructure to restore natural hydrologic cycle, increasing groundwater recharge and quality, and reducing peak intensities
- Flood control measures for structures (buildings)
- Repair and upgrade existing water storage tanks
- Continue and expand public education on stormwater/drinking water linkage, including town hall demonstration, education and implementation help for homeowner
- Water conservation education and restrictions to reduce peak demands
- Drainage system pollutant investigation and maintenance, including per SWPP/NPDES Phase II
- Distributed generation, redundant and backup power, and communication
- Flood proofing drinking water pumping stations and wells
- Roadside tree maintenance and response to tree falls, especially storm related
- Purchase chipper for quicker inhouse response for tree falls
- Convert septic systems to sewer system, continue to aggressively upgrade substandard systems (including financial assistance as well as educating residents on maintenance.)

Medium Priority Actions

- Communications with foreign language speakers: work with schools and police, identify translators, identify a website of call center translation services
- Obtain variable message board signs for key locations in the community
- Road and impervious area cloud burst/intense storm related stormwater management, addressing short-term flooding events: continue clearing basins ahead of storms; disconnect drainage/route into green infrastructure for peak reduction and quality improvement
- Complete the assessment and mapping of stormwater infrastructure, especially for spill responses
- Spot cleaning of natural drainage infrastructure, and scheduling in areas of recurring issues; continue to use Norfolk County Mosquito Control for cleaning, as well as mapping historic cleaning
- Effective documentation of technical operations for training and knowledge transfer to new operations staff
- Survey trees on public property for maintenance needs

Additional Priority Actions

- Identify snow storage areas, perform regular maintenance, and make improvements at compost site
- Install or provide enhanced habitat to encourage natural solutions to natural issues such as mosquito control, lack of pollinators, etc.

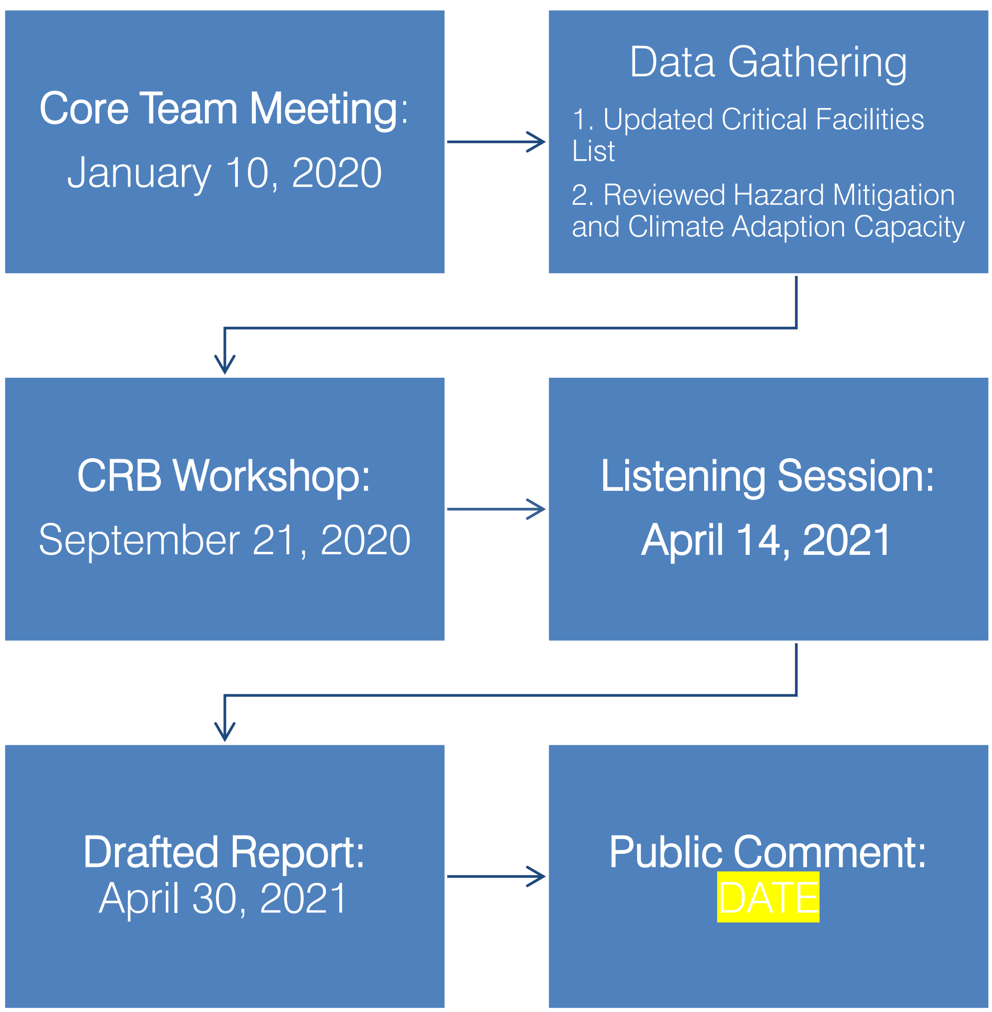
3.4 Public Involvement: Listening Sessions

To gather information from the general public and to educate the public on hazard mitigation and climate change, the Town hosted a public listening session. The Community Resilience Building Workshop process and findings were presented at the listening session open to the public on April 14, 2021, which was held virtually due to the COVID pandemic followed by a public comment period from DATE. The Town received no comments subsequent to the meeting. The listening session was publicized in accordance with the Massachusetts Public Meeting Law (see public meeting notices in Appendix C). More information about the meetings and public comments are available in Appendix 2.

3.5 Continuing Public Participation

Following FEMA approval of the HMP-MVP Plan, the Core Committee, originally convened as the steering committee for establishing the Plan, will transition their work to updating and keeping the Plan current. The Core Committee membership will initially be the same as when they worked on developing the Plan, but members may be added as needed. This ongoing review and evaluation will be accomplished by monitoring implementation, evaluating effectiveness of mitigation strategies, and updating the plan as needed. The Core Committee will provide residents, businesses, and other stakeholders the opportunity to learn about natural hazard mitigation and climate change resilience planning and inform the Town's understanding of local hazards. All updates and reviews of the Plan made by the Core Committee will be placed on the Town's web site and meetings will be publicly noticed in accordance with town and state open meeting laws. The list of Core Committee membership is presented in Table 3-1 (above).

3.6 Planning Timeline



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

1. Local Hazard Mitigation Planning Team / Municipal Vulnerability Preparedness Core Committee

   Meeting 1: January 10, 2020 - Plan for MVP Workshops/HMP Community Meeting

   The Core Committee provided comments on the actions and HMP-MVP through email. The Avon Public Works Director coordinated this process.

2. HMP Stakeholder Meetings / MVP Community Resilience Building Workshops

   Workshop: September 20, 2020

3. Public Listening Session to Review Draft Plan

   Meeting: April 13, 2021
   Public Comment Period: DATE

4.0 RISK ASSESSMENT & VULNERABILITIES

This risk assessment examines the natural hazards that have the potential to impact Avon. This assessment includes a description of the type, location, and extent of natural hazards, along with information on previous occurrences of natural disasters. This section also includes an analysis of the vulnerability of existing buildings, infrastructure, and critical facilities as well as potential future development; an estimate of potential dollar losses to vulnerable structures; and a description of land uses and development trends.

4.1 Update Process

To update Avon's hazard identification and risk assessment, Weston & Sampson researched and analyzed hazard and land use data, met with municipal staff, conducted an MVP workshop, and completed a GIS vulnerability analysis. The purpose of the GIS vulnerability assessment is to estimate the extent of potential damages from natural hazards of varying types and intensities. A vulnerability assessment and estimation of damages was performed for flooding through a Geographic Information System (GIS)-based exposure analysis that combined the Town's Assessor data records with available hazard data layers. These layers were used to map and illustrate hazard risk.

4.2 Statewide Overview of Hazards

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. Table 4-1 summarizes the frequency and severity of hazard risk in Avon and Massachusetts. These frequency and severity classifications can be used to help prioritize mitigation actions for each hazard.

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 (less than 1% per year)
- *Low frequency*: events that occur from once in 50 years to once in 100 years (1% to 2% per year);
- *Medium frequency*: events that occur from once in 5 years to once in 50 years (2% to 20% per year);
- *High frequency*: events that occur more frequently than once in 5 years (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. Summary of Risks by Hazard Type in Massachusetts and Avon

Hazard	Frequency		Severity	
	Massachusetts	Avon	Massachusetts	Avon
Inland Flooding	High (1 flood disaster declaration event every 3 years; 43 floods per year of lesser magnitude)	High	Serious to Catastrophic	Minor to Serious
Dam Failure	Very Low	Very Low	Extensive to Catastrophic	Minor
Coastal Hazards	High (6 events per year over past 10 years)	N/A (Not a coastal community)	Serious to Extensive	N/A (Not a coastal community)
Tsunami	Very Low (1 event every 39 years on East Coast, 0 in MA)	N/A (Not a coastal community)	Extensive to Catastrophic	N/A (Not a coastal community)
Hurricane/Tropical Storm	High (1 storm every other year)	Medium	Serious to Catastrophic	Serious
High Wind	High (43.5 events per year)	High	Minor to Extensive	Minor to Extensive
Tornadoes	High (1.7 events per year)	Low	Serious to Extensive	Serious to Extensive
Thunderstorms	High (20 to 30 events per year)	High	Minor to Extensive	Minor to Extensive
Nor'easter	High (1 to 4 events per year)	High	Minor to Extensive	Minor to Extensive
Snow and Blizzard (Severe Winter Weather)	High (1 per year)	High	Minor to Extensive	Minor to Extensive
Ice Storms (Severe Winter Weather)	High (1.5 per year)	High	Minor to Extensive	Minor to Extensive

Hazard	Frequency		Severity	
	Massachusetts	Avon	Massachusetts	Avon
Earthquake	Very Low (10-15% probability of magnitude 5.0 or greater in New England in 10 years)	Very Low	Minor to Catastrophic	Minor to Catastrophic
Landslide	Low (once every two years in western MA)	Low	Minor to Extensive	Minor
Brush Fires	High (at least 1 per year)	Medium	Minor to Extensive	Minor to Extensive
Extreme Temperatures	High (1.5 cold weather and 2 hot weather events per year)	High	Minor to Serious	Minor to Serious
Drought	High (8% chance of "Watch" level drought per month (recent droughts in 2016 and 1960s))	High	Minor to Serious	Minor to Serious

Source: Table adapted from the 2018 SHMCAP and 2013 Massachusetts State Hazard Mitigation Plan, with assistance from the Town of Avon

Not all hazards included in the 2018 State Hazard Mitigation and Climate Adaptation Plan, or the 2013 Massachusetts State Hazard Mitigation Plan apply to the Town of Avon. Given Avon's inland location, coastal hazards and tsunamis are unlikely to directly affect the Town. It is assumed that the entire Town of Avon 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.

4.3 Top Hazards as Defined in the Community Resilience Building Workshop

The Avon Core Team recommended four top hazards/climate change impacts for use during the CRB Workshop. These hazards include:

1. Flooding
2. Winter Storms
3. Wind
4. Drought

The CRB Workshop included group discussions about Town features, environmental hazards, and anticipated climate change impacts.

Flooding was a common issue discussed during the workshop. Workshop attendees also discussed the impact of severe storms and wind events, saying that portions of Avon experience more power outages than the rest of Town. Utility lines in the area are vulnerable due to tree lined streets throughout the Town. Participants also discussed the impact of drought on the drinking water supply and how having infrastructure in place for water supply back up is needed.

The sections below include more information about environmental hazards, climate change projections, and historic and anticipated impacts in Avon.

4.4 Flood-Related Hazards

Avon is located within the Taunton River Watershed and is home to the Brockton Reservoir and Waldo Lake, as well as several smaller bodies of water. Flooding represents a high-frequency, potentially serious severity hazard for Avon.

Flooding can be caused by various weather events including hurricanes, extreme precipitation, thunderstorms, nor'easters, and winter storms. Flooding can be both riverine (topping the banks of streams, rivers, ponds) and from stormwater that is not properly infiltrated into the ground. While Avon experiences these events, the impacts of climate change will likely lead to increasingly severe storms and, therefore, increasingly severe impacts. The impacts of flooding include injury or death, property damage, and traffic disruption. 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 subsections provide more information on historic flooding events, potential flood hazards, a vulnerability assessment, locally identified as areas of flooding, and information on the risk of dam failures.

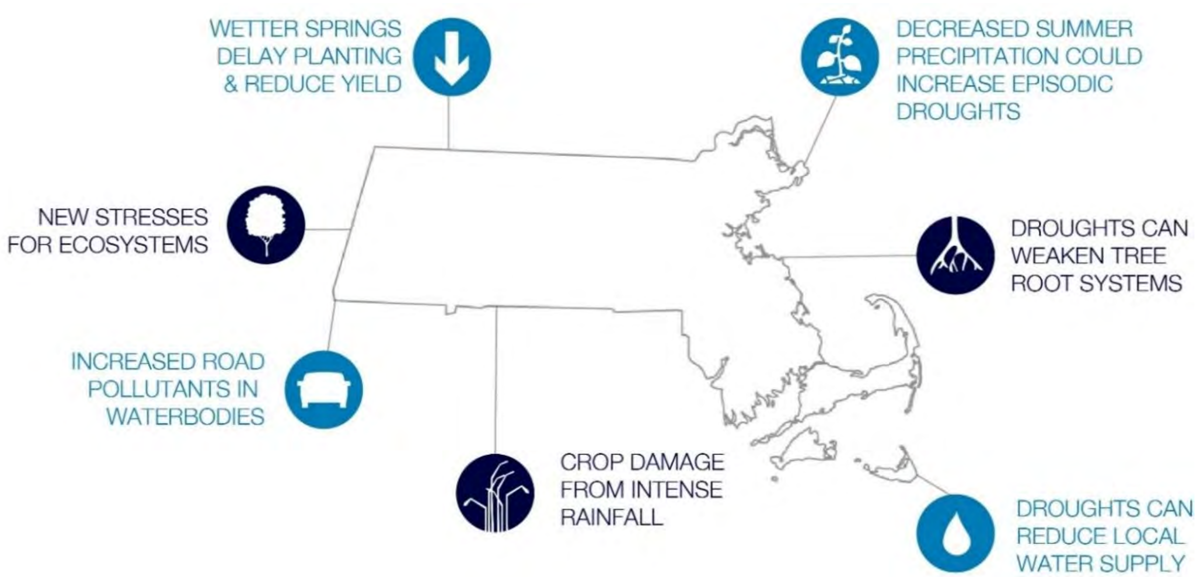


Figure 4-1. Potential Impacts of Increasing Precipitation

Flood hazards are also linked to erosion, which can compromise receiving water quality, slope stability, and the stability of building foundations. These impacts put current and future structures and populations located near steep embankments at risk. Erosion can also undercut streambeds and scour around stream crossing, creating a serious risk to roadways.

The following sub-sections provide more information on historic flood events, locally identified flood areas, potential flood hazards, a vulnerability assessment, and information related to dam failure risk. The analysis of flood hazard areas was informed by the FEMA National Flood Insurance Program (NFIP) Flood Insurance Rate Map (FIRM), a GIS vulnerability analysis, information from Avon town staff, input collected during expert interviews with local leaders, and accounts of past flood events provided by Avon MVP Workshop participants.

Flooding events in Avon have been classified as a high frequency event. As defined by the Massachusetts State Hazard Mitigation and Climate Adaptation Plan this hazard occurs once every three years (33% chance) (MEMA and EOEEA, 2018)

4.4.1 Areas Vulnerable to Flooding

Flooding can be both riverine (topping the banks of streams, rivers, ponds) and from stormwater that is not properly infiltrated into the ground.

Riverine Flooding

Avon is home to a series of streams, ponds, and other waterbodies that include:

- Rivers, Streams, and Brooks:Beaver Brook, Trout Brook, Mary Lee Brook, Three Swamp Brook
- Lakes and Ponds:Brockton Reservoir, Waldo Lake

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.

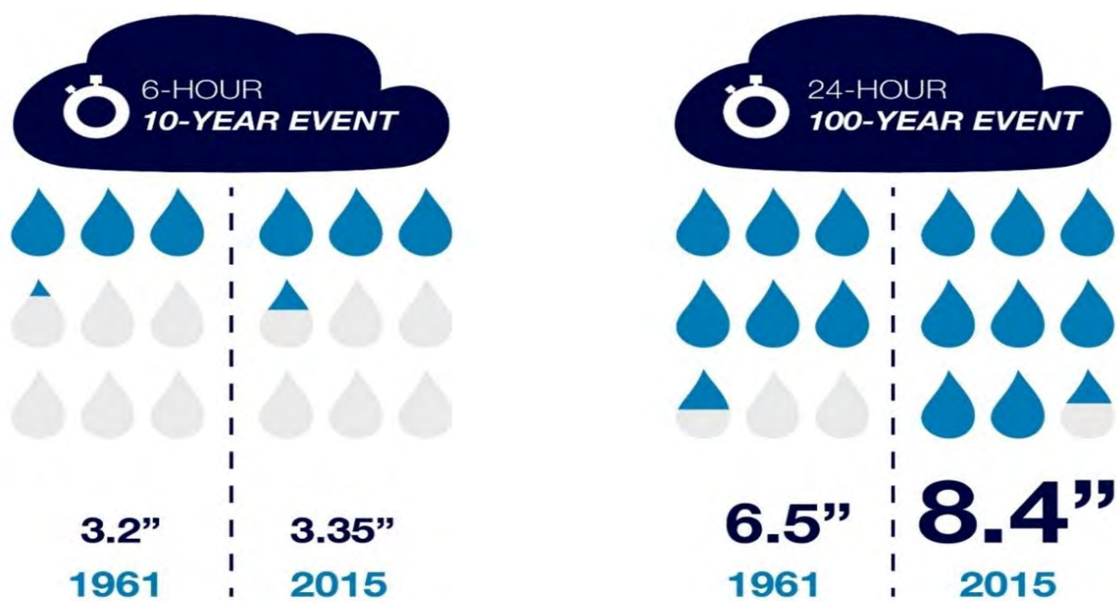


Figure 4-2. Design Storm Standards from 1961 (TP-40) and 2015 (NOAA Atlas 14)

FEMA Flood Zones

FEMA-designated flood zones from the NFIP FIRM are included in Map 3 in Appendix B and are considered more vulnerable to flood events. Areas within these zones are more vulnerable to flood events. The definitions of flood zones are provided below.

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 AH (1% chance of inundation in any year): Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are between one and three feet. Base Flood Elevations (BFEs) derived from detailed hydraulic analyses are shown in this zone. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone AO (1% chance of inundation in any year): Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between one and three feet. Average flood depths derived from detailed hydraulic analyses are shown in this zone. Mandatory flood insurance purchase requirements and floodplain management standards apply. Some Zone AO have been designated in areas with high flood velocities such as alluvial fans and washes. Communities are encouraged to adopt more restrictive requirements for these areas.

Zone X500 (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.

Zone VE (1% chance of inundation in any year): Zone VE is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

Source: Federal Emergency Management Agency (FEMA), "Flood Zones."

Locally Identified Areas of Flooding

The areas identified as being the most vulnerable to flooding are those areas located within the 100-year floodplain. According to FIRM maps, areas most vulnerable to flooding in Avon are areas along Beaver Brook and Trout Brook, the Brockton Reservoir and Waldo Lake in D.W. Field Park and northeast Avon (particularly the area east of Page Street to the Randolph town line). Please see Section 4.4.5 for more detailed information. In addition to these areas, town officials also noted the following locations were where flooding has historically occurred, some of which flooded as a result of the March 2010 floods:

- The parking lot of the Avon Public Library

- Kiddie Drive
- West Main Street, south of South Street
- Doherty Avenue
- West High Street at Old Pratt Street

4.4.2 Norfolk County Flooding Events

NOAA's National Centers for Environmental Information Storm Events Database provides information on previous flood events for Norfolk County, which includes the Town of Avon. The storms are categorized by event type, including flood and flash flood events. 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)." 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" (NOAA, 2018c)

Norfolk County experience 75 flood events between 1998 and 2018. Twenty-seven of these events were flash floods. No deaths or injuries were reported, and the property damage totaled $41.2 million dollars (not adjusted for inflation). It should be noted that not all the flooding that occurred was county-wide, therefore not all the flooding events shown below directly affected Avon. However, this does provide an idea of the monetary cost that flooding can have on an area. The most significant flooding in Norfolk County occurred in March 2010. During the March 14 - March 21 flood, rainfall totals reached 10 inches in eastern Massachusetts.

4.4.3 GIS Flooding Exposure Analysis

Hazard location and extent of riverine flooding was determined using the current effective FEMA Flood Insurance Rate Map (FIRM) data for Avon dated 2017. The FIRM is the official map on which FEMA has delineated both the special flood hazard areas and the risk premium zones applicable to the community 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"). For purposes of this exposure analysis, the following special flood hazard areas as identified in the Town of Avon's current FIRMs were included:

- Flood Zone AE – Regulatory Floodway
- Flood Zone A (AE, AH) – 1% Annual Chance Flood Hazard
- Flood Zone X (shaded) – 0.2% Annual Chance Flood Hazard

The town's existing tax parcel and property value data 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 for Fiscal Year 2019, as described below in Table 4-2 on the following page.

Table 4-2. Avon's Land Use Classification Based on Massachusetts Land Use Codes

Land Use Categories with Land Use Descriptions	Land Use Code
Commercial	
Auto Repair Facilities	3320
Automotive Vehicles Sales and Service	3300
Buildings for manufacturing operations	4000
Commercial Greenhouses	3180
Discount Stores, Junior Department Stores, Department Stores	3220
Eating and Drinking Establishments - restaurants, diners, fast food establishments, bars, nightclubs	3260
Electricity Regulating Substations	4240
Gas Pressure Control Stations	4280
General Office Buildings	3400
Improved, Selectmen or City Council (Municipal)	9310
Lumber Yards	3130
Mixed-Use (Primarily Industrial, some Other)	0400
Other Storage, Warehouse, and Distribution facilities (see also use code 401)	3160
Parking Lots - a commercial open parking lot for motor vehicles	3370
Sand and Gravel Mining/Quarry	4100
Shopping Centers/Malls	3230
Small Retail and Services stores (under 10,000 sq. ft.)	3250
Warehouses for storage of manufactured products	4010
Land (Other) -	
Accessory Land with Improvement	1060
Farm Buildings - barns, silo, utility shed, etc.	3170
Public Service -	
Elementary Level	9400
Medical Office Buildings	3420
Residential -	
Apartments with Four to Eight Units	1110
Mobile Home (includes mobile home park land)	1030
Multiple Houses on one parcel	1090

Land Use Categories with Land Use Descriptions	Land Use Code
Other Congregate Housing (includes non-transient shared living arrangements)	1250
Residential Condominium	1020
Single Family Residential	1010
Three-Family Residential	1050
Two-Family Residential	1040
Vacant Land (Developable) -	
Developable Industrial Land	4400
Developable Residential Land	1300
Potentially Developable Residential Land	1310
Vacant Land (Undevelopable) -	
Undevelopable Residential Land	1320

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.

To calculate the exposure of parcels and buildings to the flood hazards, parcels with buildings, that are located completely or partially, within recognized hazard zones were identified using the ArcGIS overlay analysis (i.e., select by location using the intersect function). The number of parcels and buildings for each land use category was then totaled, along with the value of buildings and real property associated with those parcels. These figures provide a strong indication of current hazard vulnerability, as well as potential future vulnerability as it relates to vacant and potentially developable parcels.

The following types of critical facilities were identified for the Town of Avon and included in the exposure analysis:

- Town Hall
- Dams
- Water Storage Tanks
- Police Department
- Fire Department
- Nursing Homes
- Pump Stations
- Schools
- Daycares
- Bridges

42 critical facilities are located within the Town of Avon. These facilities were identified and mapped in ArcGIS based on the confirmed physical location/address. Like the vulnerability analysis for parcels and buildings, each was then overlaid with the identified and mappable hazard zones (FEMA Flood Zones). For purposes of this analysis it was assumed that the physical location of a critical facility within a hazard area (completely or partially) meant that it is exposed and potentially vulnerable to that specific hazard. However, it is recognized that more site-specific evaluations may be required to confirm this assumption.

4.4.4 Repetitive Loss Structures

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 and NFIP 2018a). There are no repetitive loss or severe loss properties identified in Avon.

4.4.5 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). Dam failures during flood events are of concern in Massachusetts, given the large number of dams constructed in the 19th century (MEMA and DCR 2013, 298).

Dams can fail due to overtopping caused by floods that exceed the peak-flow capacity of the dam, deliberate acts of sabotage, structural failure of materials used in dam construction, movement or failure of the foundation supporting the dam, settlement and cracking of concrete or embankment dams, piping and internal erosion of soil in embankment dams, and inadequate maintenance and upkeep (MEMA and DCR 2013, 210).

Many dam failures in the United States have been secondary results of other disasters, such as earthquakes, landslides, extreme storms, and massive snowmelt (MEMA and DCR 2013, 210).

Although dam failure does not occur frequently in Avon, it could 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.

There have been no recorded dam failures in Avon, 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 concern 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 is one dam in Avon. The Brockton Reservoir Dam is a fixed concrete structure with a stone spillway that holds water at its normal level and discharges it to a stream running to Waldo Lake. The controlled release of water from the reservoir is by three gates taking water from two screened openings in the face of the dam or from a system of stone encased perforated pipes just above the reservoir bottom. Water taken from these goes to a water treatment plan or to a piped bypass spillway discharging to the stream flowing to Waldo Lake. The dam also has a toe drain system in the bottom of its downstream face to catch and potentially damaging seepage.

Information related to these dams is summarized in Table 4-3. 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 4-3. Inventory of Dams in Avon

Dam Name	Impoundment	Dam Owner	Hazard Potential Classification
Brockton Reservoir Dam	Brockton Reservoir	City of Brockton	Significant

As of February 2017, all dams classified as high hazard potential or significant hazard potential were required to have an Emergency Action Plan (EAP). 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. All high hazard potential and significant hazard potential dams in Avon are detailed below.

4.5 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 Avon's current 100-year wind speed is 110 mph, climate change will likely increase events and severity. Please refer to Map 5 in Appendix B for more information.

Extreme winds can take down trees and branches that cause service disruptions. An identified issue during storms in Avon is the damage to power and phone wires from overhanging trees that have not been trimmed by the electric utilities (National Grid and Eversource Energy) or the phone or cable companies. The utilities' tree maintenance program should be upgraded in an effort to reduce the risk associated with tree damage to utility lines. High winds and heavy snow loads caused significant power line damage in Avon during a nor'easter in 2018. Falling trees and branches can also block traffic and emergency routes. This is a regional issue that affects cities and towns beyond Avon.

During Avon's MVP Workshop in September 2020, attendees discussed the impact of past storms on power systems and service disruption. The most common concern with wind related events was power outages due to tree damage. Avon has a high percentage of their roadways adjacent to wooded areas that pose a threat to power lines during wind events.

4.5.1 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 (MEMA and DCR 2013, 323).

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 Avon'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 (MEMA and DCR 2013, 324).

The region has been impacted by hurricanes throughout its history, starting with the Great Colonial Hurricane of 1635. Between 1851 and 2012, Massachusetts experienced 11 hurricanes and one named tropical storm. This includes six category 1 hurricanes, two category 2 hurricanes, and three category 3 hurricanes (Blake, Landsea, and Gibney 2011, 21). Hurricanes that have occurred in the region since 1938 are listed in Table 4-4:

Table 4-4. Hurricane Records for Eastern Massachusetts, 1938 to 2012

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 Earl	September 4, 2010
Tropical Storm Irene	August 28, 2011
Hurricane Sandy	October 29-30, 2012
Hurricane Florence	September 18, 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 (MEMA and DCR 2013, 324). More information is included in Table 4-5 below:

Table 4-5. 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 is severe, there are

Scale No. (Category)	Winds (mph)	Potential Damage
		extensive glass failures, and entire buildings could fail.

Source: MEMA and DCR 2013, page 325 (table originally created by NOAA)

Hurricane damage in Avon 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 Avon was outlined by the census tracts in the Town. The probabilistic scenario was used for Avon. 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 Avon 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 4-6. Category 2 Hurricane Damage

Infrastructural Damage from a Category 2 Hurricane on Buildings in Avon				
Building Type	Number of Buildings in Avon	Total Number of Buildings Damaged	Percent of Buildings Damaged	Total Value of Building Damage
Residential	1,537	88	6%	$5,205,000
Commercial	219	9	4%	$846,000
Industrial	62	3	5%	$288,960
Institutional	26	1	4%	$38,370

Table 4-7. Category 4 Hurricane Damage

Infrastructural Damage from a Category 4 Hurricane on Buildings in Avon				
Building Type	Number of Buildings in Avon	Total Number of Buildings Damaged	Percent of Buildings Damaged	Total Value of Building Damage
Residential	1,537	400	26%	$527,130,000
Commercial	219	48	22%	$513,610,000
Industrial	62	14	23%	$125,615,000
Institutional	245	54	22%	$29,692,000

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 townwide hazard in Avon and are considered a medium frequency event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard can occur between once in 5 years to once in 50 years (a 2% to 20% chance per year).

4.5.2 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, 4-242). 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 in 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, but they can occur at any time. For example, 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, 4-244).

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 4-8 provides more detailed information on the EF Scale.

Table 4-8. 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

Source: Massachusetts State Hazard Mitigation Plan 2013, page 416

Massachusetts experiences an average of 1.7 tornadoes per year. The most tornado-prone areas of Massachusetts are the central counties. Tornadoes are comparatively rare in eastern Massachusetts, although Norfolk is considered an at-risk location (EEA and EOPSS 2018, 4-243). The most devastating tornado in Massachusetts in the history of recorded weather occurred in Worcester in 1953, it killed 94 people, injured more than 1,000, and caused more than $52 million in damage (more than $460 million in current dollars). The most recent tornadoes in Massachusetts occurred in 2011 in Springfield, 2014 in Revere, and 2016 in Concord (Morrison 2014; Epstein 2016).

There have been 11 recorded tornados in Norfolk County since 1953. One fatality and 23 injuries were reported (Lietz 2019). Table 4-9 below provides additional information.

Table 4-9. Tornado Records for Norfolk County

Date	Fujita	Fatalities	Injuries	Width	Length	Damage
6/9/1953	3	0	17	667	28	$500K-$5M
11/21/1956	2	0	0	17	0.1	$500-$5000
8/9/1972	1	1	6	30	4.9	$5K-$50K
9/6/1973	1	0	0	10	1.1	$5K-$50K
7/10/1989	0	0	0	23	0.1	$500-$5000
5/18/1990	0	0	0	10	0.2	$500-$5000
5/18/1990	0	0	0	10	0.2	$500-$5000
6/30/2001	0	0	0	80	0.1	-
8/21/2004	1	0	0	40	6	$1.5M
5/9/2013	0	0	0	50	0.38	$20000
6/23/2015	0	0	0	200	0.48	$4.1M

Source: Lietz 2019

Although tornadoes are a potential townwide hazard in Avon, there have been no recorded tornadoes in the Town. If a tornado were to occur in Avon, damages would depend on the track of the tornado and would be most likely be high 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 Avon 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). Tornados are difficult to simulate well in climate models because of their small size. However, it is predicted that the frequency of tornados in eastern Massachusetts will rise in the future due to climate change.

4.5.3 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, 4-225).

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, 4-224–4-226). Previous nor'easters events are listed in Table 4-7 below.

Table 4-6. Recent Nor'easter Events for Massachusetts

Nor'easter Event	Date
Blizzard of 1978	February 1978
Severe Coastal Storm ("Perfect Storm")	October 1991
Great Nor'easter of 1992	December 1992
Blizzard, Nor'easter	January 2005
Coastal Storm, Nor'easter	October 2005
Severe Storms, Inland and Coastal Flooding	April 2007
Winter Storm and Nor'easter	January 2011
Severe Storm and Snowstorm	October 2011
Severe Winter Storm, Snowstorm, and Flooding	April 2013
Severe Winter Storm, Snowstorm, and Flooding	April 2015
Severe Winter Storm and Flooding	March 2018
Severe Winter Storm and Snowstorm	March 2018

Some of the historic events described in the "Flood-Related Hazards" section of this report were 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 Avon 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, Avon is not subject to the coastal hazards often associated with nor'easters.

Nor'easters in Avon 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).

4.5.4 Severe Thunderstorms

Thunderstorms in Massachusetts are usually accompanied by rainfall; however, during periods of drought, lightning from thunderstorm cells can start fires. Thunderstorms with little or no rainfall are rare in New England but have occurred (EEA and EOPSS 2018, 4-173).

Thunderstorms are typically less severe than other events discussed in this section. However, thunderstorms can cause significant damage and are a townwide risk in Avon. Thunderstorms can include lightning, strong winds, heavy rain, hail, and sometimes tornadoes. Thunderstorms commonly last for about 30 minutes and can generate winds of up to 60 mph.

NOAA's National Centers for Environmental Information offers thunderstorm data for Norfolk County, which includes Avon. Between 2008 and 2019, 87 thunderstorm events caused $732,500 in property damages. No injuries or deaths were reported.

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 Avon. 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).

4.6 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 where there are large snowbanks. Impassable streets can also complicate emergency response efforts during an extreme event.

Winter storms are a potential townwide hazard in Avon. 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.

Figure 4-3. Snow Removal in Avon.

4.6.1 Heavy Snow and Blizzards

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

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 20ºF. 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, 4-223).

There is no widely used scale to classify snowstorms. The Northeast Snowfall Impact Scale (NESIS) developed by Paul Kocin of The Weather Channel and Louis Uccellini of the National Weather Service (Kocin and Uccellini, 2004) characterizes and ranks high-impact northeast snowstorms. These storms have large areas of 10-inch snowfall accumulations and greater. NESIS has five categories, as shown in Table 4-8. The index differs from other meteorological indices in that it uses population information in addition to meteorological measurements. Thus, NESIS gives an indication of a storm's societal impacts. This scale was developed because of the impact northeast snowstorms can have on the rest of the country in terms of transportation and economics. NESIS scores are a function of the area affected by the snowstorm, the amount of snow, and the number of people living in the path of the storm. The aerial distribution of snowfall and population information are combined in an equation that calculates a NESIS score, which varies from 1 for smaller storms to over 10 for extreme storms. The raw score is converted into one of the five NESIS categories. The largest NESIS values result from storms producing heavy snowfall over large areas that include major metropolitan centers. NOAA began using the NESIS in 2005 to determine impact from snow events (MEMA and DCR 2013, 400).

Table 4-7. NESIS Categories

Category	NESIS	Value Description
1	1 – 2.499	Notable
2	2.5 – 3.99	Significant
3	4 – 5.99	Major
4	6 – 9.99	Crippling
5	10+	Extreme

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan (EEA and EOPSS 2018)

The current winter snowfall record in Eastern Massachusetts is 108.6 inches during the 2014-2015 season ((NOAA, 2015). Map 6 in Appendix B indicates that the average annual snowfall in Avon is between 48.1 inches to 72 inches. The town provides standard snow plowing operations and clearing snow has not posed any significant challenges, though the small physical size of Avon does make snow storage during high accumulation events problematic.

The "Blizzard of 1978" is a well-known winter storm that deposited more than three feet of snow and led to multi-day closures of roads, businesses, and schools. Table 4-9 provides additional information on significant snow events.

Table 4-8. Severe Winter Storm Records for Massachusetts

Type of Event	Date
Blizzard	February 1978
Blizzard	March 1993
Blizzard	January 1996
Severe Snowstorm	March 2001

Type of Event	Date
Severe Snowstorm	December 2003
Severe Snowstorm	January 2004
Severe Snowstorm	January 2005
Severe Snowstorm	April 2007
Severe Snowstorm	December 2010
Severe Snowstorm	January 2011
Blizzard	February 2013
Blizzard	January 2015
Severe Snowstorm	March 2018

Source: National Oceanic and Atmospheric Administration

According to the National Centers for Environmental Information Storm Events Database provide information for blizzards, winter weather, heavy snow, and winter storms. There were 298 winter events between 1996 and 2019 in Norfolk County totaling $21,228,000 dollars in damage. In total there were 3 deaths and 2 injuries associated with these winter events.

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

4.6.2 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 criterion 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. 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, 462).

NOAA's National Centers for Environmental Information Storm Events Database offers hail events data for Norfolk County Between 2000 and 2018, there were 73 hail events, but caused no reported property damages. No deaths or injuries were reported.

Ice storms are classified as medium frequency events in Avon. 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). No recorded ice storms have occurred in Norfolk County since 1998

4.6 Geological Hazards

Geologic hazards can include earthquakes, landslides, sinkholes, and subsidence. Statewide data did not identify any local areas that were previously recorded as being vulnerable to geologic hazards. Please refer to Map 4 in Appendix B for more information on geologic hazards in Avon.

4.6.1 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 4-10 summarizes Richter scale magnitudes and corresponding earthquake effects (MEMA and DCR 2013, 220).

Table 4-9. Richter Scale and Effects

Richter Magnitude	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 100km 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.

Source: Louie 1996

Earthquakes occur, albeit infrequently, in New England as compared to other parts of the country. 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. A vast majority of these earthquakes are recorded but pose little to no risk to people or infrastructure. 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, 228-232).

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 Massachusetts ranges from 10 %g to 20 %g, with a 2% probability of exceedance in 50 years. Figure 4-4 provides additional information.

Avon is located in an area with a peak ground acceleration (PGA) of 14 %g to 16 %g with a 2% probability of exceedance in 50 years (Figure 4-4). This is the third/fourth 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 as shown on Map 4 in Appendix B, no earthquake epicenters have been recorded within Avon. 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 can trigger fires due to infrastructure damage (i.e., breaking of gas lines). The water distribution system may be disrupted, thus posing a risk for public health and safety. Serious earthquakes do occur in Massachusetts, albeit infrequently. These events can strike without warning and can have a devastating impact on infrastructure and buildings constructed prior to earthquake resistant design considerations.

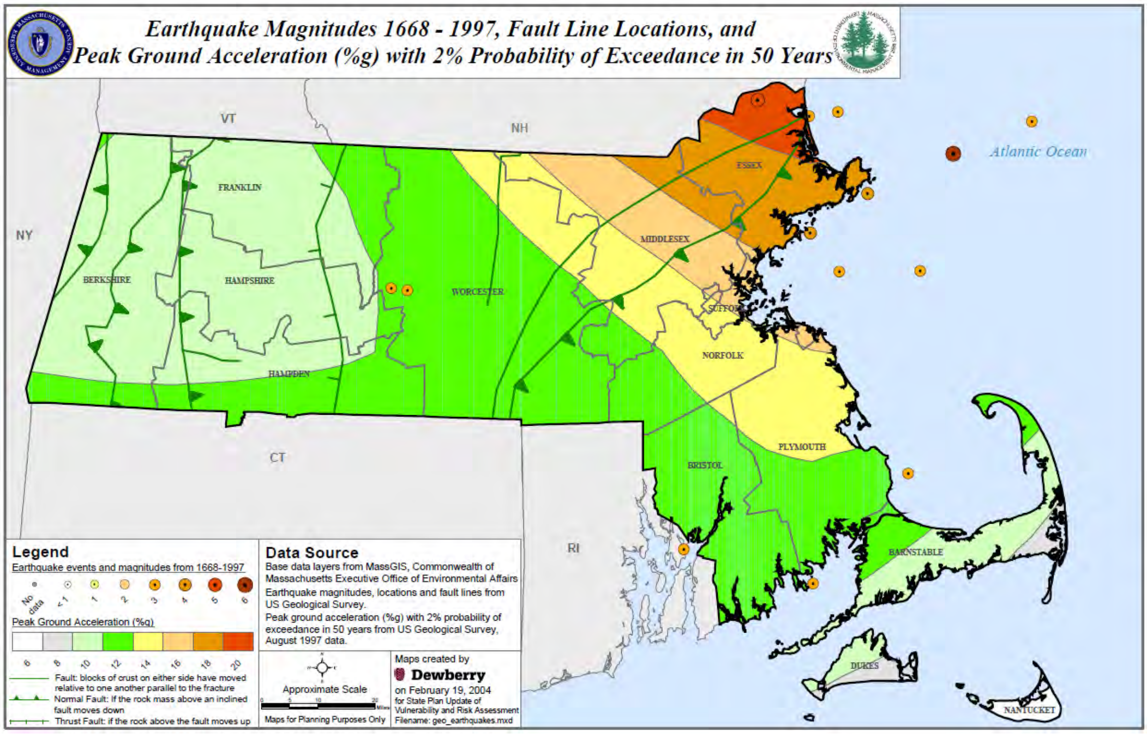


Figure 4-4. State of Massachusetts Earthquake Probability Map

Source: Massachusetts State Hazard Mitigation Plan

It can be assumed that all existing and future buildings and populations are at risk of an earthquake. Impacts from earthquakes can be from slight to moderate building damage, to catastrophic damage and fatalities, depending on the severity of the earthquake. 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).

Potential earthquake damage was modeled for Avon. 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 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 Avon was outlined by the census tracts in the Town. The arbitrary event scenario was used for Avon. 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 Avon if either a magnitude 5.0 or a magnitude 7.0 earthquake occurred with the epicenter located in the center of Avon. 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 4-10. Magnitude 5.0 Earthquake Damage

Infrastructural Damage from a Magnitude 5.0 Earthquake on Buildings in Avon				
Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged	Percent of Buildings Damaged by Type	Value of Building Damage[1]
Residential	1,537	747	49%	$46,243,700
Commercial	219	172	78%	$111,609,900
Industrial	62	50	80%	$30,953,700
Other	249	194	78%	$6,028,600
TOTAL	**2,067**	**1,163**		**$194,835,900**

[1]Includes Building, Content and Inventory

Table 4-11. Magnitude 7.0 Earthquake Damage

Infrastructural Damage from a Magnitude 7.0 Earthquake on Buildings in Avon				
Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged	Percent of Buildings Damaged by Type	Value of Building Damage[1]
Residential	1,537	1,518	99%	$327,050,000
Commercial	219	219	100%	$754,540,000
Industrial	62	62	100%	$187,470,000
Other	249	249	100%	$40,600,000
TOTAL	**2,067**	**2,048**		**$1,309,660,000**

[1]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 very low frequency events in Avon. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, these events occur less frequently than once in 100 years (a less than 1% chance of occurring each year).

4.6.2 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 a factor in landslides, 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 2019a).

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 is at significant risk for landslide. 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 2019a). Landslides can damage buildings and infrastructure and cause sedimentation of waterbodies.

Landslide intensity can be measured in terms of destructiveness, as demonstrated by Table 4-13 below.

Table 4-12. 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

Source: Cardinali et al. 2002

Map 4 in Appendix B indicates that all of Avon is classified as having a low risk for landslides. No significant landslides have been recorded for Avon or Norfolk County (Appendix B of EEA and EOPSS 2018). A landslide has never been reported in Avon and the Town is not especially vulnerable to landslides due to its lack of hills and generally flat topography. Landslides are classified as low frequency events in Avon. These events can occur once in 50 to 100 years (a 1% to 2% chance of occurring each year).

4.7 Fire-Related Hazards

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.

A wildfire can be defined as any non-structure fire that occurs in the vegetative wildland, including grass, shrub, leaf litter, and forested tree fuels. Wildfires can be caused by natural events, human activity or in an intentional controlled manner, as in the case of prescribed fire, and often begin unnoticed, but spread quickly, igniting brush, trees, and homes (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.

According to the SHMCAP (Appendix B), the most recent large-scale wildfire occurred in September 1995 in the Town of Russell in Hampden County. Since wildfires are not common in Massachusetts, this plan focuses on brush and urban fires.

While brush fires have not resulted in major property damage or death in Avon in the past, they can lead to death and property damage if not properly managed. 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, including those over the age of 65, households with young children under the age of 5, people with mobility limitations, and people with low socioeconomic status (EEA and EOPSS 2018, 4-180). 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.

4.7.1 Potential Wildfire and Brushfire Hazard Areas

A brushfire is a fire burning in vegetation that is predominantly shrubs, brush and scrub growth. A wildfire is any non-structural fire, other than a prescribed fire, that occurs in the wildland. The Avon Fire Department responds to several brushfires annually, but they have not resulted in major property damage or deaths. Causes of these fires are due to human carelessness, such as juvenile activity. Approximately 84% of brush fires are caused by humans (Balch et al. 2017). Lightning can also be a culprit, igniting a fire when striking dry tinder on the forest floor. The two areas of town most vulnerable to wildfires are the D.W. Field Park area in the southwest portion of town and an undeveloped forest/wetlands area in the northeast corner of town. While no significant fire has occurred in either area, it remains vulnerable due to its sheer size. Also of potential concern is the Wildland-Urban Interface (WUI), which is the area where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels. Avon has a few interface areas, which would be more vulnerable to fire hazards. The areas are identified as Areas of Concern. Figure 4-5, below, shows the locations of historical brush fires and the number of acres burned in Massachusetts between 2001 and 2009.

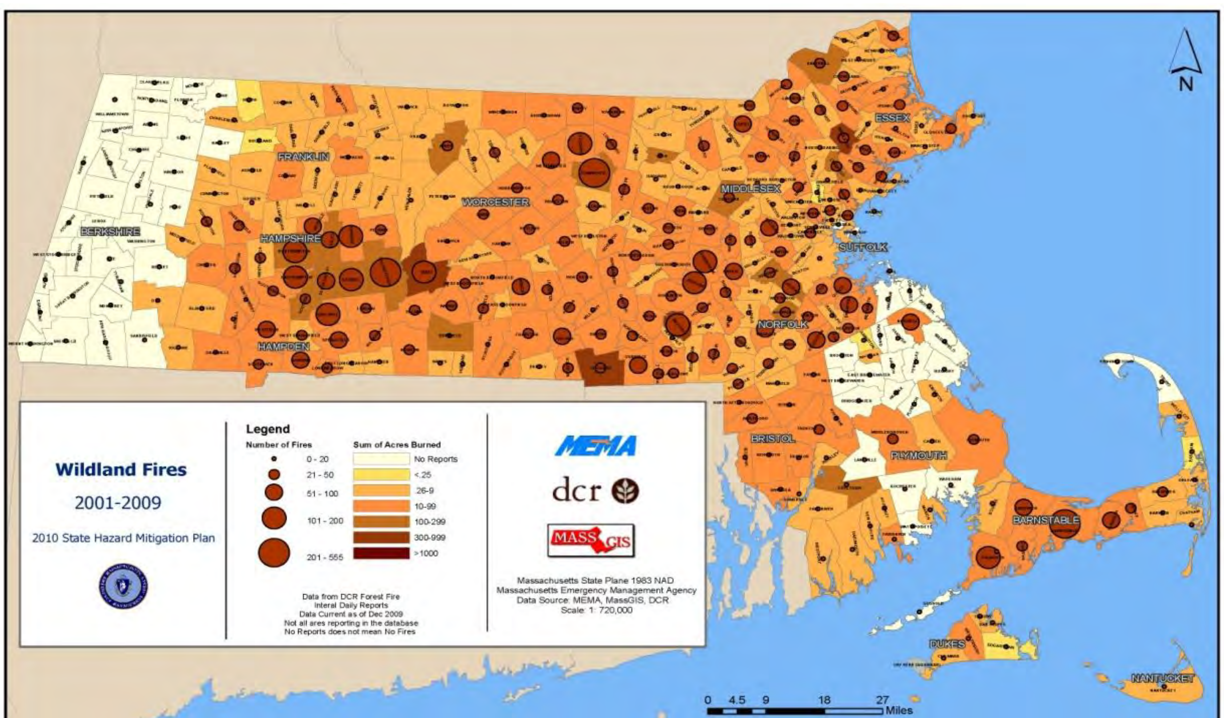


Figure 4-5. Massachusetts Brush Fires, 2001 to 2009

Source: MEMA and DCR 2013, page 261

Brush fires are classified as medium frequency events. As defined by the 2013 State Hazard Mitigation Plan, these events occur between once in 5 years to once in 50 years (a 2% to 20% chance of occurring per year).

4.8 Extreme Temperatures

Extreme temperatures are considered a townwide hazard in Avon. These events can include both temperatures over and under seasonal averages. These extreme temperature events can range from brief to lengthy.

The Boston area has four clearly defined seasons. Extreme temperatures fall outside of the ranges typically experienced during these seasons. 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 2018b). Figure 4-6 below provides a summary of anticipated temperature changes for Massachusetts by the end of the century.

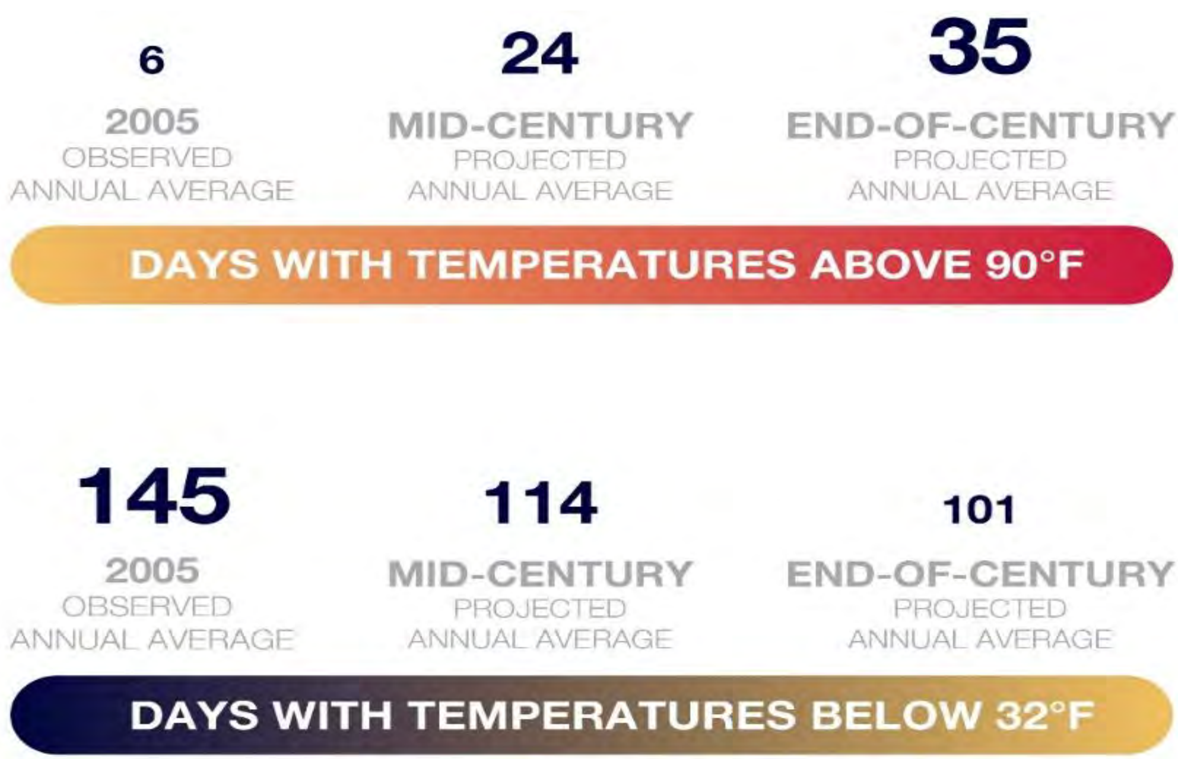


Figure 4-6. Anticipated Temperature Changes in Massachusetts

4.8.1 Extreme Cold

Extremely cold temperatures are measured using the Wind Chill Temperature Index provided by the National Weather Service (NWS). The updated index was implemented in 2001and helps explain the impact of cold temperatures on unexposed skin. Figure 4-7 on the following page provides more information.

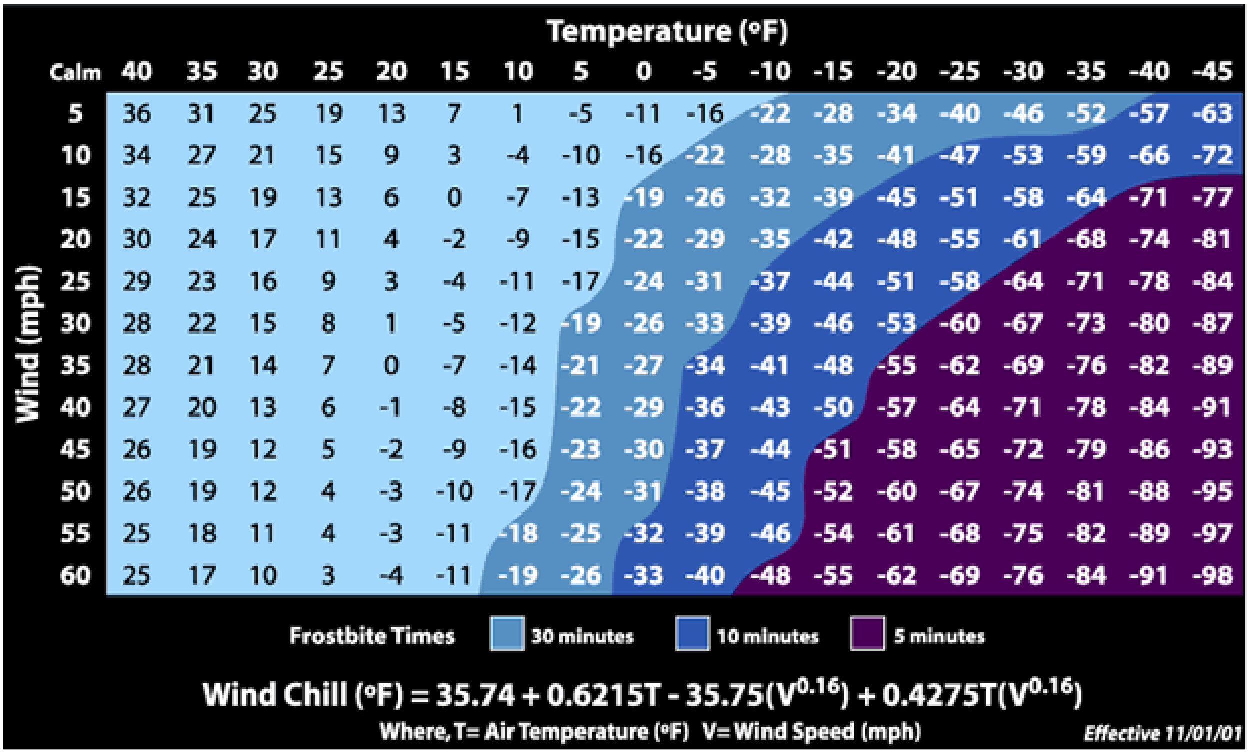


Figure 4-7. Windchill Temperature Index and Frostbite Risk

Source: National Weather Service

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 Avon, 16.0% of the population are over 65 years old and 14.3% percent of the population has a disability (ACS 2013-2017). 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.

NOAA's National Centers for Environmental Information Storm Events Database provides data for extreme cold events. Between 2000 and 2019, Norfolk County experienced nine extreme-cold and wind-chill events, which caused no injuries or property damage; but did result in one death, which occurred in 2007. Table 4-14 provides more information.

Table 4-13. Norfolk County Extreme Cold and Wind Chill Events 2000-2019

Date	Deaths	Injuries (non-mortality)	Property Damage
2/3/2007	1	0	0
2/16/2015	0	0	0
2/16/2015	0	0	0
2/16/2015	0	0	0
2/16/2015	0	0	0
2/13/2016	0	0	0

Date	Deaths	Injuries (non-mortality)	Property Damage
2/14/2016	0	0	0
2/14/2016	0	0	0
2/14/2016	0	0	0
TOTALS	1	0	0

Source: NOAA 2019a

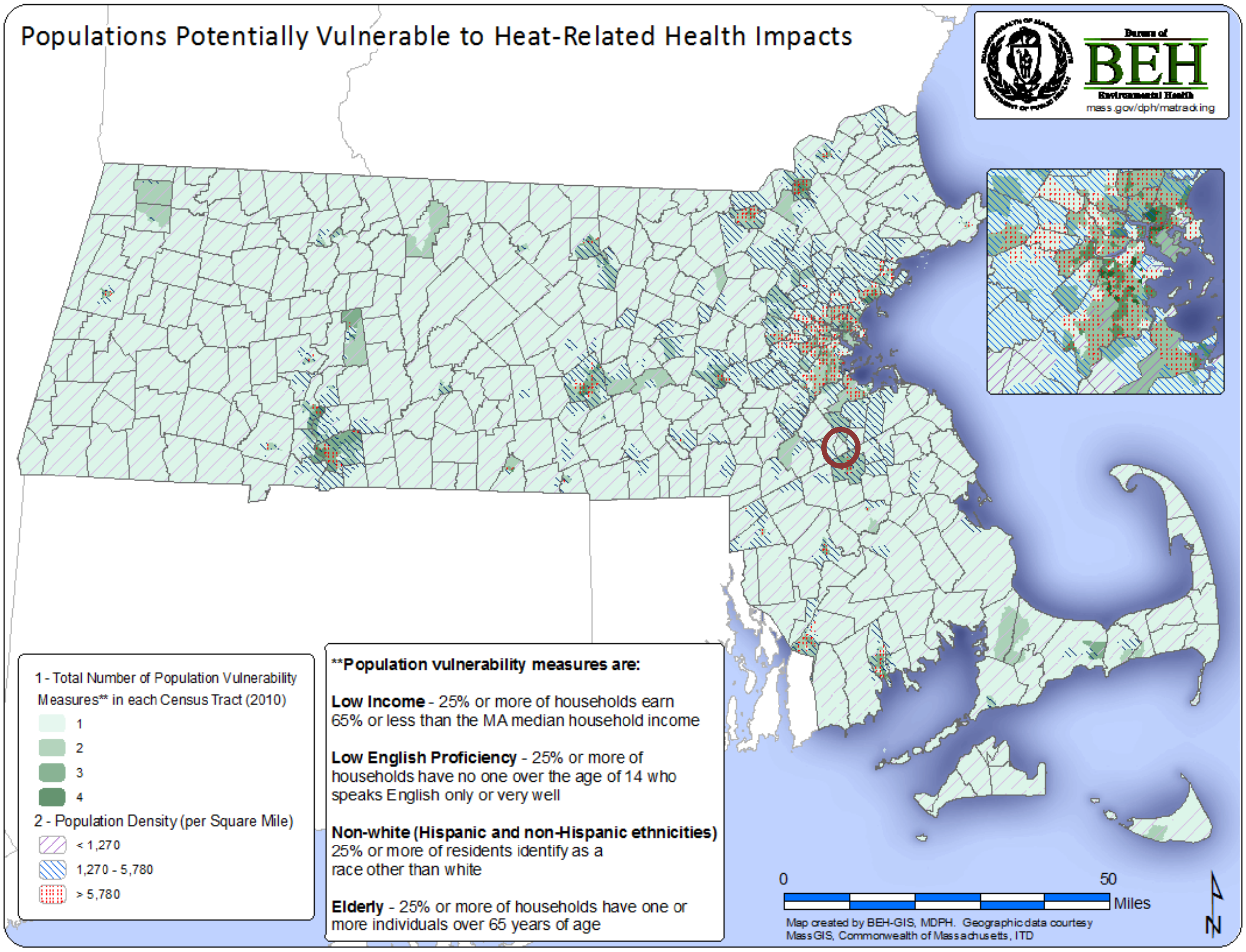
4.8.2 Extreme Heat

Increased temperatures will impact all locations within Avon. 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 4-8 below, compiled by the Massachusetts Department of Public Health Bureau of Environmental Health (MA DPH 2019), Avon has a population density of less than 1,270 persons per square mile and contains a single census tract. The town as a whole has no population vulnerability measures.

Figure 4-8. Population Potential



(Avon is shown as a red circle).

Source: Massachusetts Department of Public Health, Bureau of Environmental Health, 2019.

The National Weather Service issues a heat advisory when the heat index (Figure 4-9) is forecast to reach 100-104˚ F for two or more hours (https://www.weather.gov/bgm/heat). 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.

Relative Humidity (%)	Temperature (°F) 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.
Caution	80 °F – 90 °F	Fatigue possible with prolonged exposure and/or physical activity.

Figure 4-9. Heat Index Chart

(Source: https://www.weather.gov/safety/heat-index)

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 Avon, children under five years old make up 3.6% of the population, and 16% are over 65 years old. 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; ACS 2013-2017).

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 Avon does not collect data on heat occurrences. The best available local data are for Norfolk County, through the National Environmental Information Center. NOAA's National Centers for Environmental Information Storm Events Database provides data on excessive heat. Annually, there are approximately 11 days per year with temperatures over 90˚F.

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.

4.9 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).

Average annual precipitation in Boston is 53.32 inches per year, with approximately two to five-inch average amounts for each month of the year (NOAA 2019c). 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 six regions: Western, Central, Connecticut River Valley, Northeast, Southeast, and Cape and Islands. Avon is located within the Northeast region (EEA and MEMA, 2013). In a Drought Management Plan, a seventh region, representing the Islands alone, has been proposed (Massachusetts Water Resources Commission, 2019).

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 other measures as needed to avoid more serious shortages (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 that 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 4-10 illustrates statewide drought levels in Massachusetts from 1850 to 2012, using the Standardized Precipitation Index (SPI). Table 4-15 below summarizes a history of Massachusetts droughts between 1879 and 2017.

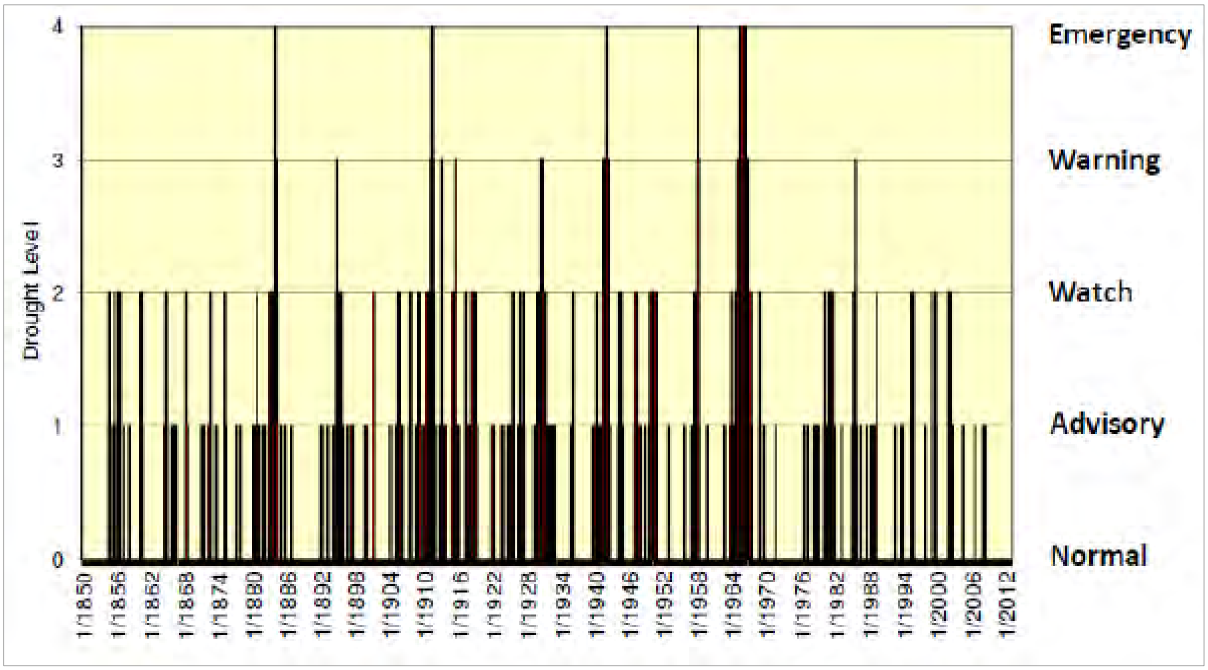


Figure 4-10. Statewide Drought Levels Using SPI Thresholds, 1850 to 2012

Source: EEA and MEMA 2013, page 37.

Table 4-14. 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.

Date	Area Affected	Recurrence Interval (years)	Remarks
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).

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, 36).

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, 36; DCR 2017b, 1).

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, 36). There were six drought watches in Massachusetts in 2002, five drought watches in 2016, and two drought watches in 2017 (DCR 2017b, 1). Figure 4-11 presents an example of drought conditions in the six drought regions.

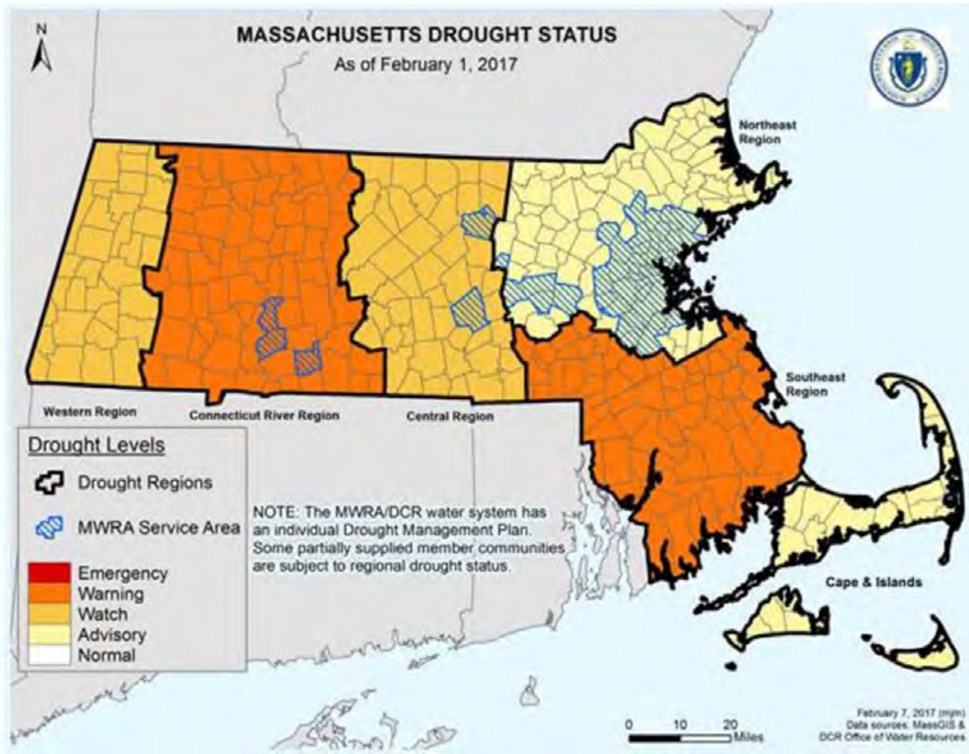


Figure 4-11. Massachusetts Drought Status, February 2017

Source: Massachusetts Department of Conservation and Recreation

Drought is a potential townwide hazard in Avon. 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, 4-45, 4-178). During Avon's MVP Workshop in September 21, 2020 workshop participants discussed the connections between multiple hazards and their potential impact on the Town. One example given was the potential for a severe drought to increase the risk of brush fires.

A long-term drought could lead to impacts to Avon's wetlands and streams. It could also have adverse impacts to the Town of Avon's water supply which draws its water from seven groundwater supply wells. In a drought emergency affecting the water supply of the Massachusetts Water Resources Authority, water use restrictions would be implemented in Avon, which could result in loss of landscaped areas and business revenues depending on the length of the water use restriction.

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).

4.10 Impacts of Climate Change

Many of the hazards that Avon is currently experiencing could be worsened by climate change. Below we discuss some potential impacts by hazard type.

4.10.1 Climate Change Impacts: Flooding

Boston's average annual precipitation is 53.32 inches (NOAA 2019b). Extreme rain and snow events are becoming increasingly common and severe particularly in the Northeast region of the country (Figure 4-12). 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, 15-16).

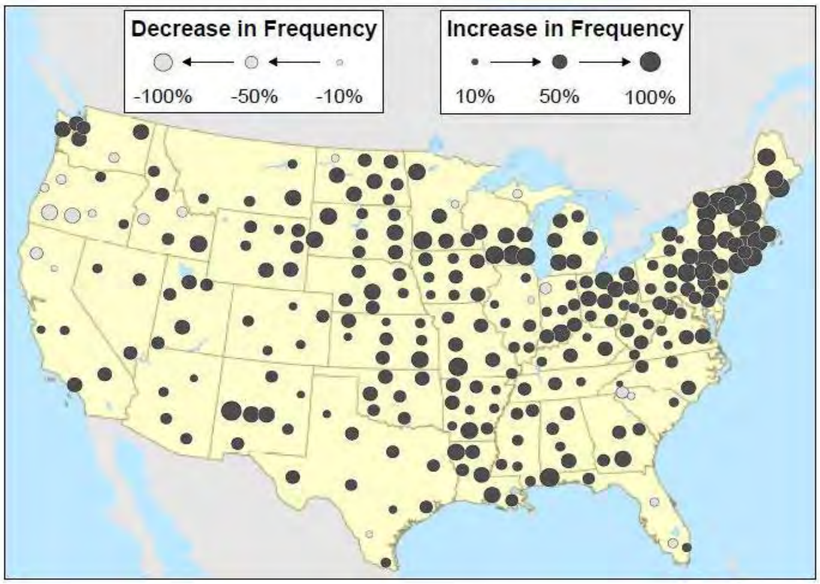


Figure 4-12. Changes in Frequency of Extreme Downpours

Source: Madsen and Willcox 2012, page 19

4.10.2 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).

4.10.3 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 4-13 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).

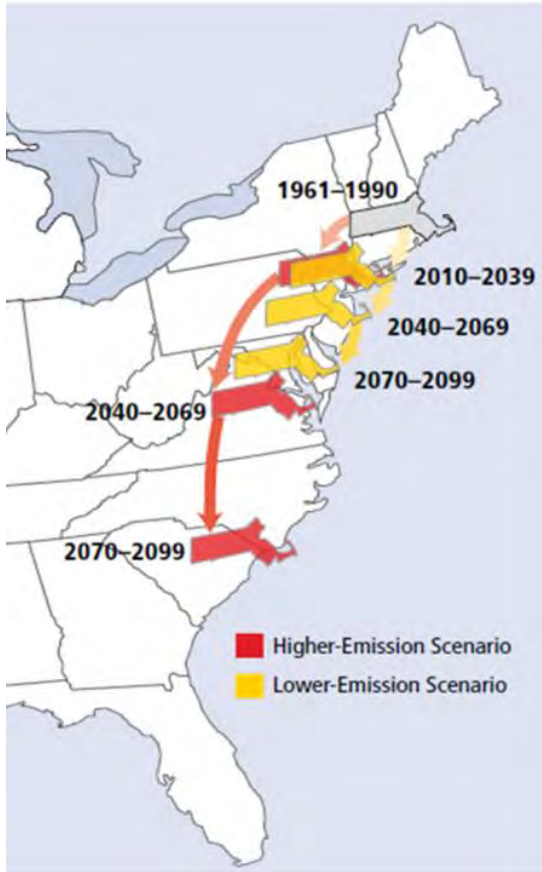


Figure 4-13. Massachusetts Extreme Heat Scenarios.

Source: Frumhoff et al. 2007

4.10.4 Climate Change Impacts: High Winds

While Avon's current 100-year wind speed is 110 mph, climate change will likely increase the number of extreme wind events and their severity. Additionally, rising sea temperature could lengthen the hurricane season and fuel stronger hurricane events. The *Fourth National Climate Assessment Volume II: Impacts, Risks, and Adaptation in the United* notes that hurricane "intensity, frequency, and duration have all increased since the early 1980s." (Jay, 2018) This source predicts the continuing intensity and associated rainfall with rising temperatures. This would result in greater losses due to increased flooding, associated building damages and business interruption impacts (Walsh and Wuebbles, 2014). The anticipated increase in frequency and intensity of severe thunderstorms may also increase the risk of tornadoes (EEA and EOPSS 2018, ES).

4.10.5 Climate Change Impacts: Winter Storms

There is evidence suggesting that nor'easters along the Atlantic coast are increasing in frequency and intensity. Future nor'easters may become more concentrated during the coldest winter months when atmospheric temperatures are still low enough to result in snowfall rather than rain (EEA and EOPSS 2018, 4-224). Climate projections indicate that climate change will result in more precipitation during the winter in the Northeast (EEA, 2018a). This trend may result in more frequent and/or more severe winter storms.

4.11 Summary of Hazard Vulnerability

It is important to be aware of the location of critical infrastructure in relation to all potential hazards in the community. Table 2-3 provides details in regard to the name and type of each piece of critical infrastructure in Avon.

5.0 HAZARD MITIGATION GOALS

The following is a list of hazard mitigation goals that were developed for Avon's HMP:

1. Prevent and reduce the loss of life, injury, public health impacts and property damages resulting from natural hazards.

2. Use best available data and management practices to prepare for and address the adverse effects of changing weather patterns (i.e., climate change).

3. Provide for effective hazard preparation and implementation through appropriate:

    - Funding.
    - Personnel training and transfer of knowledge and skills.
    - Equipment and capital improvement (e.g., infrastructure).
    - Emergency systems.
    - Communication and notifications systems.

4. Educate the public about hazard mitigation and provide opportunities for the public to engage in hazard mitigation planning.

5. Encourage the business community, major institutions and nonprofits to work with Avon to develop, review, to implement the hazard mitigation plan.

6. Work with surrounding communities, state, regional and federal agencies to ensure regional cooperation and mitigation for hazards that affect multiple jurisdictions.

7. Incorporate hazard mitigation, as appropriate, into Avon's plans and policies to ensure effective preparedness and proper land development.

6.0 EXISTING MITIGATION MEASURES

FEMA categorizes hazard mitigation measure into four types: Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, and Education and Awareness Programs as presented below in Table 6-1. The existing protective measures available to the Town of Avon 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.

Table 6-1. 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 also 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	• Radio or television spots • Websites with maps and information • Real estate disclosure • Presentations to school groups or neighborhood organizations

Measure	Action	Examples
	officials, stakeholders, and the public is more likely to lead to direct actions.	• Mailings to residents in hazard-prone areas. • StormReady • Firewise Communities

(*FEMA*, 2013p. 6-4)

The town's existing mitigation measures are described by hazard type here and are summarized in Table 6-2 below. Many upgrades to existing measures are noted in the following sections.

6.1 Existing Townwide Mitigation for Flood Related Hazards

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

Participation in the NFIP – Avon participates in the NFIP with 14 policies in force as of March 02, 2020. FEMA maintains a database on flood insurance policies and claims. This database can be found on the FEMA website at https://www.fema.gov/policy-claim-statistics-flood-insurance

The following information is provided for the Town of Avon:

Table 6-2. National Flood Insurance Program in Avon

Flood Insurance Data	
Flood insurance policies in force (September 30, 2018)	14
Coverage total of flood insurance policies	$5,885,200
Premiums paid	$17,340
Total number of closed paid losses	3
Total dollar amount of closed paid losses	$717

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.

Street sweeping – The town performs street sweeping annually on major roads and secondary roads.

Catch basin cleaning – The town cleans its catch basins annually.

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

Stormwater System and Outfalls Mapped in GIS – The town is in the process of developing a drainage system inventory and integrating the data into the Town's Geographical Information System (GIS).

Zoning Regulations – Zoning is intended to protect public health and safety through the regulation of land use. The Avon Zoning Ordinance includes a Floodplain District (Section 255-11.3).

The town's Floodplain District (Zoning Ordinance Section 255-11.3) is implemented as an overlay and includes all special flood hazard areas within the Town designated as Zone A, .AE, A99, V, or VE on the Norfolk County Flood Insurance Rate Map issued by FEMA for the NFIP

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

Stormwater Management Plan – The town has a Stormwater Management Plan, which has been finalized.

Wetlands Protection Act – The Avon Conservation Commission administers the state's Wetlands Protection Act (Chapter 239) to protect resource areas in and around wetlands, including land subject to flooding.

Reviews and Inspections of New Developments – Town staff and boards provide drainage reviews and the Public Works Department inspects utility connections for water sewer and drains once construction of a site is completed.

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

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

6.2 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.

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

Emergency Action Plan – The Town has adopted the *Emergency Action Plan for Brockton Reservoir Dam* in order to provide an action plan for response to an emergency situation to protect person and property downstream of the Brockton Reservoir Dam.

6.3 Existing Townwide 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 the Town – The town's Public Works Department maintains street trees and numerous trees on public grounds, historic sites, conservation areas, park areas, and cemeteries.

Tree Maintenance by Energy Utilities National Grid and Eversource Energy) – Utilities trim trees along the power lines. Preventative maintenance of trees along the power lines would be beneficial.

6.4 Existing Townwide Mitigation for Winter-Related Hazards

Snow Removal Requirements in the General Code –The town's general code provides an opportunity for the Board of Selectmen to annually declare a Winter Parking Ban on town ways and property to be in effect from November 1 to April 1 of the succeeding year. This provides for the ability for the Town to cause to be removed any vehicle which interferes with snow removal or safe vehicular traffic upon public ways or property.

Snow-Plowing Operations – The Public Works Department provides standard snowplowing operations, including sanding and salting.

6.5 Existing Townwide 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.

Public Education – The Fire Department provides substantial public education on fire prevention on their website at www.avon-ma/gov/fire-department.com.

Backup Firefighting Water Supplies – The town has several surface waterbodies that can be used for backup water supplies for fighting fires.

Statewide Fire Mobilization Plan – The state has a fire mobilization plan for brush fires.

6.6 Existing Townwide Mitigation for Extreme Temperature-Related Hazards

Schools as Emergency Shelters – The Middle High School and Elementary School would serve as shelters in the event of extreme-temperature hazards.

Medical Reserve Corps Volunteer (Stoughton, Holbrook, Avon, Randolph) – Avon has a regional volunteer program, which is administered through the health department, where residents can help provide critical services during emergency situations.

6.7 Existing Townwide 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 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.

6.8 Existing Multi-Hazard Mitigation Measures

Comprehensive Emergency Management Plan (CEMP) – Every community in Massachusetts is required to have a Comprehensive Emergency Management Plan. These plans address mitigation, preparedness, response and recovery from a variety of natural and man-made emergencies. These plans contain important information regarding flooding, hurricanes, tornadoes, dam failures, earthquakes, and winter storms. Therefore, the CEMP is a mitigation measure that is relevant to all the hazards discussed in this plan.

Local Emergency Planning Committee (LEPC) – 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 Town of Avon has identified locations where hazardous materials are stored, used, and transported.

LEPC Emergency Plan – The LEPC response plan is available via the Town website.

Public Education – Emergency Preparedness public education is available on the Town's website, via the Fire Department, and Police Department, Emergency Management Department.

Code RED – The town has a Code RED Emergency Notification System that automatically calls all residents and businesses to communicate emergency information. Residents may update their Code Red information on the Town website.

Schools as Emergency Shelters – The Middle High School would serve as shelters in the event of a disaster.

Multi-Department Review of Developments – Multiple departments, such as Health, Public Works, Fire, Police, Emergency Management and Conservation, thoroughly review all subdivision and site plans prior to approval.

Stable Communications Systems – Avon has reliable communications towers that house communications equipment for the Police and several other town departments.

Backup Generators – In the event of power outages due to downed limbs, the Town does have backup generators at critical town buildings and facilities.

Buried Utilities – New subdivision developments are required to install underground utilities.

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

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

6.9 Compilation of Existing Mitigation

There are numerous existing natural hazard mitigation measures already in place in Avon (Table 6-3).

Table 6-3. Existing Mitigation Measures

Type of Existing Mitigation Measures	Area Covered	Effectiveness/ Enforcement	Improvements/ Changes Needed
MULTIPLE HAZARDS			
Comprehensive Emergency Management Plan (CEMP)	Townwide	Effective	Needs to be periodically updated
Communications Equipment (Stable)	Townwide	Effective	None
Massachusetts State Building Code	Townwide	Most effective for new construction.	None
Multi-Department Review of Developments	Townwide	Effective	None
Local Emergency Management Planning Committee (LEPC)	Townwide	Effective	None
LEPC Emergency Plan	Townwide	Effective	None
Backup Generators	Critical Town Building and Facilities	Effective	None

Type of Existing Mitigation Measures	Area Covered	Effectiveness/ Enforcement	Improvements/ Changes Needed
Enforceable Standard to Require Installation of Buried Utilities in New Subdivisions	Townwide	Effective	None
Reverse 911	Townwide	Effective	None
Public Education	Townwide	Effective	Continue to expand outreach
Medical Reserve Corps Volunteers	Townwide	Effective	None
FEMA Deployment	Statewide	Effective	None
FLOOD HAZARDS			
Participation in the NFIP. The town actively enforces the floodplain regulations.	Areas identified on the FIRM maps	There are 184 policies in force. FIRM map dated 2019	Encourage all eligible homeowners to obtain insurance
Stormwater System and Outfalls Mapped in GIS	Townwide	The town has developed a drainage system inventory and integrated the data into a Geographical Information System (GIS)	Should be periodically updated
IDDE Program Implementation	Townwide	Effective	Continue sampling at outfalls.
Street sweeping	Townwide	Effective	None
Catch basin cleaning	Townwide	Effective	None
Drainage system maintenance	Townwide	Effective	Ongoing maintenance needed
Ongoing Drainage Improvement Program	Townwide	Effective	Ongoing improvements needed
Zoning – Floodplain District	Townwide	Effective	None
Wetlands Protection Act	Wetland Resource Areas	Effective	None
Massachusetts Stormwater Regulations	Conservation Commission jurisdictional areas	Effective	None
Review and Inspection of New Development Drainage	Townwide	Effective	None
Public Education on Stormwater	Townwide	Effective	Continue to update and inform the public
NPDES Phase II Stormwater Program	Townwide	Effective	Continue implementation
DAM HAZARDS			

Type of Existing Mitigation Measures	Area Covered	Effectiveness/ Enforcement	Improvements/ Changes Needed
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.
Brockton Dam Upgrade	Brockton Reservoir	Effective	Continue to perform regular maintenance
Brockton Reservoir – Avon and Brockton mitigate against potential spills and contamination.	Brockton Reservoir	Effective	Continue mitigation
WIND HAZARDS			
The Massachusetts State Building Code	State-wide	Effective for most situations except severe storms	None
Tree Maintenance by the Town	Townwide	Effective	None
Tree Maintenance by Electric Utilities (National Grid and Eversource Energy)	Townwide	Effective	Further maintenance of trees along power lines would be beneficial
WINTER HAZARDS			
Snow-Plowing Operations	Townwide	Effective	None
Snow Removal Requirements in the General Code	Townwide	Effective	None
BRUSH FIRE HAZARDS			
Open Burning Permits Required	Townwide	Effective	None
Public Education	Townwide	Effective	None
Fire Department Review of Proposal Developments	Townwide	Effective	None
Statewide Fire Mobilization Plan	Statewide	Effective	None
GEOLOGIC HAZARDS			
The Massachusetts State Building Code	Townwide	Effective for most situations	None

6.10 Mitigation Capabilities and Local Capacity for Implementation

Under the Massachusetts system of "Home Rule," the Town of Avon 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 Ordinance, Stormwater Ordinance, Subdivision and Site Plan Review Regulations, Wetlands Ordinance, Health Regulations, Public Works regulations, and local enforcement of the State Building Code. Local Ordinances may be amended by the Board of Selectmen 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 Avon 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.

7.0 STATUS OF MITIGATION MEASURES FROM THE OLD COLONY REGION PLAN

7.1 Implementation Progress on the Previous Plan

At a meeting of the Avon Core Committee, town staff reviewed the mitigation measures identified in the Natural Hazard Mitigation Plan for the Old Colony Region. The Core Committee felt it was important to determine which mitigation measures were still relevant and whether each measure had been implemented or deferred. Of those measures that had been deferred, the committee evaluated whether the measure should be deleted or carried forward into this HMP-MVP Plan. The decision on whether to delete or retain a particular measure was based on the committee's assessment of the continued relevance or effectiveness of the measure and whether the deferral of action on the measure was due to the inability of the Town to act on the measure. Table 7-1 summarizes the status of the mitigation measures, along with the priority of these measures. The breakdown of high and medium priority measures, along with any other possible measures, are provided in the table. The priority "NFIP" refers to potential mitigation measures that would ensure continued compliance with the National Flood Insurance Program.

Table 7-1. 2021Status of Mitigation Measures from the Old Colony Region Plan

Category of Action & Hazard Addressed	Mitigation Measure	Priority	2021 Status Completed / In Progress / Not Completed	Include in 2021 Plan/ Priority
High Priority				
A) Structural Project-Flooding	Extend the culvert from the headwaters of the West Trout Brook to the parking lot of the Avon Public Library to mitigate periodic flooding of the library parking lot	High	Completed	No
B) Structural Project – Flooding	Enhance drainage in the Brentwood Avenue subdivision to alleviate flooding concerns	High	Completed	NO
C) Natural Resource Protection – Flooding	Continue to clear brooks and streams throughout town of trash and vegetation to allow for the free flow of water and to mitigate the threat of flooding	High	In Progress	Yes High
D) Prevention – Flooding	Create a drainage map of the entire town to identify areas in need of new or additional drainage infrastructure	High	Completed	No
Medium Priority				

Category of Action & Hazard Addressed	Mitigation Measure	Priority	2021 Status Completed / In Progress / Not Completed	Include in 2021 Plan/ Priority
E) Prevention, Strucutal Project-Flooding	Develop and implement a local flood mitigation dam management program, including inspecting, maintaining and upgrading the following dams for present functions and stormwater management potential: Brockton Reservoir Dam and dams along the lakes and ponds of D.W. Field Park.	Medium	Completed	No
F) Prevention – Wildfire	Enhance fire roads into DeMarco Park by clearing vegetation making it easier for the Police & Fire Departments to access during fires	Medium	Not Completed. (No incidents reported. Discontinue action unless a need emerges.	No
G) Structural Project – Flooding	Clean and maintain the stormwater detention pond at the intersection of Bodwell Street and Murphy Drive to alleviate the threat of flooding during periods of heavy rain	Medium	Completed (Property has been sold and is the responsibility of the new owner.)	No
Low Priority				
Structural Project – Flooding	Upgrade the surface drainage infrastructure on Bodwell Street to alleviate flooding concerns	Low	Unknown (This system is in private ownership. Discontinue.)	No
Structural Project – Flooding	Upgrade the surface drainage infrastructure on Kiddie Drive to alleviate flooding concerns	Low	Unknown (This system is in private ownership. Discontinue.)	No

As the Town moves forward into the next five-year plan implementation period; identifying and incorporating hazard mitigation into the Town's decision-making process will be a high priority. Limited staffing and financial resources are the biggest challenges the Town faces in implementing the mitigations measure identified in this plan. The plan is intended to assist the Town in prioritizing the proposed measures, which will provide guidance on how to best allocate the Town's limited resources.

8.0 HAZARD MITIGATION STRATEGY

8.1 Regional and Inter-Community Consideration

Several hazard mitigation issues are primarily local. The problem originates largely within the municipality and can be resolved at the municipal level. Other issues are inter-community and require a coordinated effort between two or more municipalities. Regional mitigation issues usually involve a state, regional and/or federal agency, or three or more municipalities.

Mitigation measures for the following regional issues should be considered as Avon develops its own local plan:

A) Coordination and Review of Developments on a Regional Basis for Stormwater Management: As Avon and the surrounding communities are undergoing development, it is vital that these communities communicate and provide input during the review process. When addressing housing, transportation, and economic development projects, the impacts on neighbors must be addressed.

B) Continue to coordinate with Brockton concerning the reservoir? An emergency action plan for the Brockton Reservoir Dam was adopted in 2020.

C) Increase Electric Utilities' Tree Maintenance Program: An issue during storms in Avon is the damage to power and phone wires from overhanging trees that have not been trimmed by the electric utilities or the phone or cable companies. Eversource should continue with their reactive and preventative measures. Eversource clear cuts every few years.

8.2 Regional Partnerships

Mitigating natural hazards, particularly flooding, 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 Town, Massachusetts Department of Transportation (MassDOT) the Massachusetts Water Resources Authority (MWRA), and the Department of Conservation and Recreation (DCR). The planning, construction, operation, and maintenance of these structures are integral to the flood 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 the sections that follow, the plan provides recommendations for activities where cooperation with these other agencies will likely be necessary. In order to implement many of these mitigation measures, all parties will need to work together towards a mutually beneficial solution.

8.3 Regional and Inter-Community Facilities in Avon

Major facilities owned, operated and maintained by state or regional entities include:

- State Routes 24 and 28
- MBTA Bus Lines
- Bus Routes and Commuter Rail Line

8.4 Planning for New Development and Infrastructure

Hazard mitigation planning needs to consider new development and associated infrastructure in order to anticipate additional hazards that may occur with community growth. As part of the process of developing recommendations for new mitigation measures for this plan, the Town considered issues related to new development, redevelopment, and infrastructure needs in an attempt to limit future risks.

New development takes into consideration the Massachusetts Building Code; this is enforced by the Building Department. New development also considers local Zoning, the Wetlands and Stormwater Ordinances. Priorities for the future include stormwater management, stormwater mapping, and installation of green infrastructure and Low Impact Development to promote stormwater recharge and alleviate flooding.

8.5 Methods for Analysis and Prioritization

During the Core Committee meetings, officials in Avon determined possible mitigation measures for the various natural hazards that have impacted or could impact the Town.

Local officials prioritized the measures, reviewing the project Goals, such as:

- The number of homes and businesses affected by the hazard.
- Whether or not road closures occurred and what impact closures had on the delivery of emergency services and the local economy.
- Whether any environmental constraints existed.
- Is there political support and public support to implement the mitigation measures?
- Can the Town provide the necessary maintenance when the mitigation measure is completed?
- Does the cost seem reasonable when considering the size of the problem and likely benefits from mitigation?

8.6 Identification of Hazard Mitigation and Climate Adaptation Strategies

The Town developed a list of priority hazard mitigation and climate adaptation strategies through 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.
- Progress on the previous plan.
- Input from stakeholders.

Stakeholders were engaged through Core Team meetings, the CRB Workshop, and the public input session. The list of all the action items from the CRB Workshop are available in Appendix A and were integrated into the final list of action items developed by the Core Team. Table 8-1 below represents the Town's recommended hazard mitigation measures and prioritization of these measures. Each mitigation measure was analyzed for its the overall benefit, the estimated cost, timeframe, and implementation responsibility to inform prioritization. A description of the ach of the prioritization categories in Table 8-1 is identified below.

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

Implementation Responsibility – Most mitigation measures will require a multi-department approach where several Town departments share responsibility. This determination is at the discretion of the governing body of the community. The designation of implementation responsibility in the table was assigned based on general knowledge of the responsibilities of each municipal department.

Timeframe – The timeframes represented below are assigned based on the complexity of the measure, the overall priority of the measure and at what stage of design and/or funding has been attained. Because the timeframe for this plan is five years, the timing for all mitigation measures has been kept within this framework. The identification of timeframes is not meant to prevent a community from actively seeking out and taking advantage of funding opportunities as they arise. Timeframes designated as "long term" are estimated to be more than five years. Those designated as "medium term" are estimated as more than three but less than five years. "Short term" is estimated to be less than three years.

Estimated Cost – Cost estimates are given when cost data was available from the community. All cost data would need to be updated at the time of design and construction and is only provided as an estimate. Costs designated as "High" are estimated to be greater than $100,000. Those designated as "Medium" are estimated to between $10,000 to $100,000. "Low" costs are estimated to be less than $10,000.

Potential Funding Sources – This column identifies the most likely sources of funding for a specific measure. The identification of potential funding sources in this table is preliminary and may vary depending on numerous factors. These factors include, but are not limited to, if a mitigation measure is conceptual or has been studied, evaluated or designed. In most cases, the measure will require an assemblage of funding sources. The funding sources identified in this table are not a guarantee that a specific project will be eligible for or receive funding. Upon adoption of this plan, the local representatives responsible for implementation should begin to explore the funding sources in more detail.

Priority – Designation of high, medium, or low priority was based on overall potential benefits, areas affected and estimated project costs. A High Priority action is very likely to have political and public support and necessary maintenance can occur following the project, and the costs seem reasonable considering likely benefits from the measure. 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.

Table 8-1. Recommended Hazard Mitigation Measures

Mitigation Action	Geographic Coverage	Implementation Responsibility	Timeframe	Estimated Cost	Potential Funding Sources	Priority
		Lead is indicated in bold	S is < 3 Years M is 3 – 5 Years L is > 5 Years	$=<$10,000 $$ is > $10,000 and <$100,000 $$$ >=$100,000		
FLOODING						
Improve drainage system maintenance (include drainage ditches and prepare a proactive Wetlands Protection Act Notice of Intent)	Townwide	Public Works	Ongoing	$$	Grants, Municipal	High
Flood control measures for structures	Townwide	Public Works	Short-term	$$$	Grants, Municipal	High
Flood proofing for pumping stations	Townwide	Public Works	Long-term	$$$	Grants, Municipal	High
Cloudburst mitigation measures for roadways	Townwide	Public Works	Short and Long-Term	$$$	Grants, Municipal	Medium
Assessment and major cleaning of drainage system	Townwide	Public Works	Short and Long-Term	$$	Grants, Municipal	Medium
Convert to sewer system or upgrade septic systems.	Prioritize Industrial/Commercial Areas (Stockwell and Memorial Drive) And Areas in Proximity to Wells	Town Council Public Works Private Parties	Ongoing, Short and Long-Term	$$$	Grants, Municipal, Private Developer	Medium to High

Mitigation Action	Geographic Coverage	Implementation Responsibility	Timeframe	Estimated Cost	Potential Funding Sources	Priority
Implement green infrastructure and improve existing BMPs.	Townwide	Public Works	Ongoing	$$$	Grants, Municipal	Medium
Implement individual stormwater project retrofits.	Townwide	Public Works	Long-term	$$$	Grants, Municipal	Medium
Complete stormwater mapping and make it accessible to emergency personnel.	Townwide	Public Works	Short-term	$$	Grants, Municipal	High
Raise public awareness on keeping drainage ditches clean and availability of the composting facility	Townwide	Public Works	Short-term	$	Municipal	High
Improve management of risk associated with PFAS, hazardous materials and waste spills and other potential contaminants	Townwide	Public Works	Short-term	$$	Grants, Municipal	High
WIND						
Distributed generation	Townwide	Town Council Public Works	Long-term	$$$	Grants, Municipal, Private Developer	High
Tree assessment and maintenance plan (include riparian areas)	Townwide	Public Works Utility Company	Short-term and Ongoing	$$	Municipal	High
Mobile chipper for post-storm fallen branch and debris management	Townwide	Public Works	Short-term	$$$	Grants, Municipal	High

Mitigation Action	Geographic Coverage	Implementation Responsibility	Timeframe	Estimated Cost	Potential Funding Sources	Priority
Repeater site antenna replacement/repair	Page Street Water Tank	Police Department Public Works	Short-term	$$$	Grants, Municipal	High
Provide backup power sources	Townwide	Town Council Public Works	Ongoing	$$$	Grants, Municipal	High
Convert to fiber optic lines	Townwide	Town Council Public Works Public Safety	Long-term	$$$	Grants, Municipal	High
Provide a radio control option for communications	Townwide	Public Safety Public Works	Short-term	$$	Grants, Municipal	High
MULTI-HAZARD						
Work with schools to improve communication with foreign born.	Townwide	School Department Town Council	Short-term and Ongoing	$	Municipal	Medium
Identify translators to assist with dissemination of information.	Townwide		Short-term and Ongoing	$	Municipal	Medium
Establish a website or call center for translation services.	Townwide	Town Council	Short-term and Ongoing	$	Municipal	Medium
Provide variable message boards in strategic locations.		Town Council Public Safety	Long-term	$$	Grants, Municipal	Medium
DROUGHT						
Provide a water supply interconnection for purchase of water.	Townwide	Town Council Public Works	Long-term	$$$	Grants, Municipal	High

Mitigation Action	Geographic Coverage	Implementation Responsibility	Timeframe	Estimated Cost	Potential Funding Sources	Priority
Repair existing water storage tanks	Page Street Central Street	Public Works	Short-term	$$$	Municipal	High
Develop a traffic reduction plan to reduce greenhouse gasses	Townwide	Public Works	Short-term	$$	Grants, Municipal	Medium
WINTER STORMS						
Add storage and implement improvements and regular maintenance at snow compost site	Downtown	Public Works	Short-term and Ongoing	$$	Municipal	Low

PLAN ADOPTION AND MAINTENANCE

9.1 Plan Adoption

The Avon HMP-MVP Plan was adopted by the Town on *[ADD DATE]*. See Appendix D for documentation. The plan was approved by FEMA on [*ADD DATE*] for a five-year period that will expire on [*ADD DATE*].

9.2 Plan Maintenance

After approval of the plan by FEMA, and adoption of the plan by the Town, the Core Committee that originally convened as the steering committee for establishing the Plan will transition its work to updating and keeping the Plan current. Coordinated by the Department of Public Works, the Core Committee will meet annually or on an as-needed basis, whichever is most frequent, to monitor plan implementation and may include additional members from local businesses, non-profits, and institutions. The town will engage the public during the next 5-year planning cycle and encourage local participation whenever possible. All updates and accomplishments of the Core Committee and the Town, related to mitigation measure and the plan itself, will be placed on the Town's web site. All public meetings to update the Plan will be publicly noticed in accordance with town and state open meeting laws and the public will be encouraged to attend and participate.

9.3 Implementation and Evaluation Schedule

Bi-Annual Survey on Progress – The coordinator of Core Committee, William Fitzgerald, will prepare and distribute a survey halfway into the five-year plan. The survey will be made available to all Core Committee members and any other interested local stakeholders. The survey will assist in determining any necessary changes or revisions to the plan that may be needed. In addition, it will help provide information on progress and accomplishments for implementation and any new hazards or problem areas that have been identified since the plan drafting.

The information collected through the survey will be used to formulate a report and/or addendum to the plan. It will be important to evaluate the status of measures accomplished and initiated towards meeting the plan's goals. Additionally, identifying areas that need to be updated in the next plan will need to be an ongoing process. The Core Committee, led by the designated coordinator, will have primary responsibility for tracking progress, evaluating, and updating the plan during the next five years and beyond.

Preparation for the Plan – FEMA's initial approval of this plan is valid for five years. During that time the Town will need to continue to track progress, amend hazards and identify additional hazards and mitigation measures. By doing so, the Town will maintain a plan, which will secure eligibility for FEMA mitigation grants, and future updates will be relatively easy since information will have been collected and updated throughout the five-year life of this plan. Given the lead time needed to secure funding and conduct the planning process, the Core Committee will begin drafting the full update of the plan in year four. The group will use the information from the year four biannual review, in addition to any other data and information collected, to identify the needs and priorities for the plan update. 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.

Update Preparation and Adoption – Once the resources have been secured to update the plan, the Core Committee will need to determine whether to undertake the update itself or hire a consultant. If the Core Committee 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 Avon HMP-MVP Plan Update will be forwarded to MEMA and DCR for review and to FEMA for ultimate approval.

9.4 Integration of the Plans with Other Planning Initiatives

Upon approval of the Avon HMP-MVP Plan by FEMA, the Core Committee 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:

Fire Department/Emergency Management

Police Department

Public Works Department

Planning Board

Conservation Commission

Parks and Recreation

Board of Health

Building

Coordination with Town Departments, Town Boards and Commissions, neighboring communities, and other interested groups and organizations will be required for successful implementation and continued updating. The adopted plan will be posted on the Town's website. Any sections of the plan containing sensitive information that would be considered inappropriate for public posting will be removed prior to posting. The posting of the plan on the Town's web site will provide a mechanism for citizen feedback, such as an e-mail address for interested parties to send comments.

Appropriate sections of the HMP-MVP Plan will be integrated into other town plans, policies and documents as those are updated and renewed, including the Open Space and Recreation Plan, Comprehensive Emergency Management Plan, and Capital Investment Program.

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APPENDIX A

Core Team Meeting Materials and Community Resilience Building Workshop

Municipal Vulnerability Preparedness Planning Grant and
Hazard Mitigation Plan Update

Core Team Meeting

Mary T. McDermitt Room, Town Hall, 65 East Main Street
Friday, January 10, 2020
9:00 am – 10:30 am

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

Core Team Roles

- Establish the goals for the project plan.
- Provide data and local expertise on the assets and vulnerabilities.
- Participate in the stakeholder workshop.
- Finalize priority actions for the final report.

Suggested Goals

1. Prevent and reduce the loss of life, injury, public health impacts and property damages resulting from natural hazards and climate change.

2. Use best available data and management practices to prepare for and address the adverse effects of changing weather patterns (i.e., climate change) and natural hazards.

3. Provide for effective climate changed and natural hazard preparation and implementation through appropriate:

- Funding.
- Personnel training and transfer of knowledge and skills.
- Equipment and capital improvement (e.g., infrastructure).
- Emergency systems.
- Communication and notifications systems.
- Shelter for displace residents.

4. Educate the public about climate change and hazard mitigation and provide opportunities for the public to engage in planning.

5. Encourage the business community, major institutions and nonprofits to work with the Town to develop, review, to implement municipal vulnerability preparedness and natural hazard mitigation.

6. Coordinate with surrounding communities, state, regional and federal agencies to ensure regional cooperation and mitigation for climate change and natural hazards that affect multiple jurisdictions.

7. Incorporate vulnerability preparedness and hazard mitigation, as appropriate, into plans and policies to ensure effective preparedness and proper land development.

Data Sources

- State data such as MassGIS.
- Local GIS data.
- Existing related plans:
    - Old Colony Hazard Mitigation Plan
    - Avon Stormwater Management Plan
    - Stormwater Asset and Water Infrastructure Management Plan
- Town bylaws and regulations
- Town annual report

Community Resilience Building Workshop Participants

How to identify participants…

- Who are the key decision makers?
- Who is directly responsible for implementing decisions?
- Who influences decision making in your community?
- Who will be affected by the decisions made?

Some typical invitees…

- Core Team
- Local Boards (utility, school, health, council on aging, etc.)
- Environmental Advocates
- Nonprofits
- Hospitals or Emergency Care Facilities
- Town Staff
- Elected Officials
- Representatives from Neighboring Towns
- Major Employers and Chamber of Commerce

Greetings,

The Town of Avon was recently awarded a grant from the Commonwealth's Municipal Vulnerability Preparedness Program to identify priority action items that will improve our community's resilience to climate change. We plan to engage municipal staff, key stakeholders, and the broader public throughout the process.

As a leader in the community, you are invited to join the Town at an **invitation-only** workshop on September 21, 2020 from 9:00 am to 1:00 pm. The workshop will take place virtually, using Microsoft Teams. You will receive a separate invitation with a link to join the Teams Meeting, which will be sent out at the end of this week.

The workshop will follow the Community Resilience Building guidance developed by the Nature Conservancy, which has been successfully used in over 100 communities. The workshop's objectives are to:

- Identify natural hazards that present the greatest threat to the community.
- Evaluate strengths and vulnerabilities of residents, infrastructure, and natural resources.
- Develop and prioritize actions that reduce the impact of hazards and increase resilience.

I hope you or a designee can join the Town at this important workshop. By participating in this program, Avon will be designated as an MVP Community and be eligible for future grants that promote resilience. Following the workshop, we will be hosting a meeting open to public to receive broader input on the planning process.

Please RSVP for the workshop by Thursday September 17, 2020 by emailing our certified MVP Provider, Jim Riordan (riordanj@wseinc.com).

Thank you for your consideration and participation!

Sincerely,

William Fitzgerald, Director
Avon Public Works

Avon
Municipal Vulnerability Preparedness (MVP)
Stakeholder Workshop

Monday, September 21, 2020, 9:00 am – 1:00 pm
Via Microsoft Teams

1. Welcome and Introductions
2. Workshop Overview
3. Introduction to the MVP Risk Matrix
4. Climate Change and Local Hazards

   BREAK (10:00– 10:15 am)

5. Identification of Features
6. Community Actions

   Break (11:30 – 11:45 pm)

7. Action Prioritization
8. Wrap-Up and Closing Remarks

Weston & Sampson

TOWN OF AVON

COMMUNITY RESILIENCE BUILDING WORKSHOP

September 21, 2020

WELCOME CORE TEAM

Robert Spurr
Jeffrey J. Bukunt
Kathleen Waldron
Brian Martin

Patricia Bessette
William Fitzgerald
Gregory Enos

WELCOME W&S

Jim Riordan

Ashley Sweet

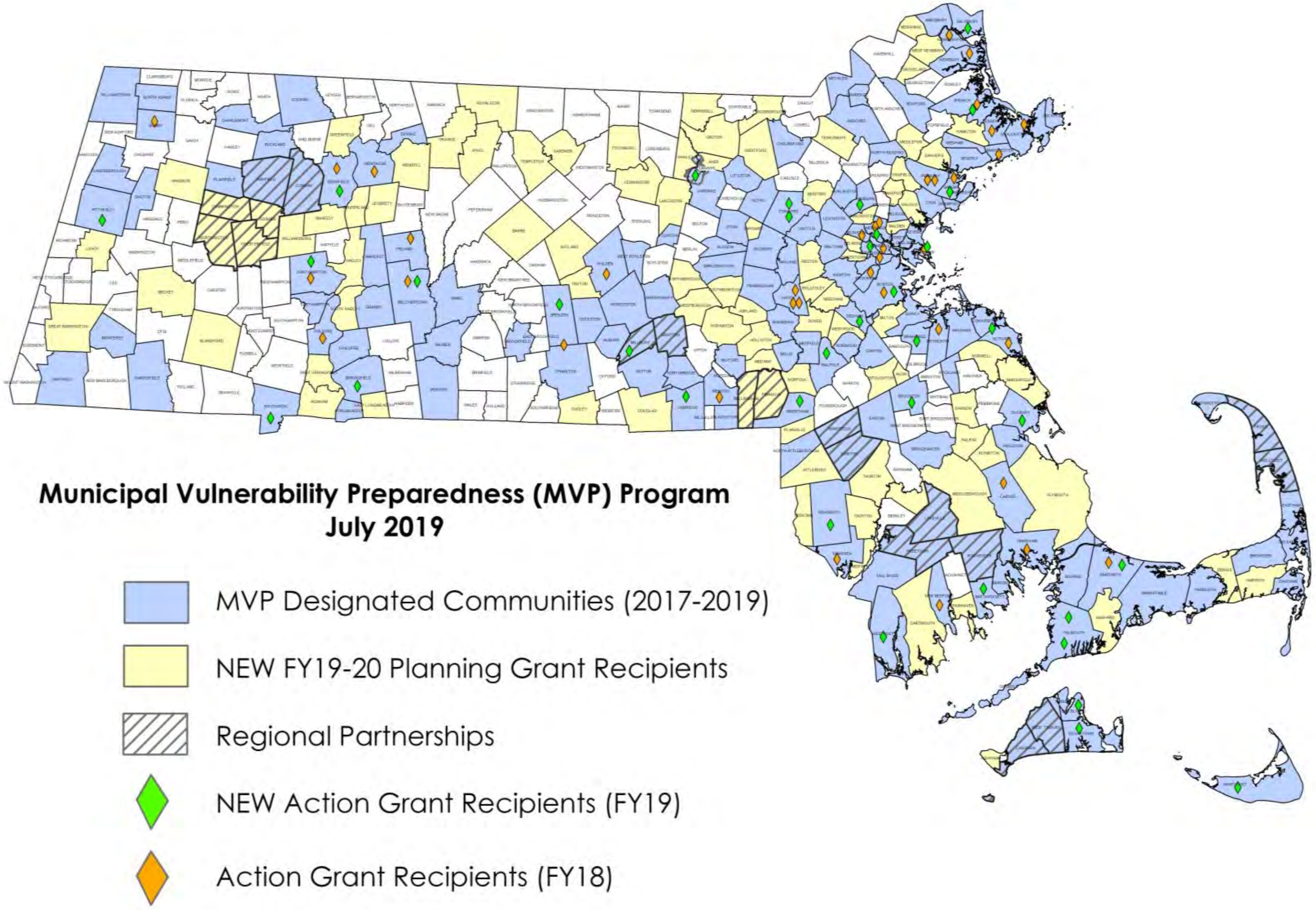
WELCOME PARTICIPANTS

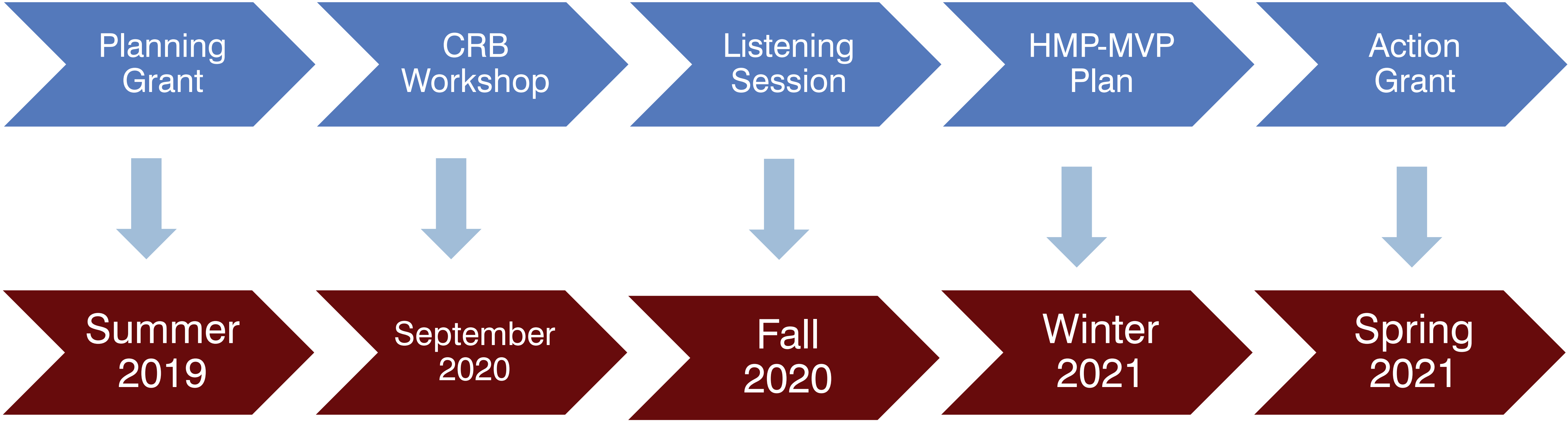
Your name

Organization/Relationship to Avon

Favorite thing about Avon

MUNICIPAL VULNERABILITY PREPAREDNESS PROGRAM (MVP)




Planning Grant
CRB Workshop
Listening Session
HMP-MVP Plan
Action Grant
Summer 2019
September 2020
Fall 2020
Winter 2021
Spring 2021

MVP IN AVON

- Increase resilience of community
- Raise awareness of climate threats
- Identify priority actions to move forward
- Create implementation pathways

HAZARDS & CLIMATE CHANGE

IN AVON AND NEW ENGLAND

Weston & Sampson

HAZARDS IN AVON

FLOOD HAZARDS

WIND HAZARDS

WINTER STORMS

EARTHQUAKES, LANDSLIDES, ETC.

FIRE

EXTREME TEMPERATURES

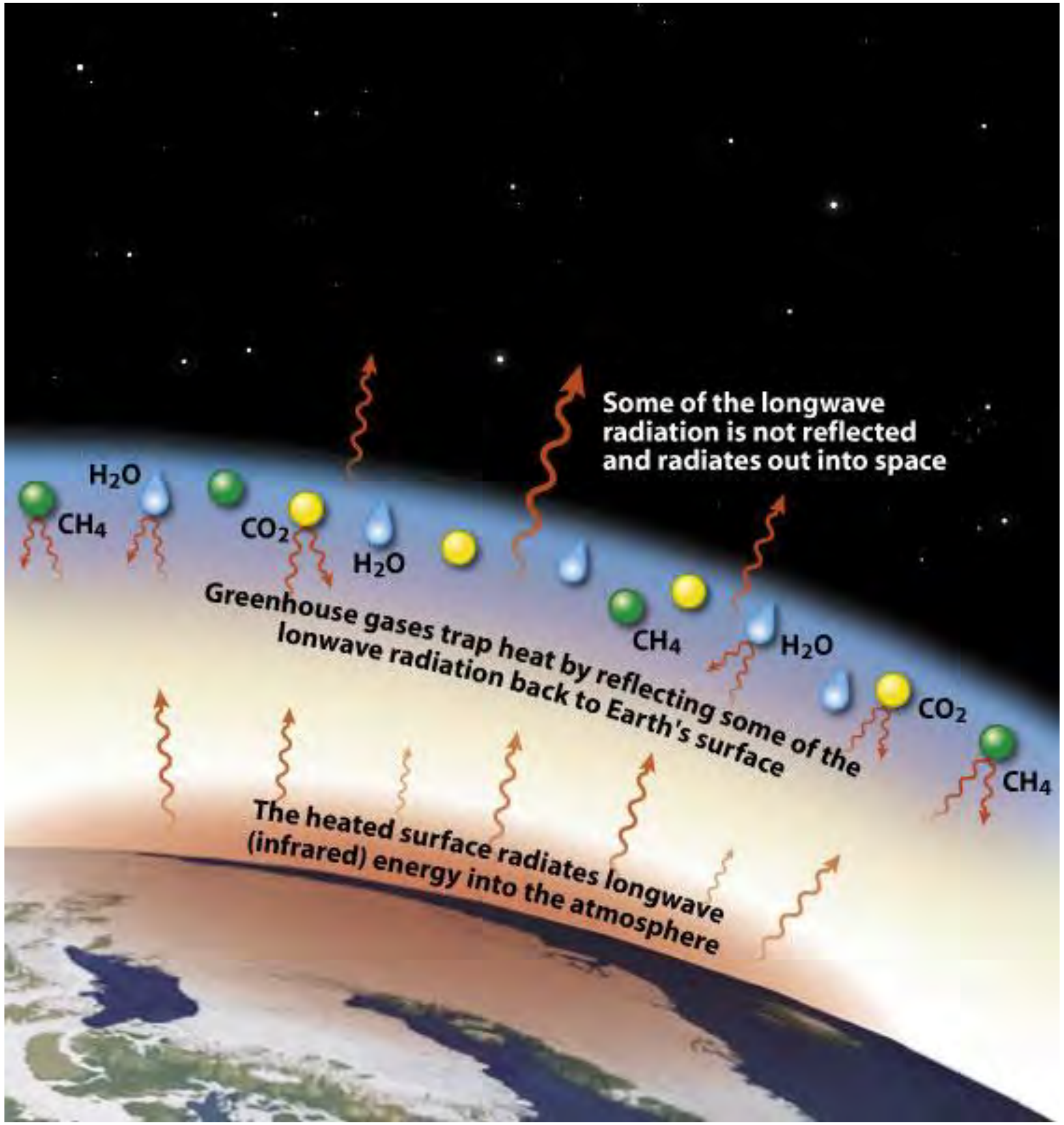
DROUGHT

CLIMATE CHANGE

GREENHOUSE GASES (GHG)

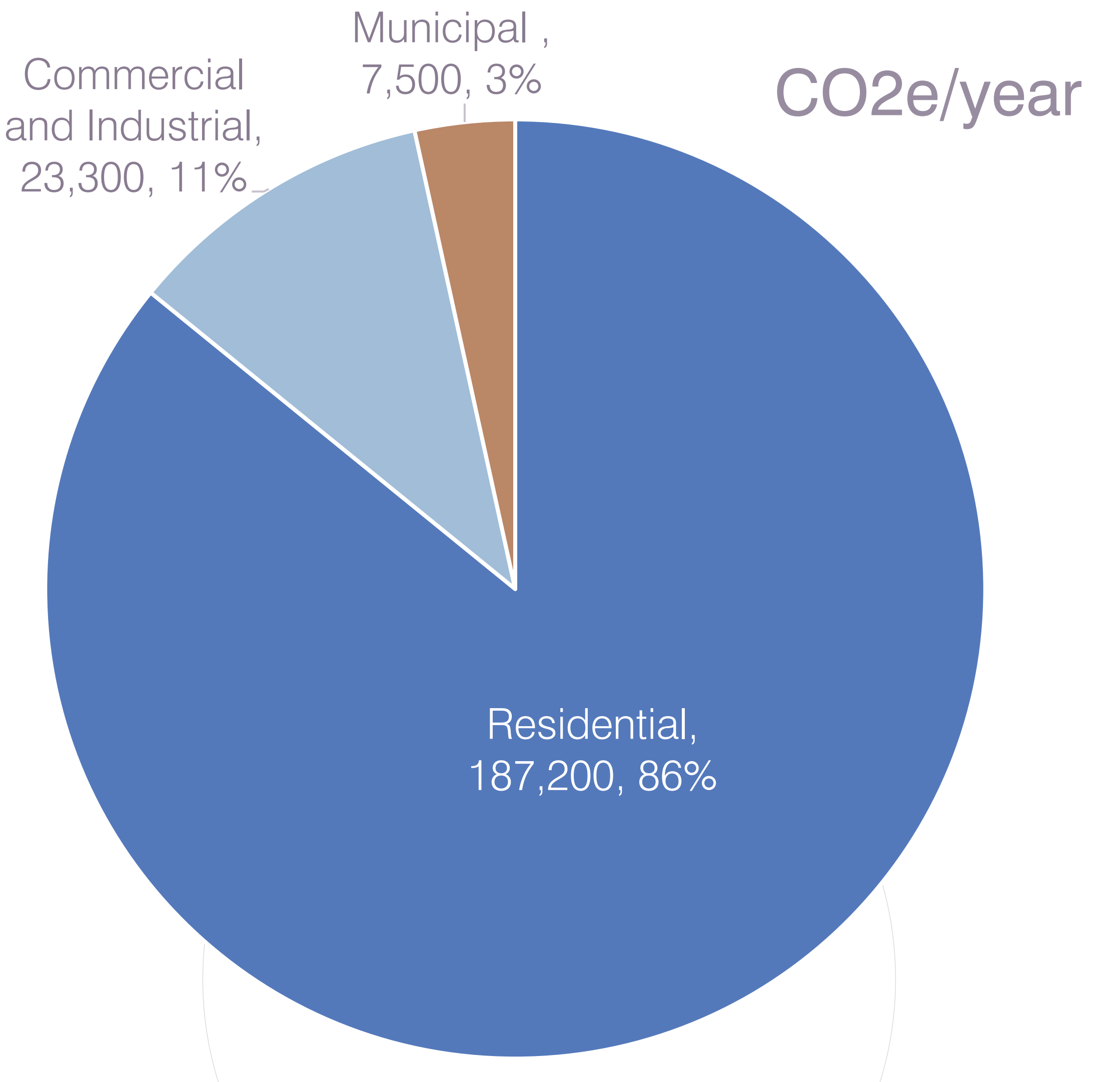
- Naturally occurring
- Act as a blanket
- Examples: carbon dioxide and methane

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

2006 GHG EMISSIONS



Hazards in Avon

Hazard	Frequency (in Avon)	Severity (in Avon)
Flooding	High	Minor to Serious
Dam Failures	Very Low	Minor
Snow and Blizzard	High	Minor to Extensive
Ice Storms	High	Minor to Extensive
Hurricanes	Medium	Serious
Nor’easters	High	Minor To Extensive
Thunderstorms	High	Minor to Extensive
Brush Fires	Medium	Minor to Extensive
Earthquakes	Very Low	Minor to Catastrophic
Landslides	Low	Minor
Extreme Temperatures	High	Minor to Serious
Drought	High	Minor to Serious

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

Weston & Sampson

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

Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "ResilientMA Datagrapher." Massachusetts Climate Change Clearinghouse. Resilientma.org/datagrapher/?c=Temp/state/tx90/ANN/MA/
Notes: Mid-century projected annual averages use a 2040-2069 time range. End-of-century project annual averages use a 2080-2097 time range.

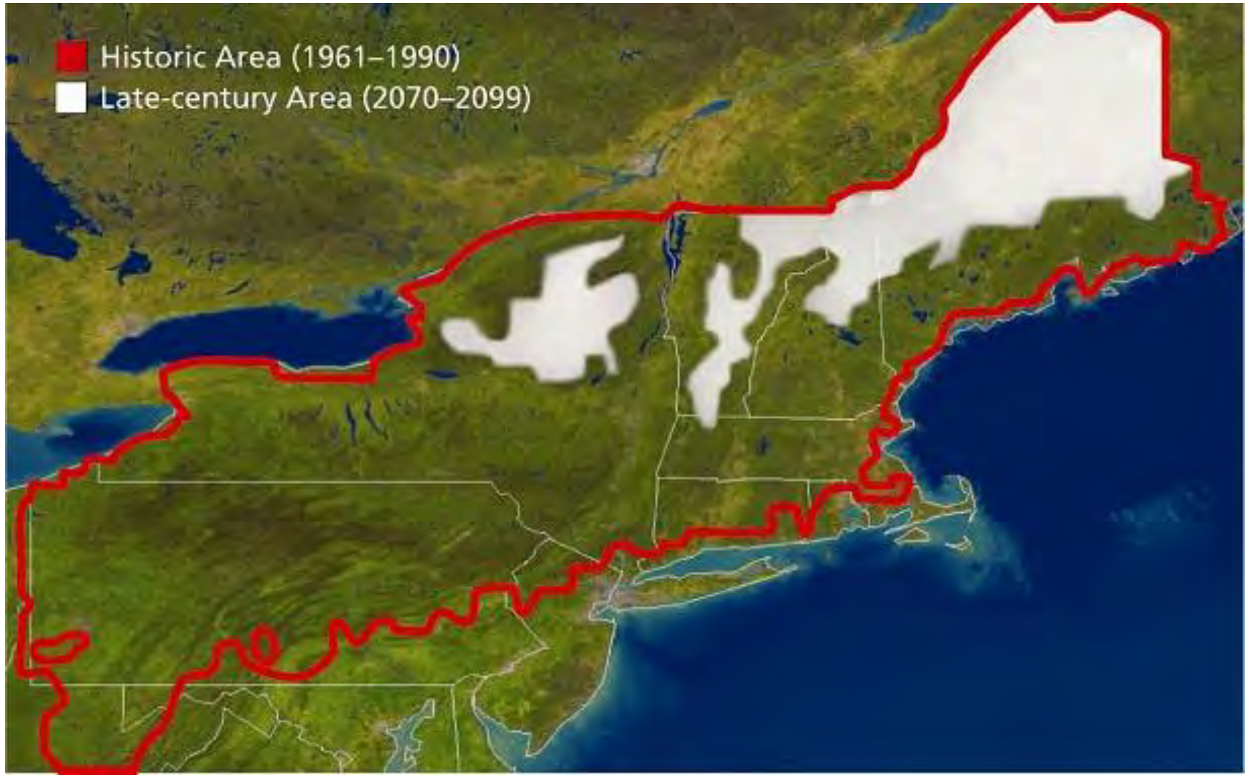


Photo: UCSUSA "Confronting Climate Change in the U.S. Northeast".

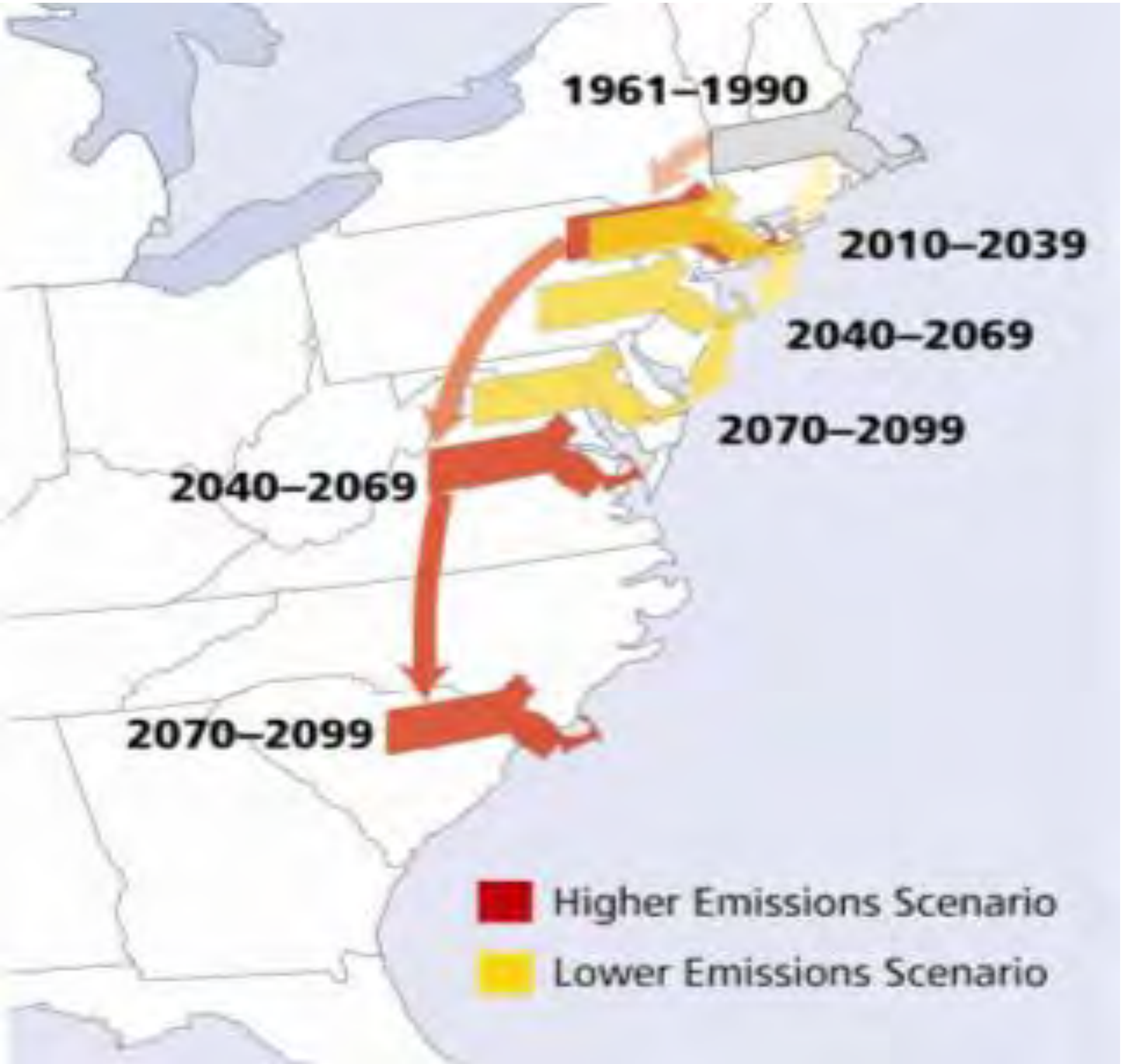


Photo: NECIA/UCS, 2007.

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INCREASING AVERAGE **TEMPERATURE**
IN MASSACHUSETTS (°F)

48.13

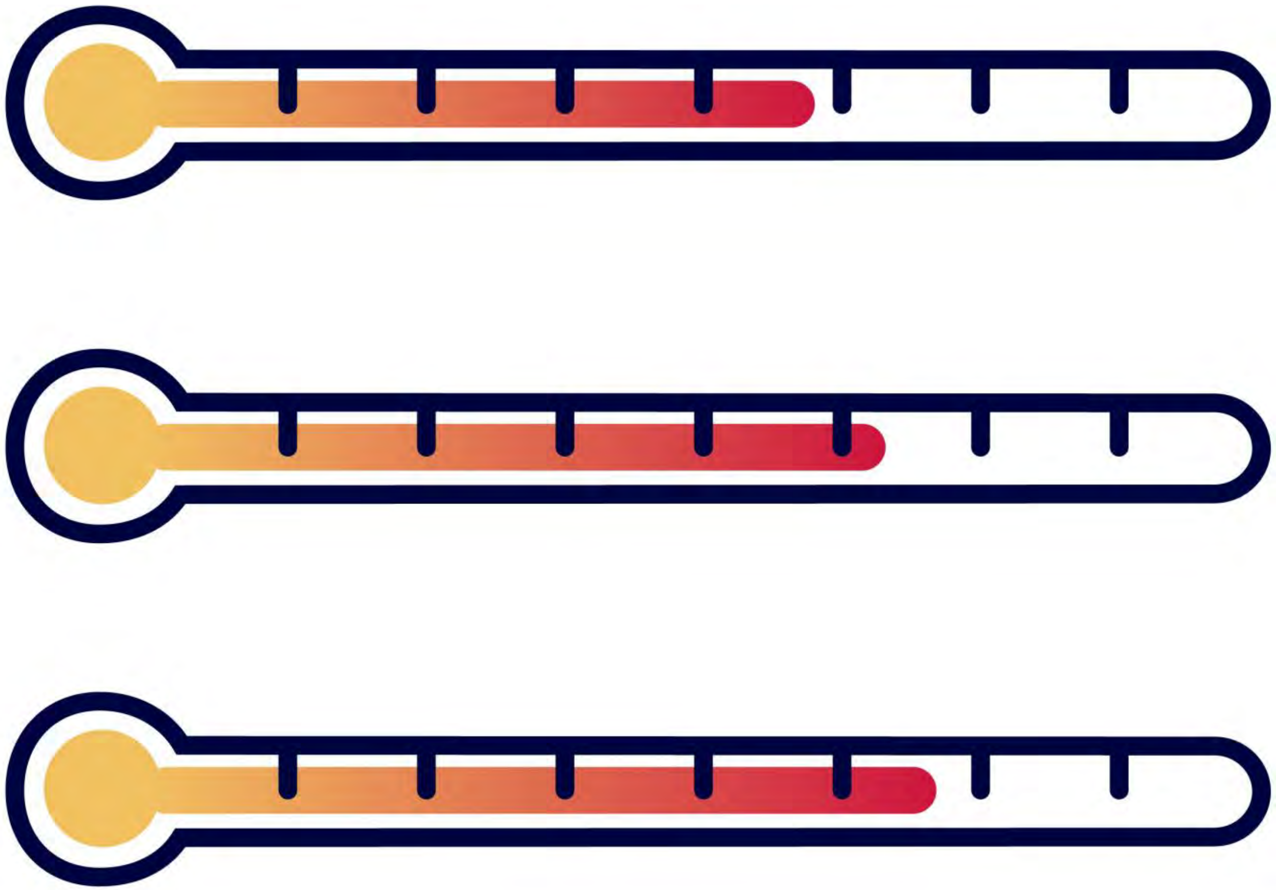
2005
OBSERVED
ANNUAL AVERAGE

53.43

MID-CENTURY
PROJECTED
ANNUAL AVERAGE

55.32

END-OF-CENTURY
PROJECTED
ANNUAL AVERAGE

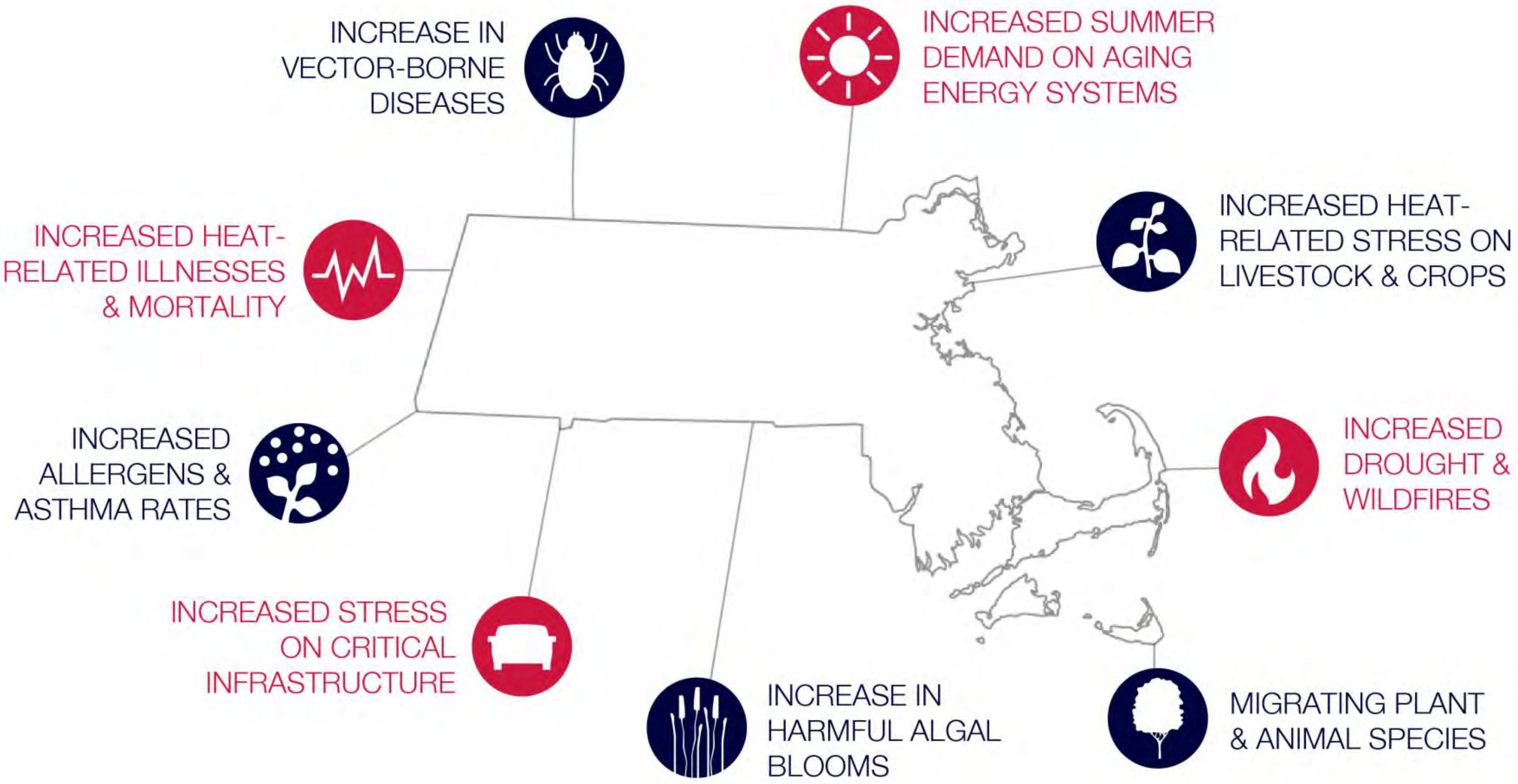


Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "ResilientMA Datagrapher." Massachusetts Climate Change Clearinghouse. Resilientma.org/datagrapher/?c=Temp/state/tx90/ANN/MA/
Notes: Mid-century projected annual averages use a 2040-2069 time range. End-of-century project annual averages use a 2080-2097 time range.

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



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Rising Temperatures." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/rising-temperatures

BOSTON
MOSQUITO SEASON GROWING
THEN
96
DAYS
On average per year
1980-1989
NOW
119
DAYS
On average per year
since 2006
CLIMATE CENTRAL

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

EXTREME PRECIPITATION

8%

Increase in extreme precipitation events by midcentury

13%

Increase in extreme precipitation events by 2100

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PROJECTED CHANGES IN **PRECIPITATION**

ANNUAL TOTAL PRECIPITATION
IN MASSACHUSETTS (IN INCHES)

56.51	58.70	59.71
2005 OBSERVED ANNUAL AVERAGE	MID-CENTURY PROJECTED ANNUAL AVERAGE	END-OF-CENTURY PROJECTED ANNUAL AVERAGE

EXTREME RAIN EVENTS WITH **MORE THAN 2" OF RAIN PER DAY** IN MASSACHUSETTS

<1 DAY/YEAR	0.9-1.5 DAYS/YEAR
CURRENT	2100

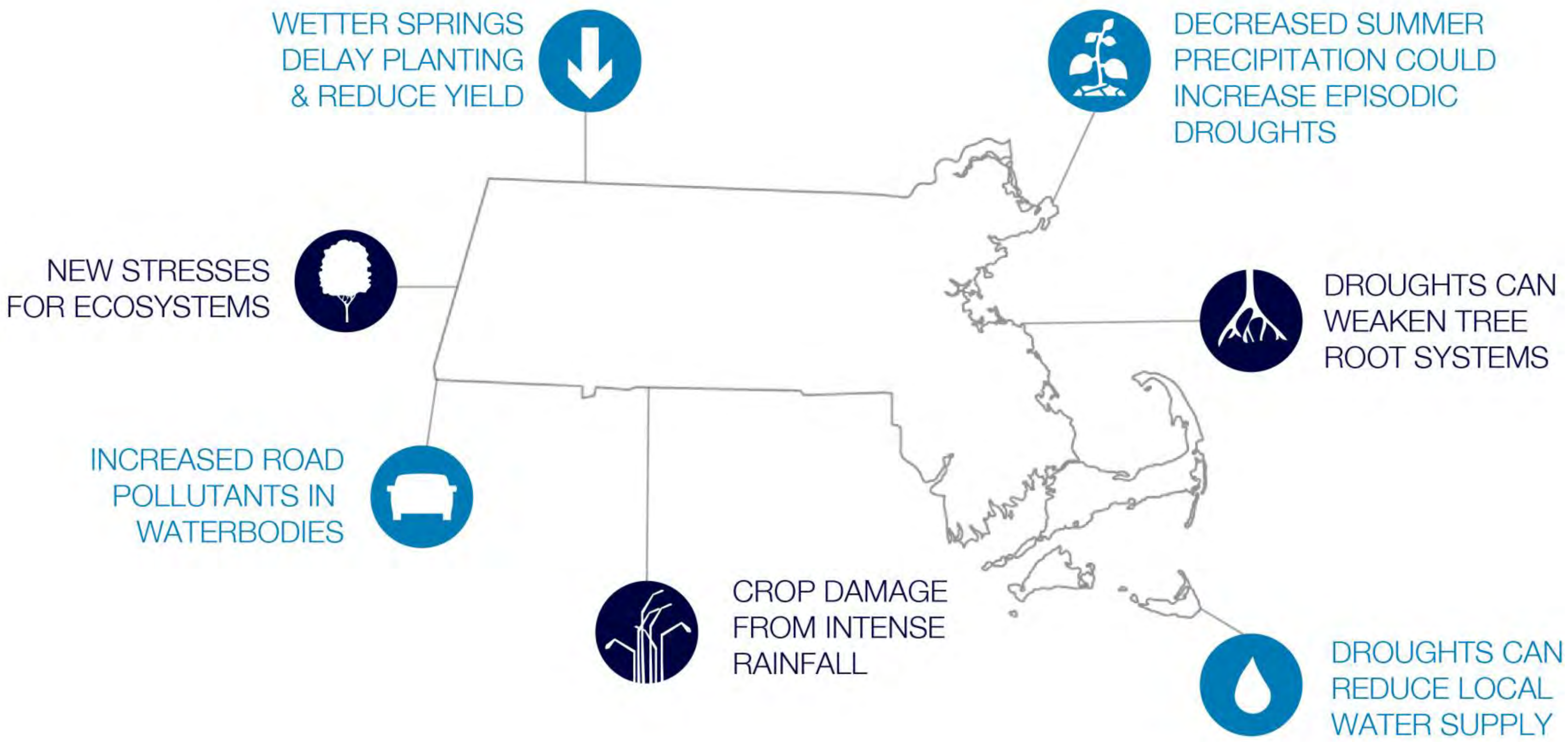
Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "ResilientMA Datagrapher." Massachusetts Climate Change Clearinghouse. Resilientma.org/datagrapher/?c=Temp/state/pcpn/ANN/MA/
Notes: Mid-century projected annual averages use a 2040-2069 time range. End-of-century project annual averages use a 2080-2097 time range.

IMPACTS OF CHANGING **PRECIPITATION**

Weston & Sampson

HIGHER AVERAGE ANNUAL PRECIPITATION

INCREASED BY ABOUT 10% IN THE NORTHEAST INTHE LAST 50 YEARS



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

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"

FLOODING

Vulnerable Areas

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

75 events reported by NOAA since 1998 for Norfolk County:

- No reported deaths or injuries
- Just over $41M in property damage
- March 2010 accounts for just over 80% of total damage

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."

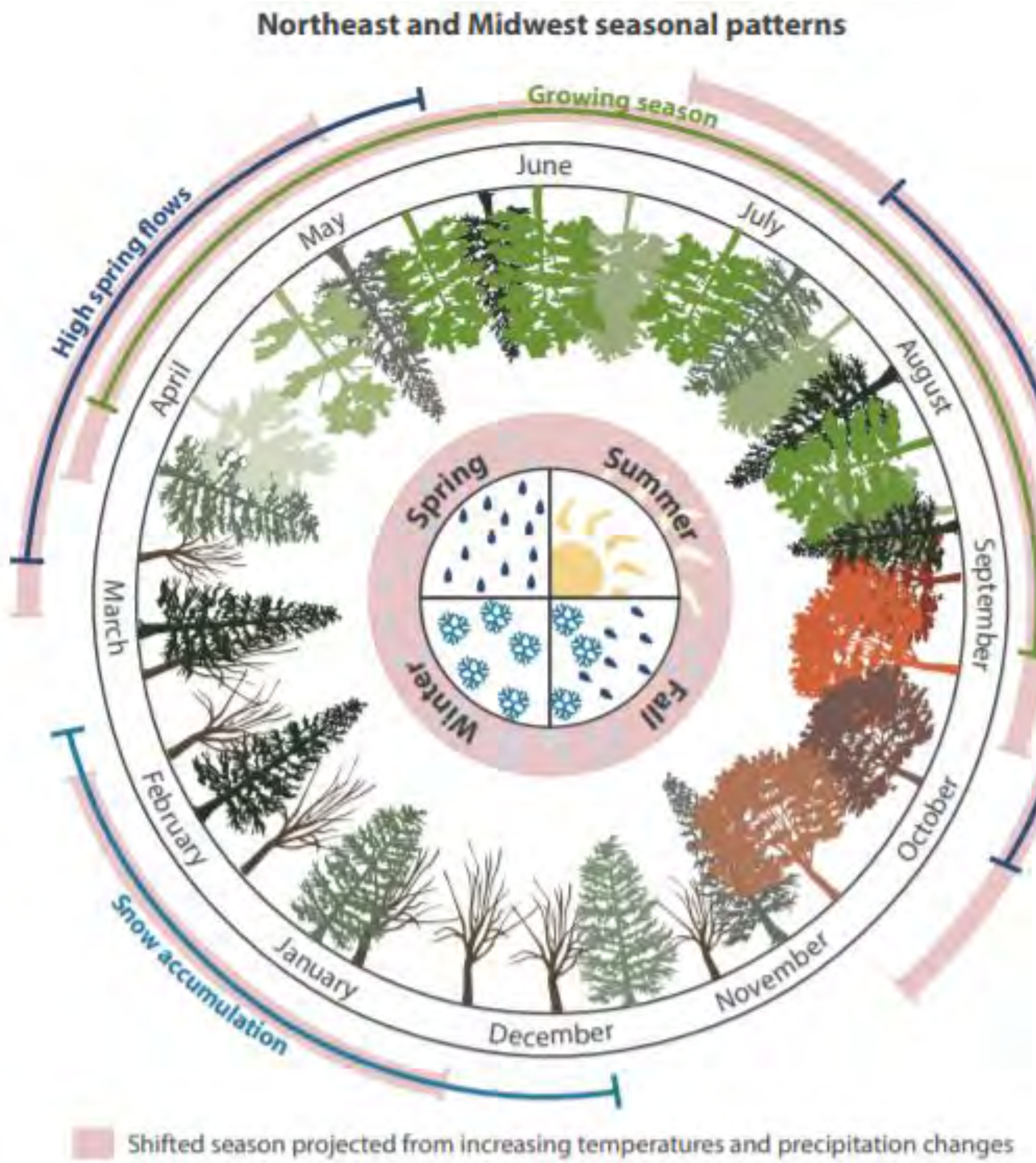


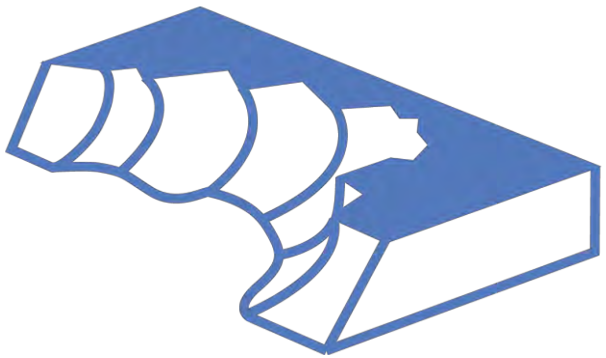
Image credit: Northeast Climate Science Center, University of Maryland Center for Environmental Science

The most notable recent drought event was in

2016 - 17

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

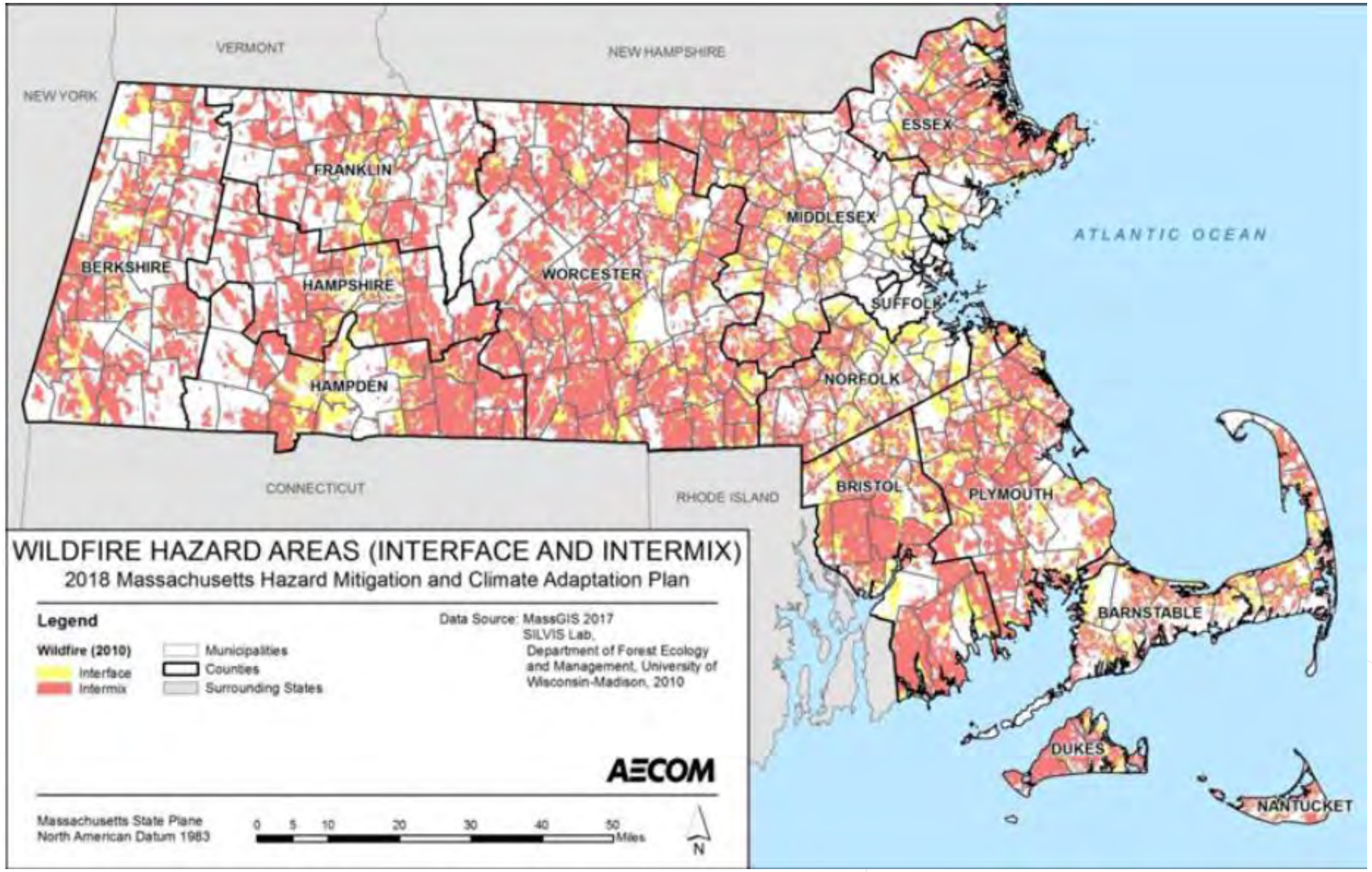
EROSION



- Caused by riverine flow & stormwater[1]
- Increased precipitation, including winter rains, could increase erosion[1]
- Drier soils will reduce resistance to erosion

1. Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 42.

FIRE


VERMONT
NEW HAMPSHIRE
NEW YORK
ESSEX
FRANKLIN
MIDDLESEX
ATLANTIC OCEAN
BERKSHIRE
HAMPSHIRE
WORCESTER
SUFFOLK
NORFOLK
HAMPDEN
CONNECTICUT
RHODE ISLAND
BRISTOL
PLYMOUTH
BARNSTABLE
DUKES
NANTUCKET
WILDFIRE HAZARD AREAS (INTERFACE AND INTERMIX)
2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan
Legend
Wildfire (2010)
Interface
Intermix
Municipalities
Counties
Surrounding States
Data Source: MassGIS 2017
SILVIS Lab,
Department of Forest Ecology
and Management, University of
Wisconsin-Madison, 2010
AECOM
Massachusetts State Plane
North American Datum 1983
0 5 10 20 30 40 50 Miles
N

HURRICANES AND EARTHQUAKES

HURRICANE

Sandy
and nor'easters

cause downed trees and power lines

Upward trend in North Atlantic hurricane activity since 1970

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

EARTHQUAKE

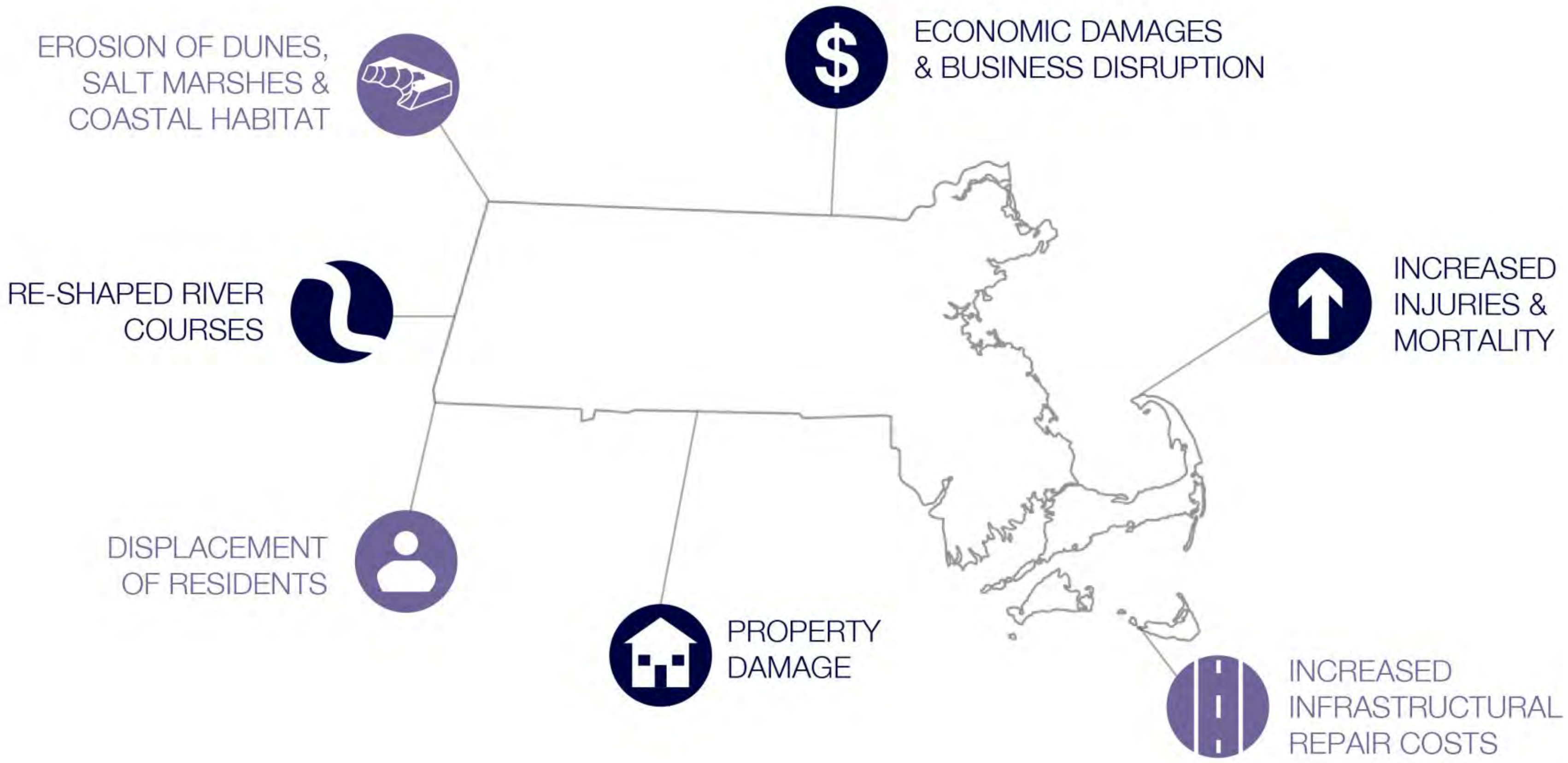
30-40

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

Source: Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)Northern Middlesex Council of Governments. 2015. "Hazard Mitigation Plan for the Northern Middlesex Region," 159-160.

IMPACTS OF **EXTREME WEATHER**

STORMS ARE BECOMING MORE INTENSE AND DAMAGING



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Extreme Weather." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/extreme-weather

HAZARD POTENTIAL OF DAMS

Dam Name	Ownership	Hazard Potential
Brockton Reservoir Dam	Town of Avon	Significant

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)

RISK MATRIX

RISK MATRIX

Community Resilience Building Risk Matrix

www.CommunityResilienceBuilding.com

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

RISK MATRIX: HAZARDS

Community Resilience Building Risk Matrix www.CommunityResilienceBuilding.com

H-M-L priority for action over the Short or Long term (and Ongoing)
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Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

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

RISK MATRIX: FEATURES

Community Resilience Building Risk Matrix www.CommunityResilienceBuilding.com

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

H-M-L priority for action over the Short or Long term (and Ongoing)
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Features	Location	Ownership	V or S					Priority H - M - L	Time Short Long Ongoing
Infrastructural									
Societal									
Environmental									

RISK MATRIX: FEATURES

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
Infrastructural			
Societal			
Environmental			

IDENTIFY HAZARDS

HAZARDS IN AVON

CHOOSE 4 FOR THE MVP ACTION PLAN

FLOOD HAZARDS

WIND HAZARDS

WINTER STORMS

EARTHQUAKES, LANDSLIDES, ETC.

FIRE

EXTREME TEMPERATURES

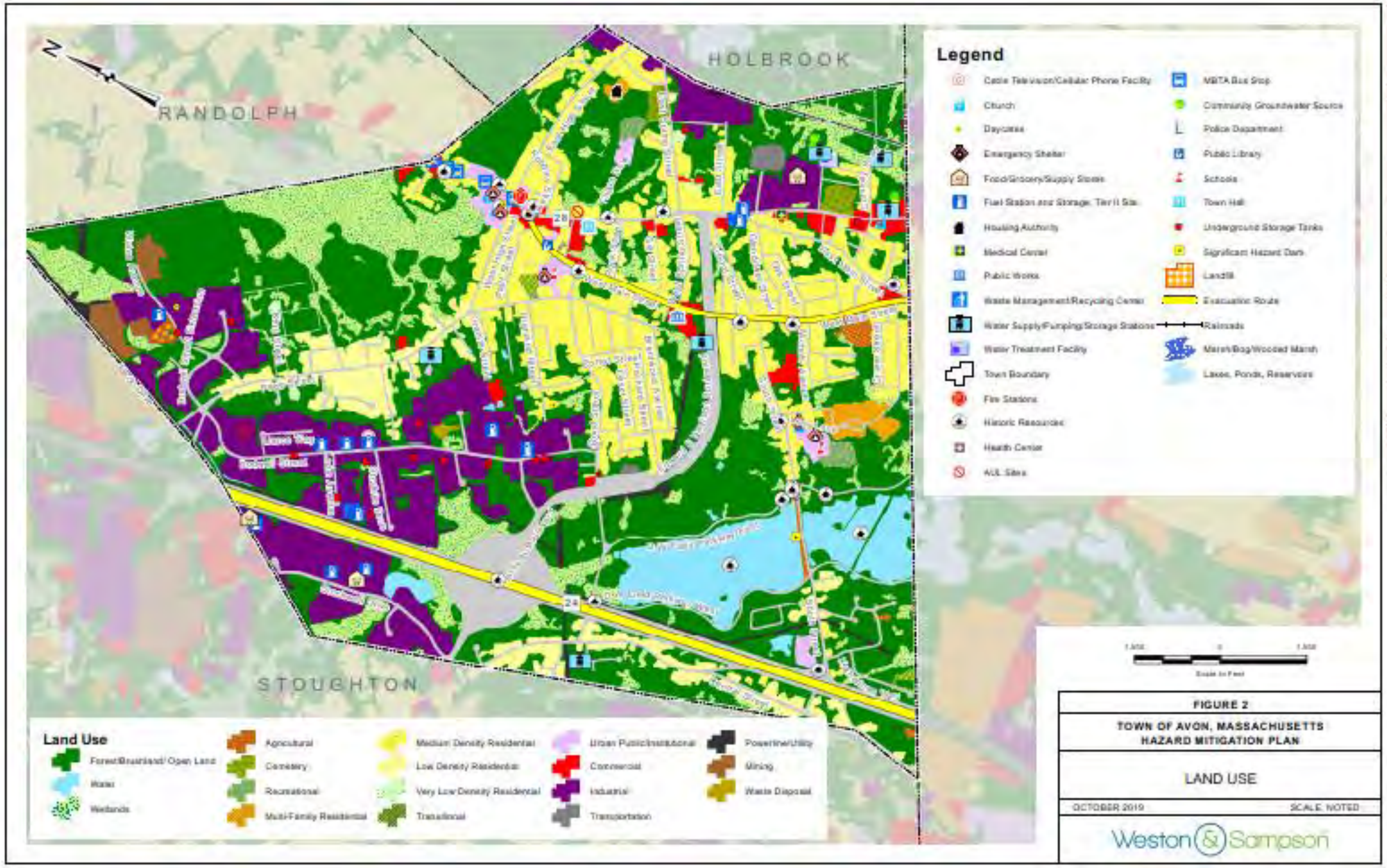
DROUGHT

CLIMATE CHANGE

15 MINUTE BREAK!

FEATURES IN AVON

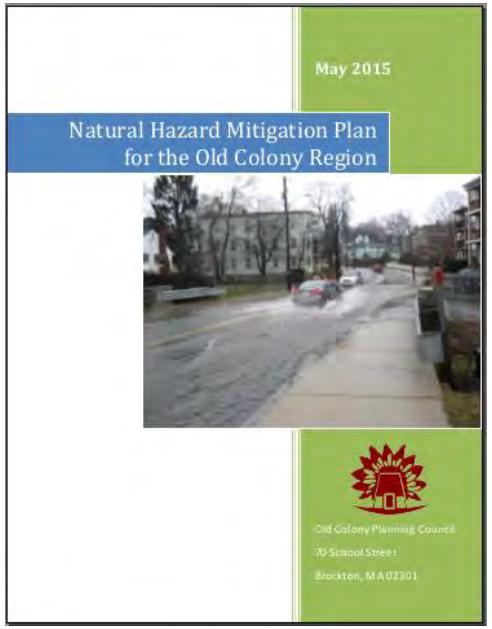
Avon’s Land Use



Avon’s Land Use

- 4,096 Acres (6.4 sq mi)

DATA RESOURCES



Within Avon and Throughout Massachusetts

Massachusetts Climate Change Projections, 2018)

Massachusetts State Hazard and Climate Adaptation Plan, 2018

Massachusetts Climate Change Adaptation Report, 2011

Old Colony Region Hazard Mitigation Plan

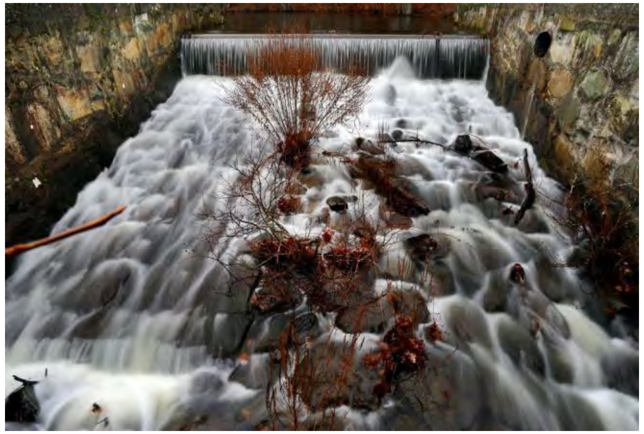
US Census, American Community Survey, 2013-2017

INFRASTRUCTURAL FEATURES

Police Department

Fire Department

Wastewater



Dams

Roadways

Water Supply

SOCIETAL FEATURES

Population	Avon	Massachusetts
2010	4,364	6,547,790
2017	4,468	6,902,149
Age		
Under 18 years:	16.9%	20%
65+ years:	16.0%	17%
Education		
Bachelor's degree or higher:	27%	42.1%
Additional Information		
Median household income:	$74,225	$74,167
Persons in poverty:	8.5%	10.5%

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

ENVIRONMENTAL FEATURES

Avon's Open Space

Brockton Reservoir

Demarco Park

RISK MATRIX: FEATURES

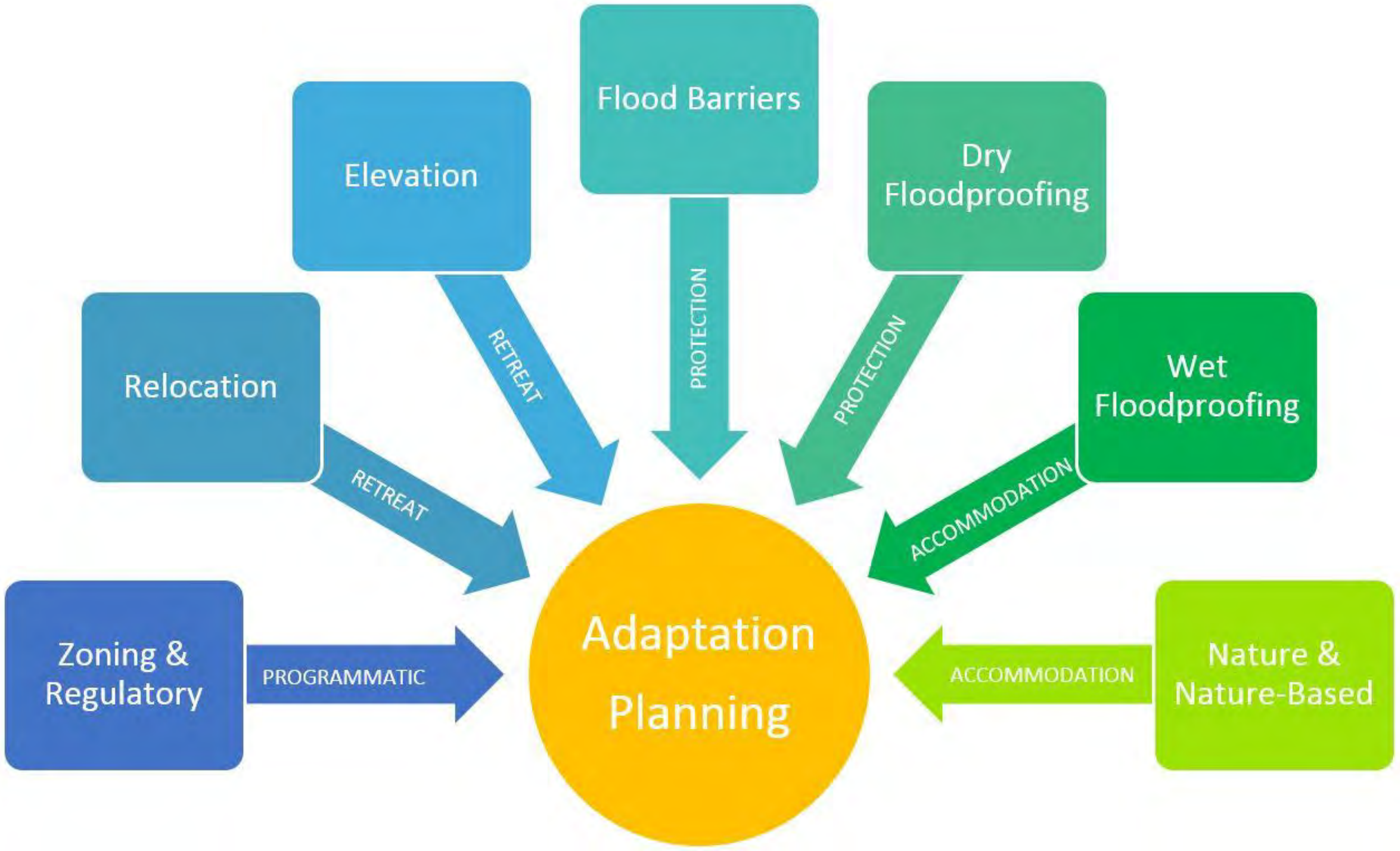
FEATURES	LOCATION	OWNERSHIP	VULNERABILITY OR STRENGTH
Infrastructural	Town wide	State	Vulnerability
Societal	Multi- vs. Single-neighborhood	Town	Strength
Environmental	Specific location	Private	Both
		Shared	

ADAPTATION STRATEGIES

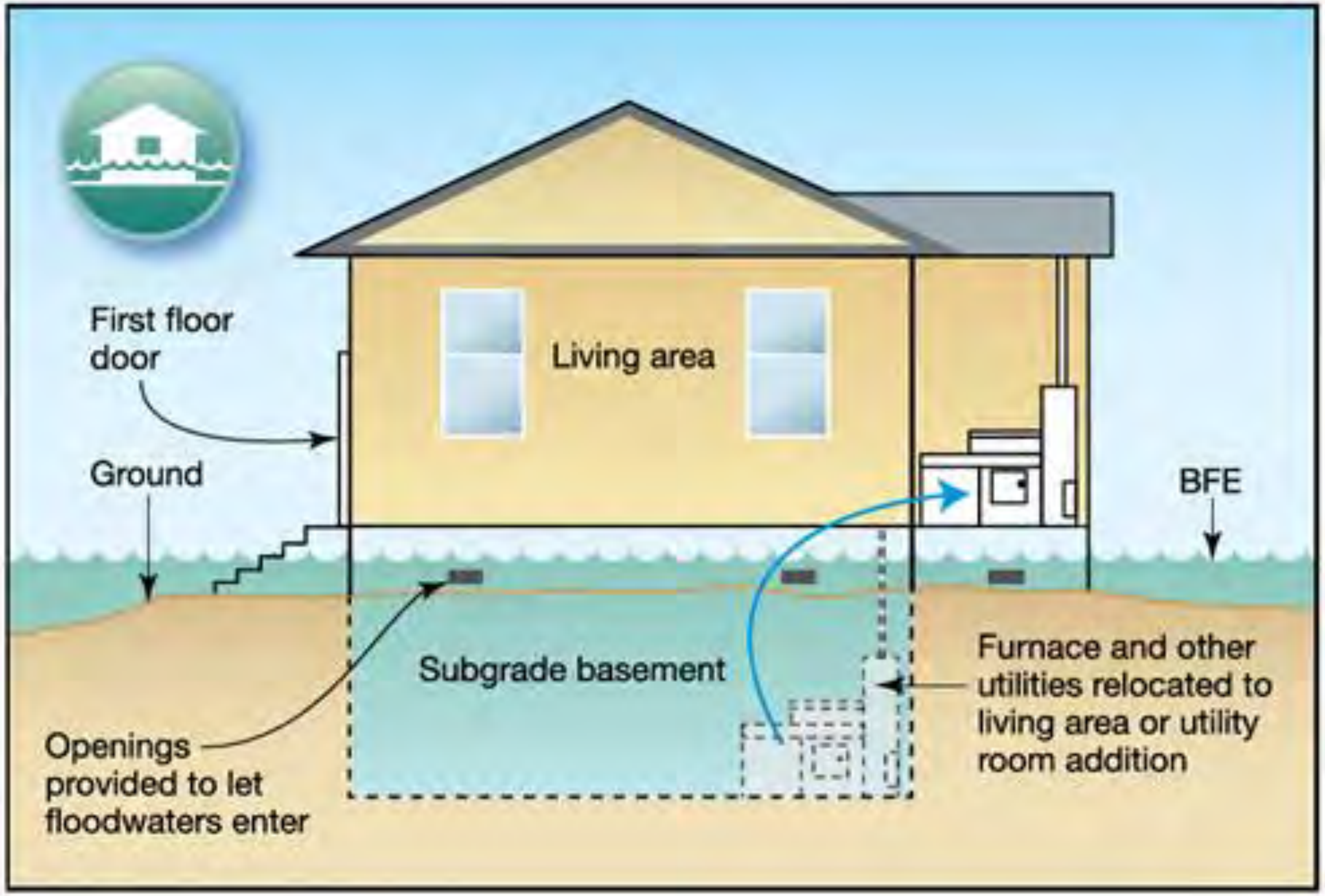
EXISTING HAZARD PROTECTION

- Participation in the National Flood Insurance Program (NFIP);
- Policy-related strategies targeting new and redevelopment projects;
- Local drainage improvement and maintenance activities;
- Emergency response planning;
- EPA Phase II Stormwater permit requirements;
- Public education;
- Cooperation with local utility companies to perform annual tree maintenance around utility lines

COMMUNITY ACTIONS

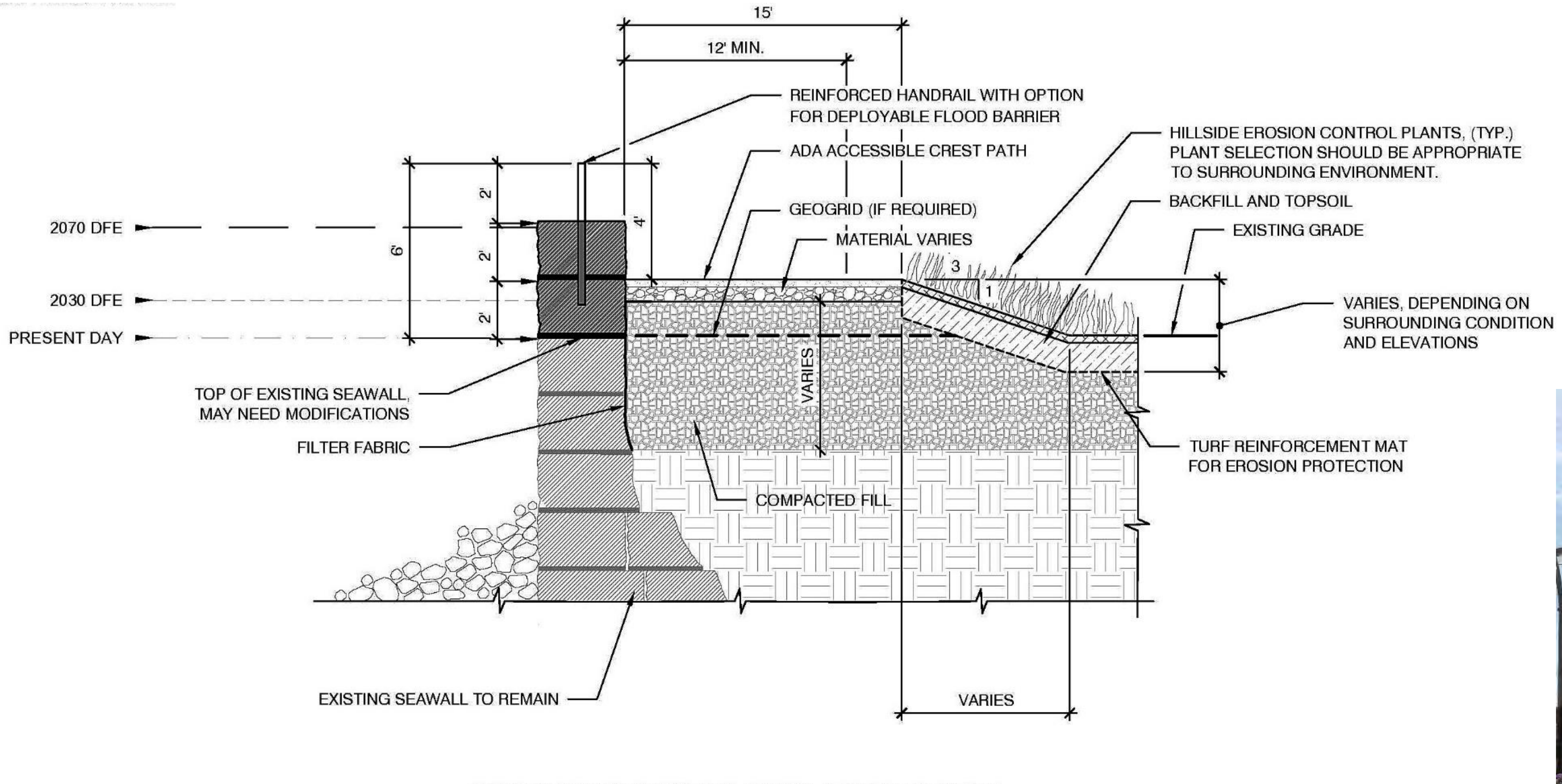


WET FLOODPROOFING

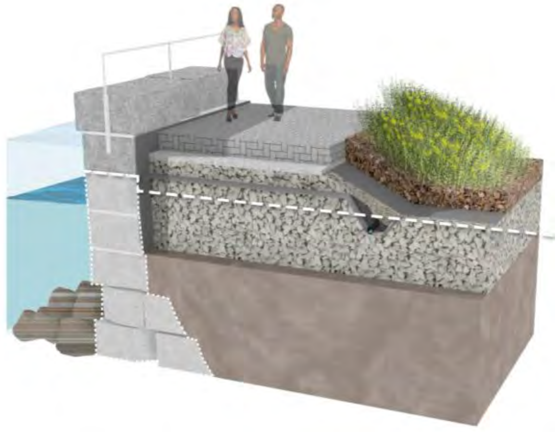


RAISED BUILDINGS

FLOOD WALLS



HARBORWALK BARRIER SEAWALL SAMPLE SECTION



DEPLOYABLE FLOOD BARRIER

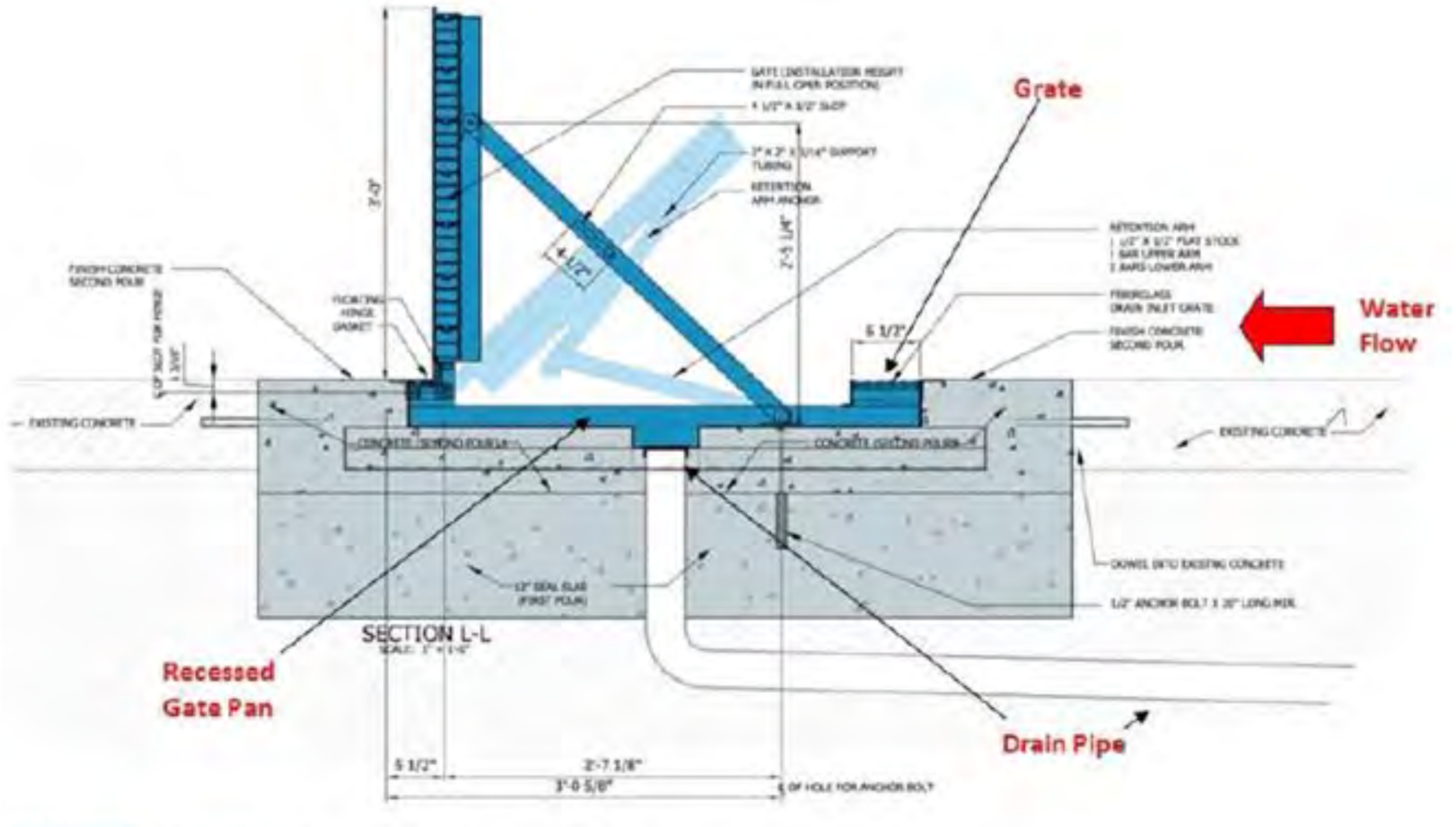
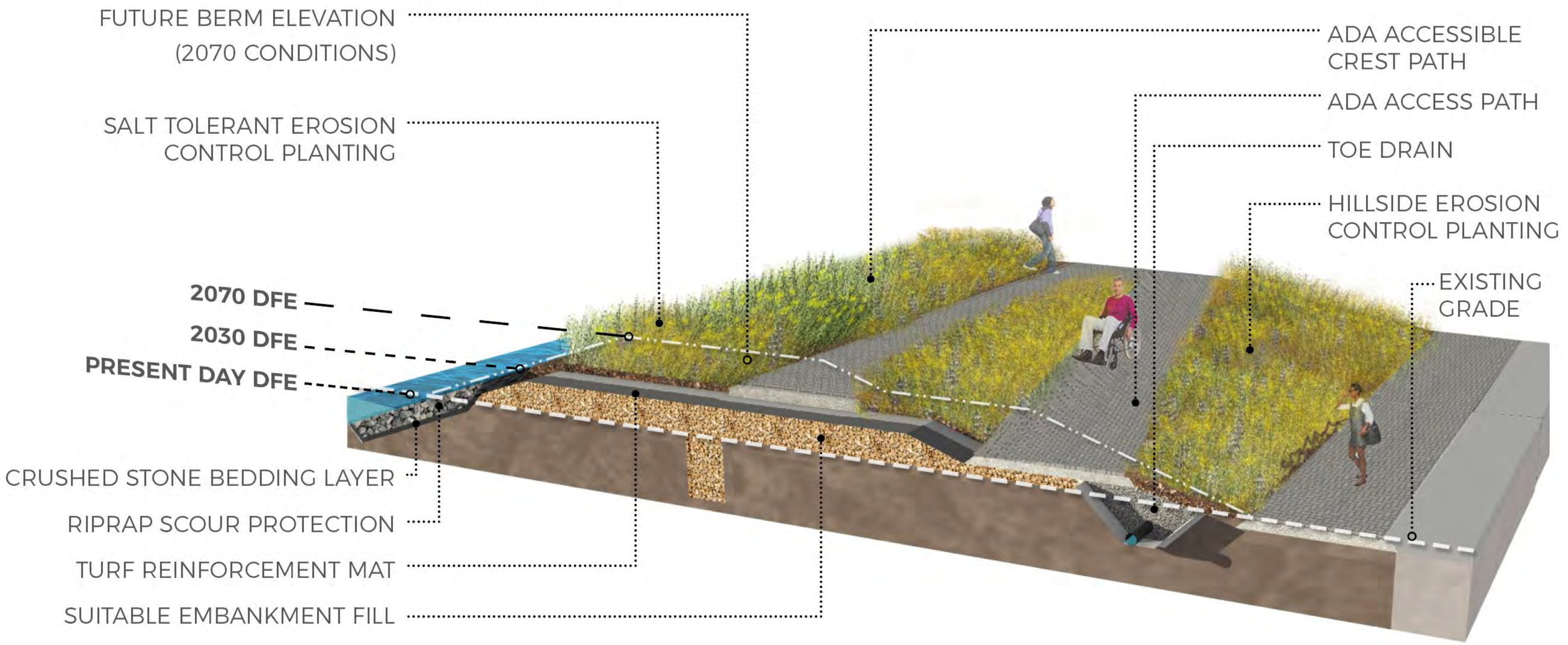


FIGURE 1 | A FloodBreak barrier gate diagram

PREVENTING SEWER BACKFLOW

VEGETATED BERM

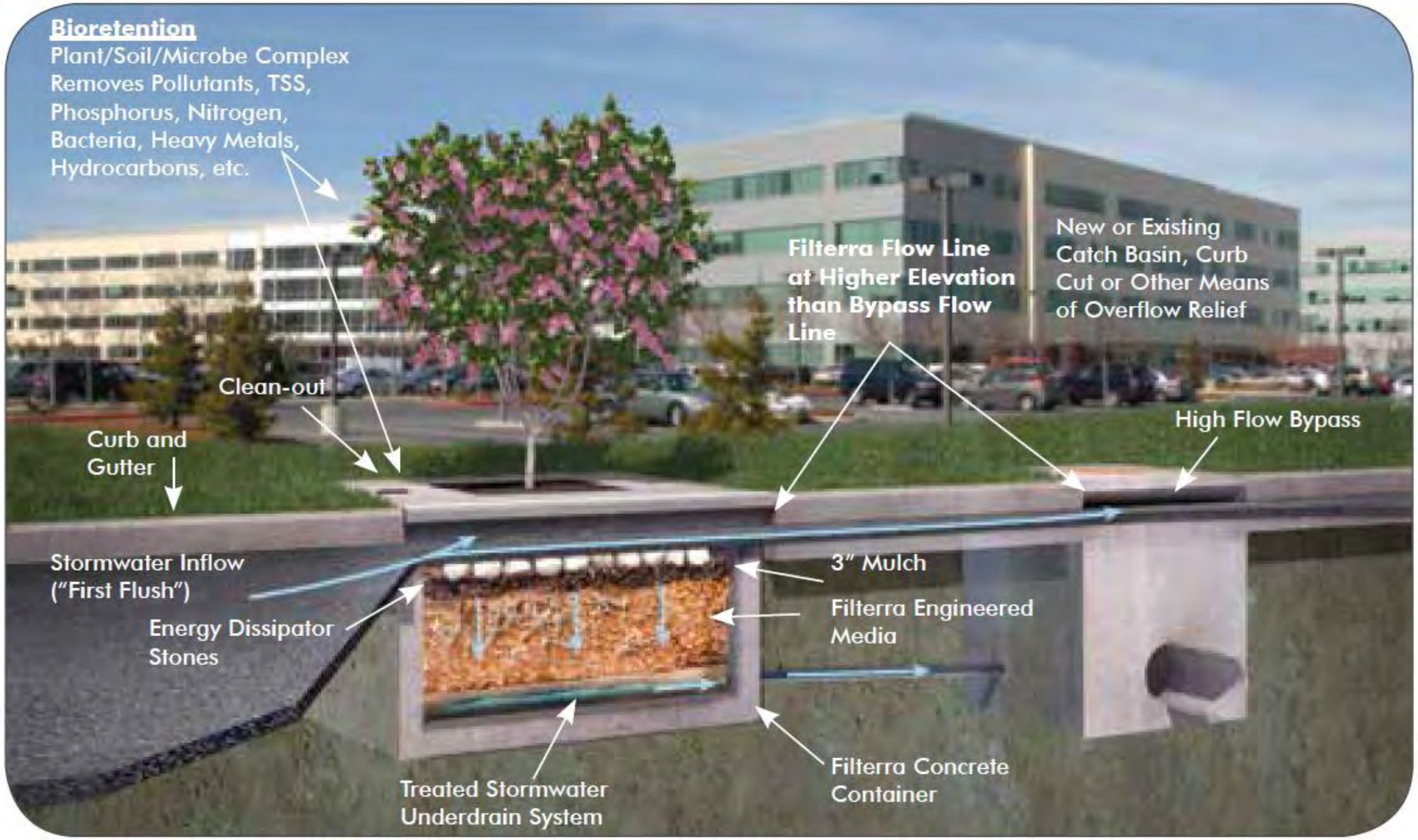


MULTI-PURPOSE FLOOD STORAGE

LOW IMPACT DEVELOPMENT (LID)

POROUS ASPHALT & PERMEABLE PAVERS

STREET TREES & TREE BOX FILTERS



STREET TREES & TREE BOX FILTERS

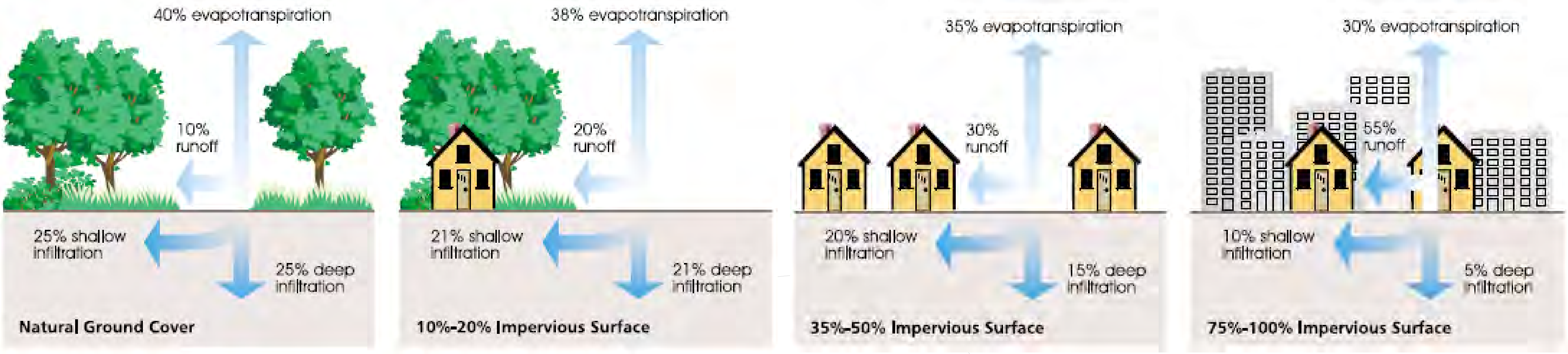
Rain Garden in a median strip of a townhouse project. Please note the depressed curb and grate inlet structure

STORMWATER DETENTION & RETENTION

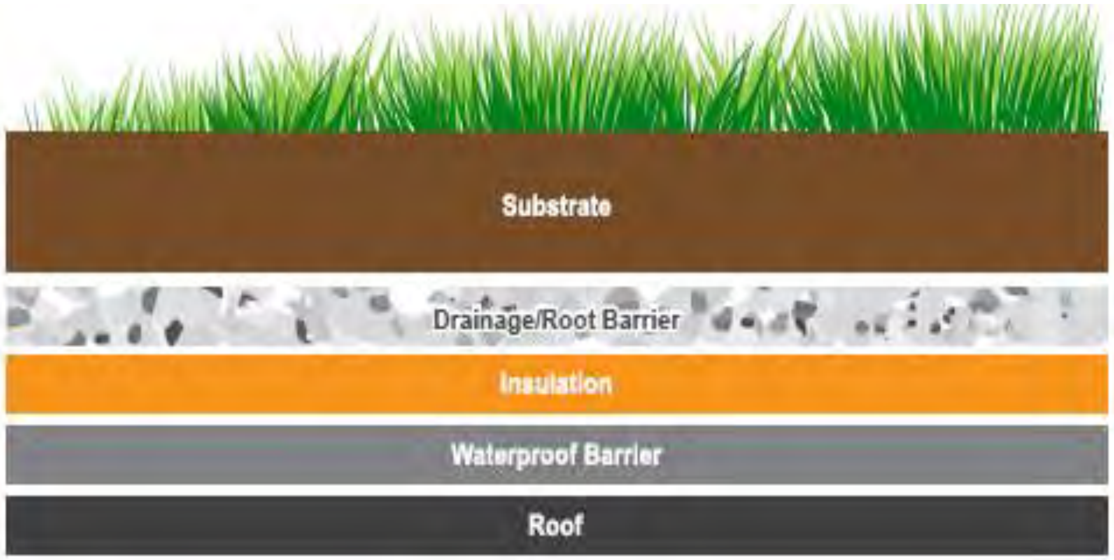
CULVERT WIDENING TO IMPROVE HABITAT & FLOW

CLOUDBURST STREETS

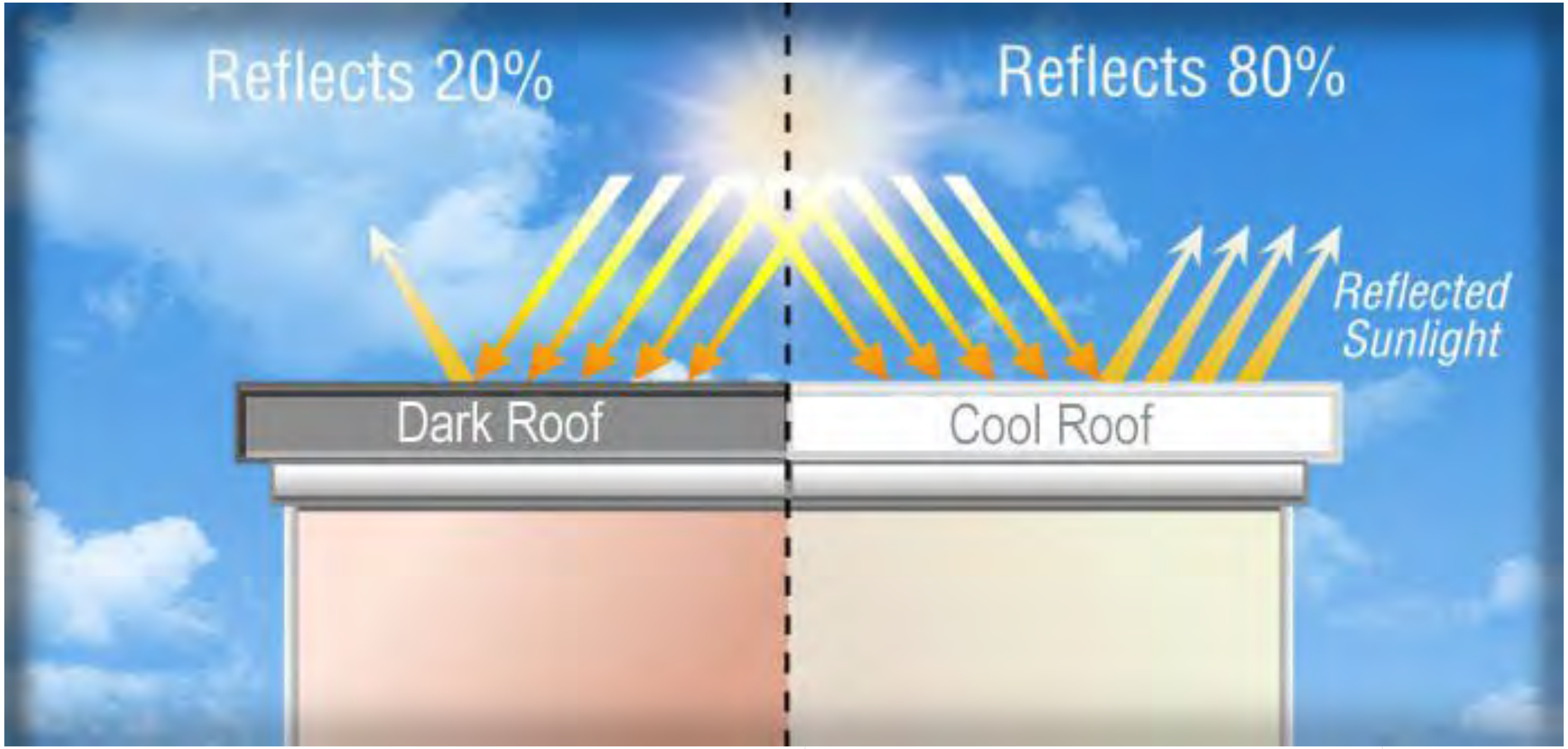
REDUCE IMPERVIOUS AREAS



GREEN ROOFS


Substrate
Drainage/Root Barrier
Insulation
Waterproof Barrier
Roof

COOL ROOFS



Source: Heat Island Group at Lawrence Berkeley National Laboratory

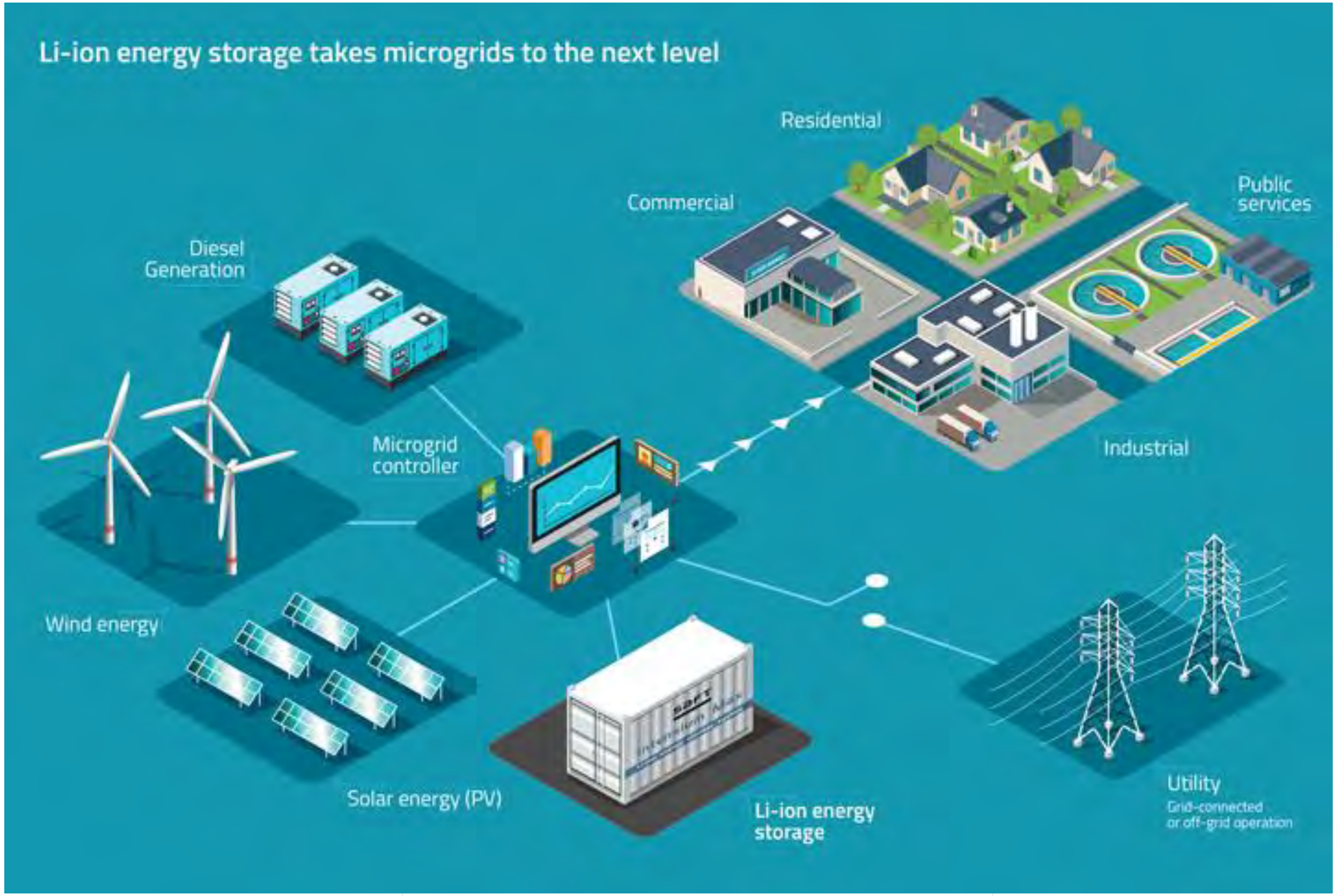
Figure 1: Dark vs. Cool Roof Surface Temperatures

A dark roof (left) becomes much hotter than a cool white roof (right) on a sunny afternoon.

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

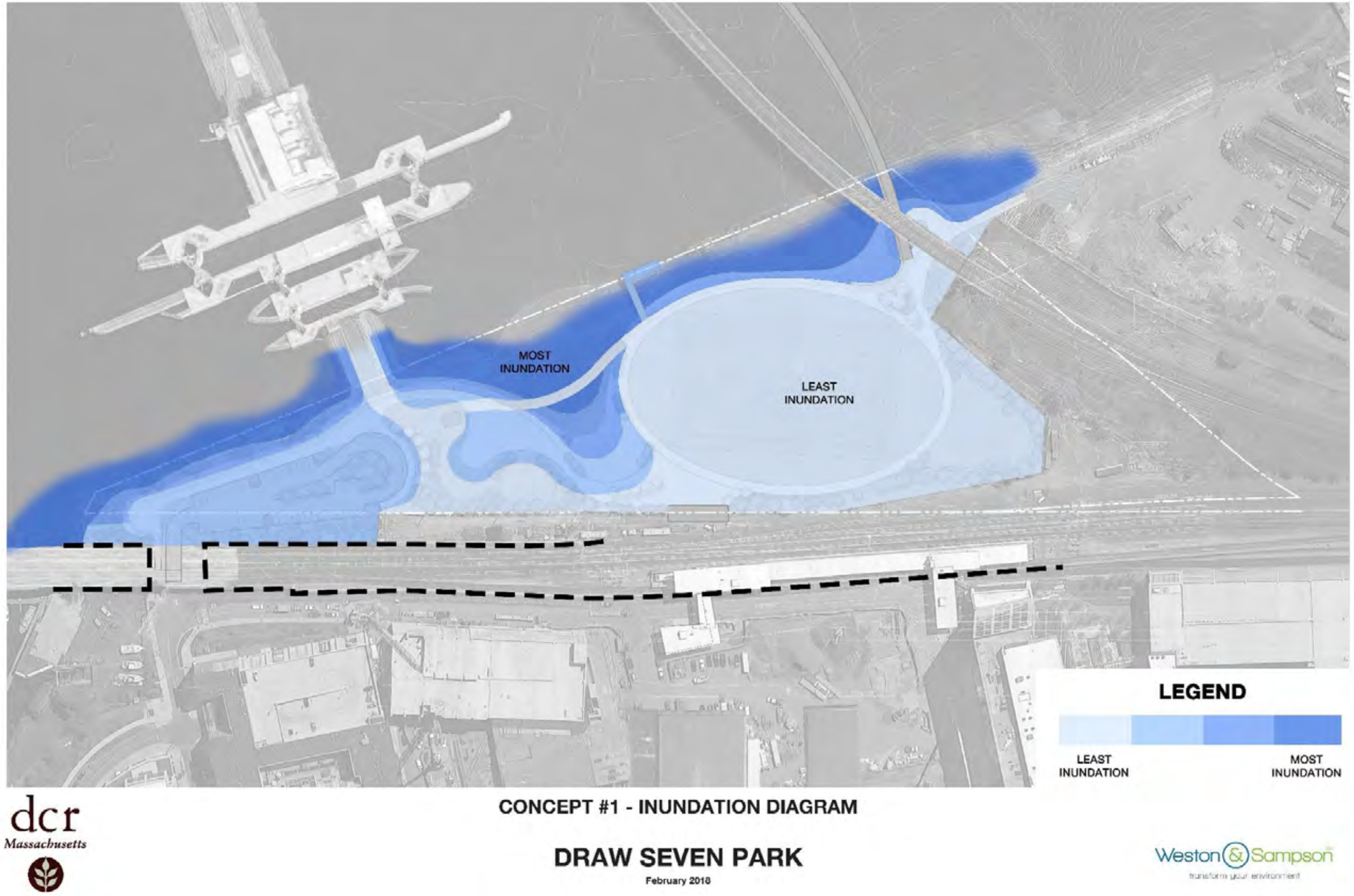
COOLING CENTERS

RENEWABLE MICRO-GRIDS

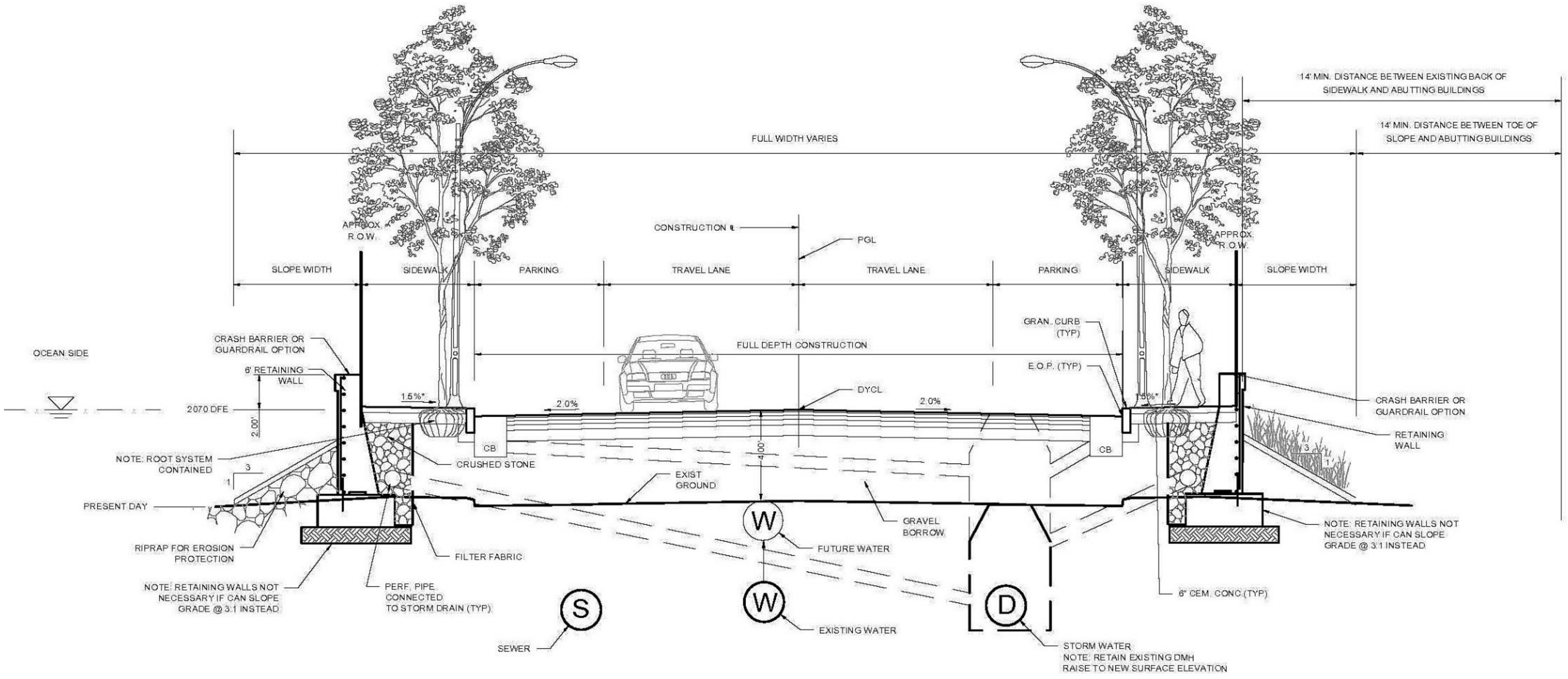


LANDSCAPE DESIGN TO ACCOMMODATE WATER

LANDSCAPE DESIGN TO ACCOMMODATE WATER



RAISED ROADWAYS



SAMPLE SECTION

RETROFITTED FLOODPROOF DOORWAYS

RE-EVALUATE LOCAL REGULATIONS & POLICIES

BROOKLINE MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) ACTION PROJECT

town of brookline, massachusetts




Weston & Sampson will audit the Town of Brookline's stormwater, floodplains, zoning bylaws, public way design guidelines, wetlands bylaws, and Department of Public Works' Site Plan Review Checklist to identify opportunities to mandate higher standards for climate resiliency and to identify any conflicts these standards might have with State policy. Our approach is centered around the promotion of nature-based solutions and strategies such as green infrastructure, low impact development (LID), open space protection, and floodplain protection. The project is funded by a Municipal Vulnerability Preparedness Action Grant from the Massachusetts Executive Office of Energy & Environmental Affairs.

Weston & Sampson will identify opportunities for incorporating standards into the Town of Brookline's bylaws and other planning instruments to increase the town's resilience against the effects of climate change, including increased temperatures as well as increased precipitation frequency/intensity and associated flooding. Implementation of this project will help to reduce risk of climate change impacts to public infrastructure, private property, natural resources, and human safety and welfare. The project's specific recommendations for bylaw amendments as well as sustainability standards for site plan review will be targeted at new and renovated projects across all building sectors: residential, multifamily and affordable housing, commercial, and institutions.

Weston & Sampson's deliverables, identified as priority action items in the town's "Climate Vulnerability Assessment," will include: recommendations for new or amended town bylaws and regulations mandating LID measures, LID Best Management Practices - narrative and Site Plan Review checklist - that targets owners and developers of new and renovated residential, multifamily, and commercial properties, and assists in educating them of the overall benefits to the environment and the value in protecting their properties from climate change impacts. The standards and checklists will serve as imperative components of the "Site Plan Review" ordinance that the town will be adopting and are intended to limit storm and flood damage, mitigate stormwater runoff, reduce impervious surfaces, and improve ecosystem resiliency.

- convene a core team of leaders from departments, boards, and commissions
- review existing By-laws
- conduct literature review of examples from other municipalities
- develop and evaluate alternatives
- develop draft recommendations; workshop them with town's Boards, Commissions, and Departments.
- develop final recommendations and assist with preparation of package to town meeting
- conduct community outreach

client contact

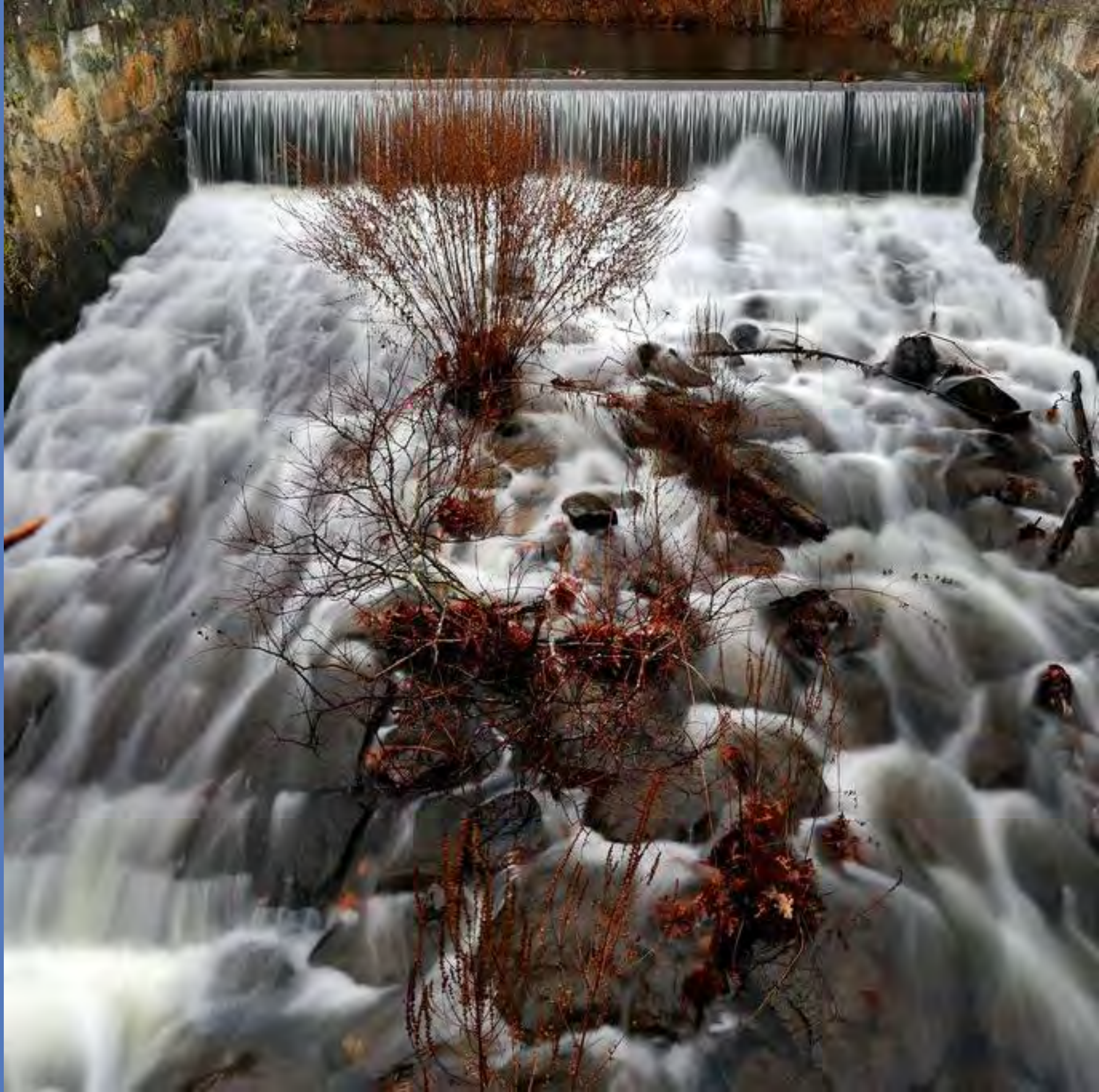
Maria Morelli
Senior Planner,
Climate Action/Land Use
Town of Brookline
Department of Planning &
Community Development
mmorelli@brooklinema.gov
617-730-2670

westonandsampson.com

15 MINUTE BREAK!

DEFINE COMMUNITY ACTIONS

IDENTIFY PRIORITY ACTIONS



WRAP-UP & CLOSING REMARKS

Example of Completed Risk Matrix: Environmental

Community Resilience Building Workshop Risk Matrix

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

Top 4 Hazards (tornado, floods, wildfire, hurricanes, snow/ice, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Coastal Flooding SLR/Storm Surge	Inland Flooding and Rain Events	Ice and Snow	Wind	Priority H - M - L	Time Short Long Ongoing
Environmental									
Beaches & Dunes	Multiple	State-Town-Private	V/S	Maintain existing beaches & dunes; Assess values and key locations relative to people and property				H	S
Forest (uniform age structure)	Town-wide	Town/State	V	Seeks management that diversifies the age structure of forests in Town; Assess and identify key vulnerabilities from tree fall				H	S
Salt Marsh	Multiple	State/Private	V/S	Maintain existing marsh; Consider additional regulatory protection (increased setbacks) to prevent impacts to resource; Assess risk reduction potential from existing and future wetlands				H	S
Shoreline Erosion	Coastal/Rivers	Town/Private	V	Assess impacts to various scenarios; Identify green infrastructure/living shoreline projects				H	S
Open Space Acquisition (for flood impact reduction)	Town-wide	Town-State-Private	V	Secure state funding; Salt marsh advancement zones	Secure state/federal funding	Include land protection needs Master Plan		H	S-L
Riparian Buffers	Town-wide	Town	V	Identify areas with greatest restoration potential; Areas for future acquisition that can prevent flooding to adjoining infrastructure				M	S
State Parks	Specific	State	V	Encourage the State to work more closely with Town to comprehensively maintain town-wide natural resources, amenities, and water quality; Coordinate with state regarding evacuation procedures				M	S
Rippowam River	Specific	State/Town	V		Improve risk reduction characteristics of waterway through natural infrastructure & riparian buffer enhancements			M	S-L
Drinking Water Reservoir	Multiple	State-Private	V	Conduct assessment to comprehensively identify vulnerabilities and develop action plans to increase resilience of natural resources and long term water quality/quantity; Implement improvements				L	L
Harbor Sedimentation	Coastal	Town	V	Reuse dredged sediment to augment natural infrastructure (beneficial reuse)				L	L
Protected Open Space	Multiple	State-Town-Private	S	Maintain existing open space to help reduce risk to Town; Seek to increase open space with the highest risk reduction characteristics					Ongoing
Beach/Dune Resiliency Plan	Coastal	Town/State	S	Continue to implement/update the Plan					Ongoing
Tree Inventory	Town-wide	Town	S	Continue to utilize tree inventory to develop comprehensive, priority-based tree maintenance plan along transportation/utility corridors					Ongoing
River Restoration Projects	Specific	Town/Private	S	Continue implementation of projects to restore river buffer and remove dam to reduce risk to adjoining homes and businesses					Ongoing

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	FLOOD	WIND	DROUGHT	WINTER STORM	Priority H - M - L	Time Short Long Ongoing
Infrastructural									
Water supply/flooding	Townwide	Town	Both	drainage system maintenance, flood control measures for structures, flood proofing pumping		Interconnect/purchase water,		H	O, S, L
Water Storage	Page st, Central St.	Town	V			Repair existing storage tanks		H	S
Water treatment	Townwide	Town	Both		distributed generation, tree maintenance		distributed generation, tree maintenance	H	L, S & O
Repeater site antenna	Page St. Tank	Town	V		bracket replacement/repair		bracket replacement/repair	H	S
Trees along roadways/ROW	Townwide	Town/Private	V		Assessment and Maintenance plans		Assessment and maintenance plan	L	S
Roads	Townwide	Town/State/Private	S	cloud burst treatments				M	S&L
Drainage	Townwide	Town	Both	Assessment and Major drainage cleaning				M	S&L
Septic system flooding	Industrial and commercial areas	Private/Town	V	Convert to sewer or upgrade septic				M/H	O, S, L
Information Technology Systems	Townwide	Town	V		back up power, convert to fiber optic lines, radio control option		back up power, convert to fiber optic lines, radio control option	H	O, S, L
Snow storage	Downtown	Town	V				add storage/improvements at compost site and regular maintenance	L	S&O
Water distribution system	Townwide	Town	S			Interconnect/purchase water,		H	O, S, L
Societal									
Communication w/foreign born population (Haiti) (Portuguese)	Townwide	Private	V	Work w/schools to communicate, identify translators, website or call center translation service	Work w/schools to communicate, identify translators, website or call center translation service	Work w/schools to communicate, identify translators, website or call center translation service	Work w/schools to communicate, identify translators, website or call center translation service	M	S&O
Elderly population	Townwide	Private	V	variable message board signs	variable message board signs	variable message board signs	variable message board signs	M	L
Daytime population increase (communication, traffic, hazard ous materials)	Industrial Park, Stockwell Drive, Memorial Drive	Private	Both	variable message board signs	variable message board signs	variable message board signs	variable message board signs	M	L

Environmental									
Stormwater pollution/impervious surface	Townwide	Town/State/Private	V	green infrastructure, improve BMPs, individual project retrofits		green infrastructure, improve BMPs as individual project retrofits		M	O, S, L
Stormwater system mapping	Townwide	Town/State/Private	V	complete and make it accessible to emergency personell with training				H	O&S
Mosquito habitat (drainage)	Townwide	Town	V	drainage system maintenance, retrofit wet ponds, bat houses				M/L	O, S, L
High groundwater/ledge (basement flooding)	Townwide	Town/State/Private	V	conversion of septic to sanitary, better drainage maintenance				M/H	O, S, L

APPENDIX B

Hazard Mapping and HAZUS Data

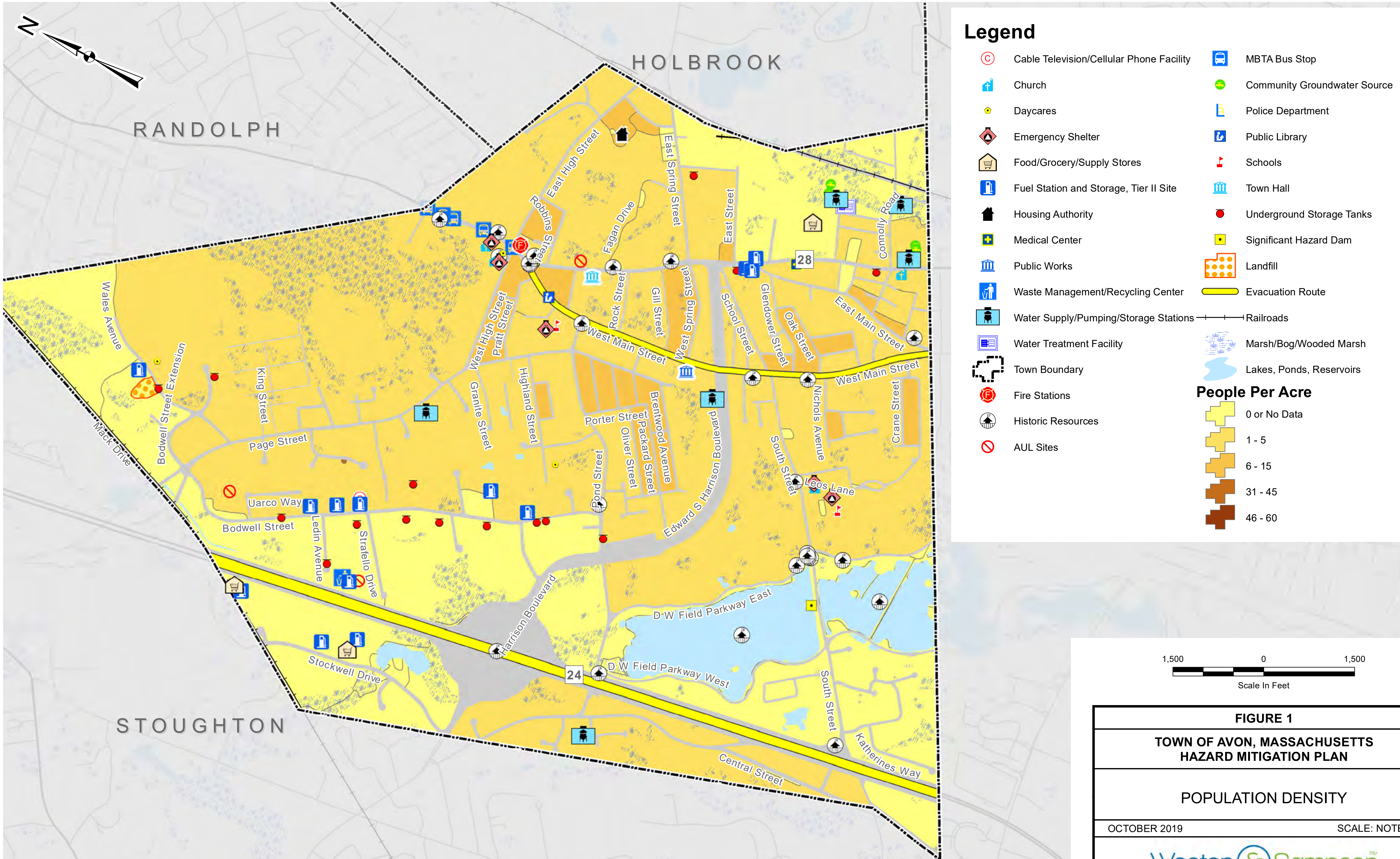


FIGURE 1

TOWN OF AVON, MASSACHUSETTS
HAZARD MITIGATION PLAN

POPULATION DENSITY

OCTOBER 2019 SCALE: NOTED

Weston & Sampson

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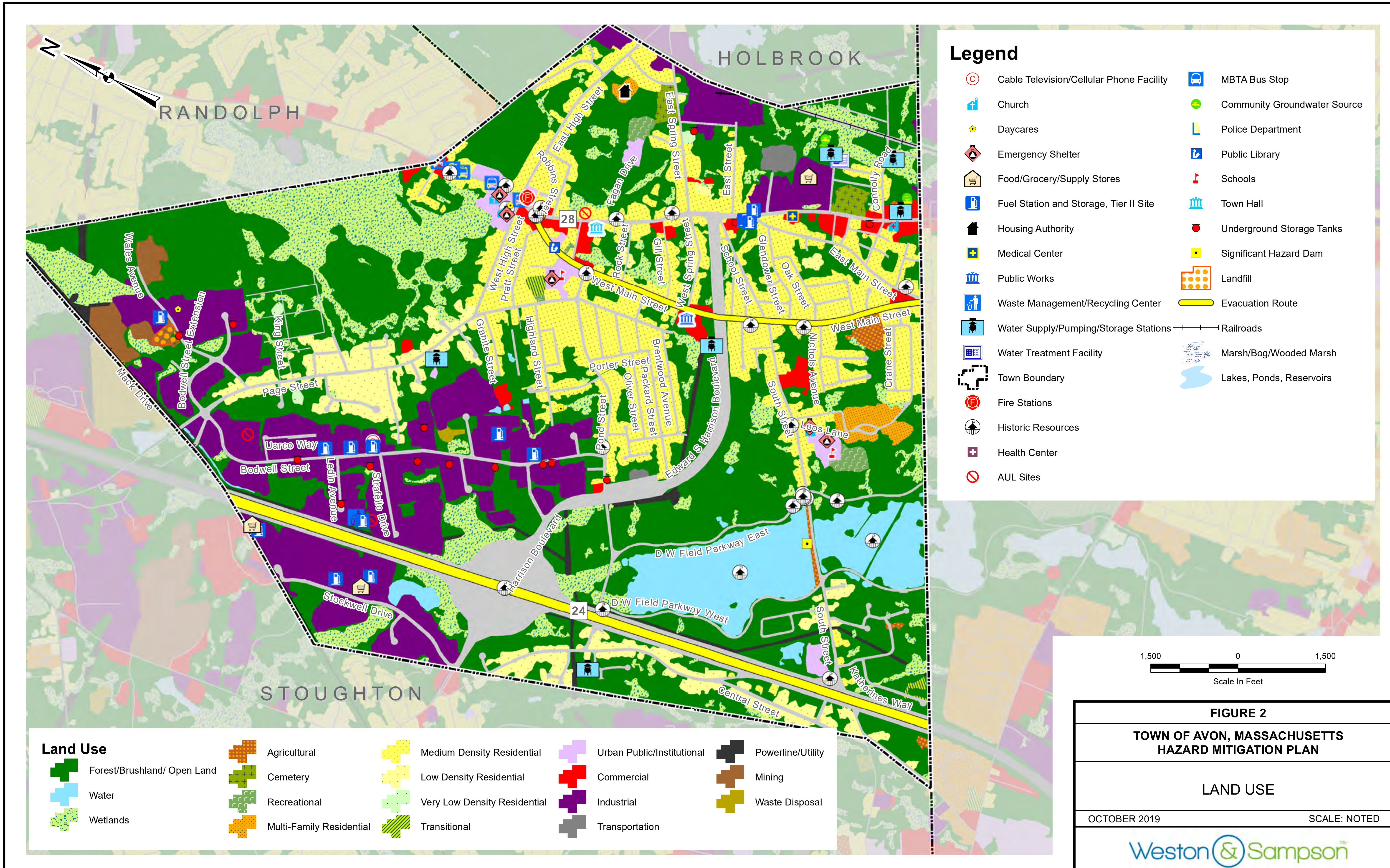


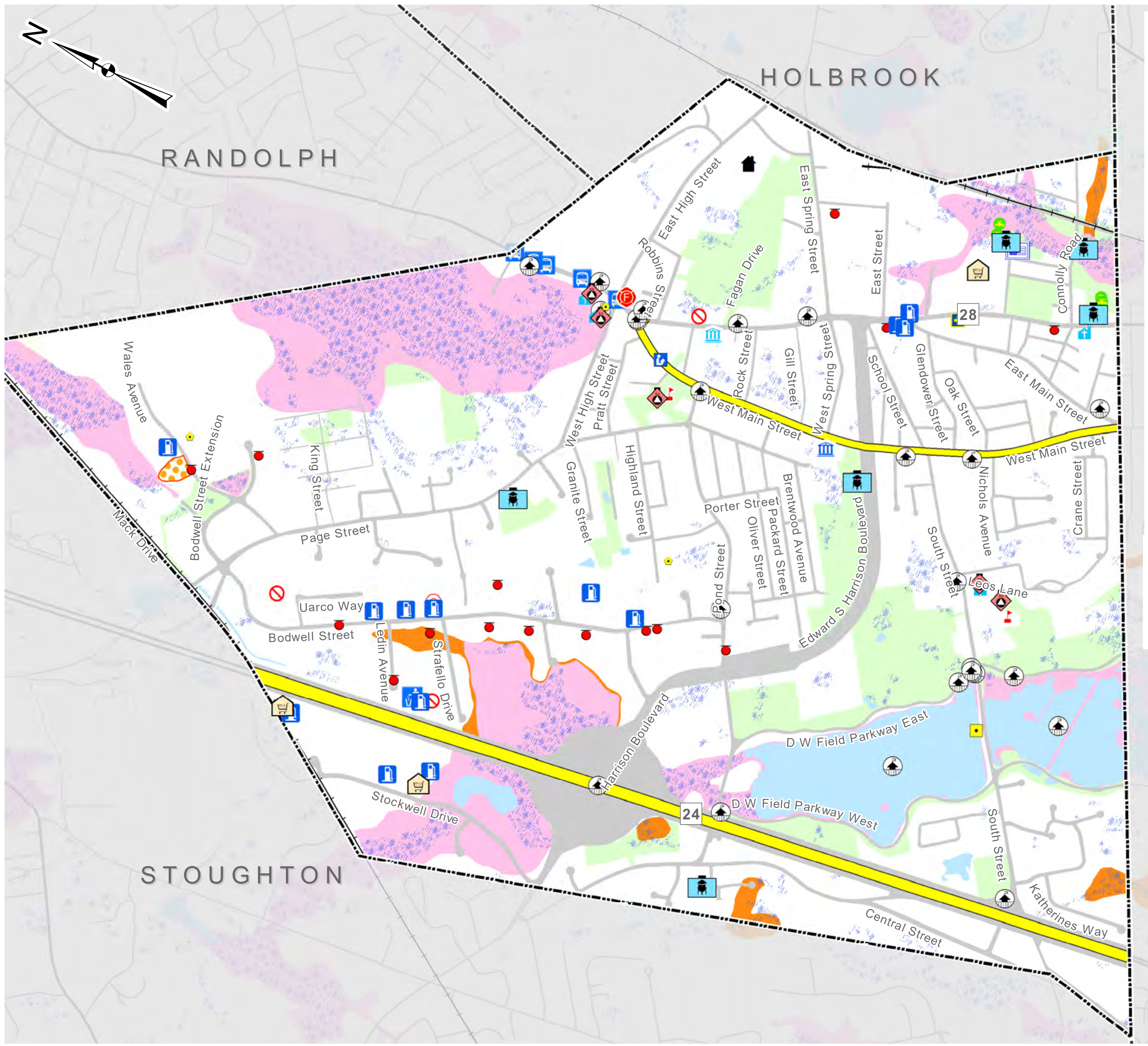
FIGURE 2

TOWN OF AVON, MASSACHUSETTS
HAZARD MITIGATION PLAN

LAND USE

OCTOBER 2019 SCALE: NOTED

Weston & Sampson



Legend

- Cable Television/Cellular Phone Facility
- Church
- Daycares
- Emergency Shelter
- Food/Grocery/Supply Stores
- Fuel Station and Storage, Tier II Site
- Housing Authority
- Medical Center
- Public Works
- Waste Management/Recycling Center
- Water Supply/Pumping/Storage Stations
- Water Treatment Facility
- Fire Stations
- Historic Resources
- AUL Sites
- MBTA Bus Stop
- Community Groundwater Source
- Police Department
- Public Library
- Schools
- Town Hall
- Underground Storage Tanks
- Significant Hazard Dam
- Landfill
- Evacuation Route
- Railroads
- Marsh/Bog/Wooded Marsh
- Lakes, Ponds, Reservoirs
- Open Space
- Town Boundary

Flood Zone Designations

- 1% Annual Chance of Flooding (Zones A, AE, AH, AO)
- 0.2% Annual Chance of Flooding (Zone X)

1,500 0 1,500
Scale In Feet

FIGURE 3

TOWN OF AVON, MASSACHUSETTS HAZARD MITIGATION PLAN

FLOOD ZONES

OCTOBER 2019 SCALE: NOTED

Weston & Sampson

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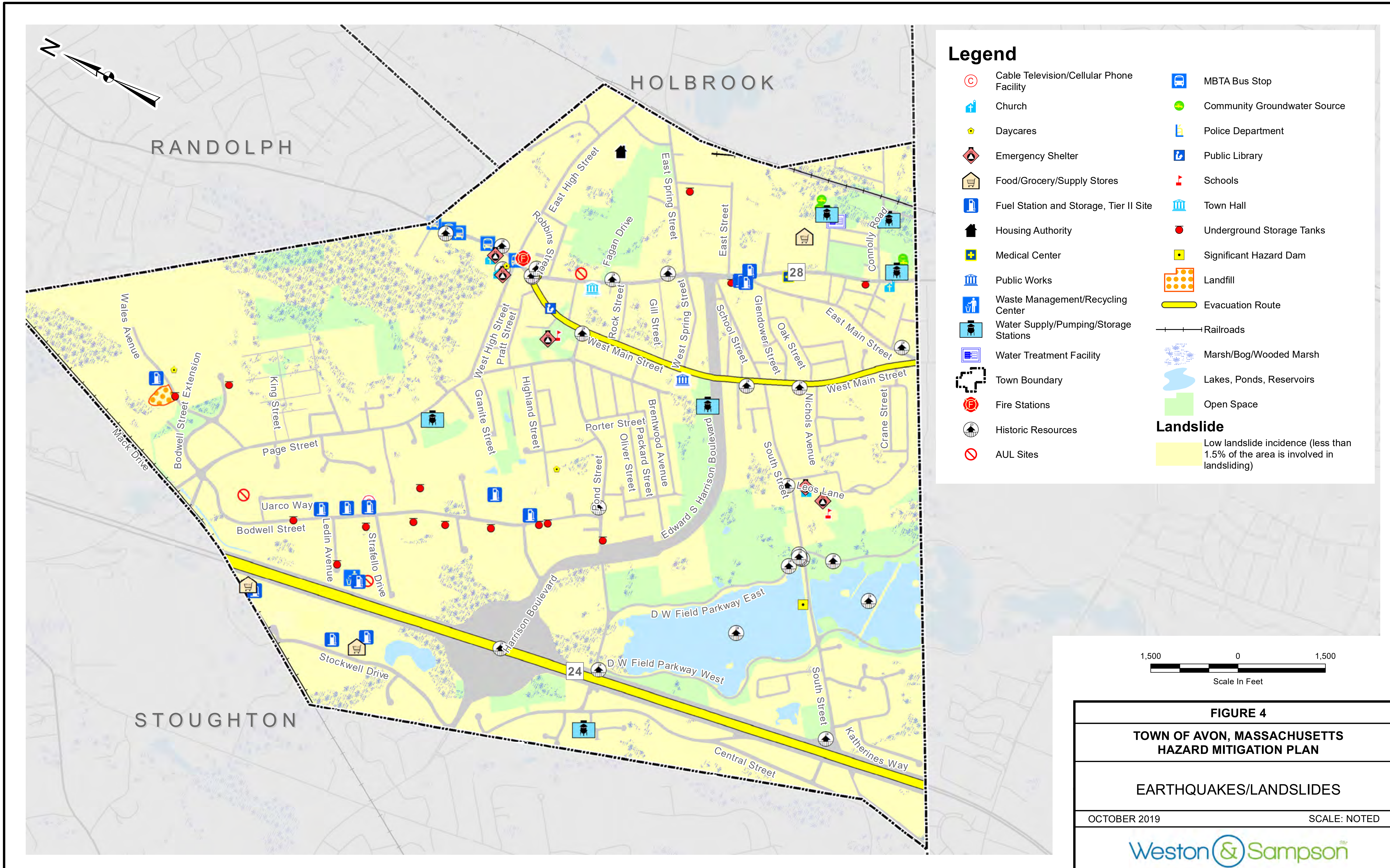

N
HOLBROOK
RANDOLPH
STOUGHTON
Legend
Cable Television/Cellular Phone Facility
Church
Daycares
Emergency Shelter
Food/Grocery/Supply Stores
Fuel Station and Storage, Tier II Site
Housing Authority
Medical Center
Public Works
Waste Management/Recycling Center
Water Supply/Pumping/Storage Stations
Water Treatment Facility
Town Boundary
Fire Stations
Historic Resources
AUL Sites
MBTA Bus Stop
Community Groundwater Source
Police Department
Public Library
Schools
Town Hall
Underground Storage Tanks
Significant Hazard Dam
Landfill
Evacuation Route
Railroads
Marsh/Bog/Wooded Marsh
Lakes, Ponds, Reservoirs
Open Space
Landslide
Low landslide incidence (less than 1.5% of the area is involved in landsliding)
1,500
0
1,500
Scale In Feet
East High Street
Robbins Street
East Spring Street
Fagan Drive
East Street
Connolly Road
28
Wales Avenue
Bodwell Street Extension
King Street
West High Street
Pratt Street
Rock Street
Gill Street
West Spring Street
School Street
Glendower Street
Oak Street
East Main Street
West Main Street
Mack Drive
Page Street
Granite Street
Highland Street
Porter Street
Oliver Street
Packard Street
Brentwood Avenue
Edward S Harrison Boulevard
Nichols Avenue
South Street
Crane Street
Leos Lane
Uarco Way
Bodwell Street
Ledin Avenue
Strafello Drive
Pond Street
Harrison Boulevard
D W Field Parkway East
D W Field Parkway West
Stockwell Drive
24
Central Street
Katherines Way
FIGURE 4
TOWN OF AVON, MASSACHUSETTS
HAZARD MITIGATION PLAN
EARTHQUAKES/LANDSLIDES
OCTOBER 2019
SCALE: NOTED
Weston & Sampson

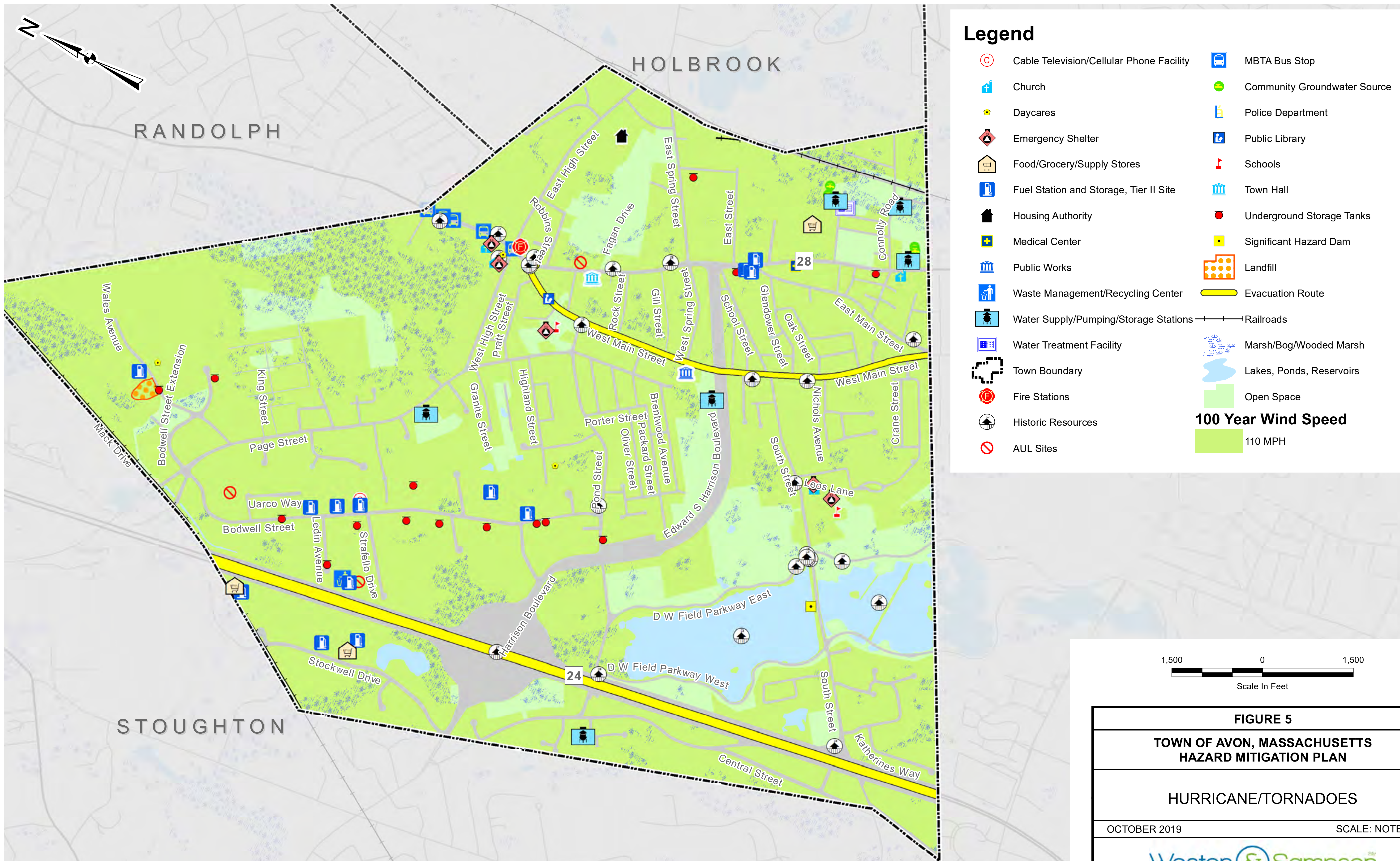


FIGURE 5

TOWN OF AVON, MASSACHUSETTS
HAZARD MITIGATION PLAN

HURRICANE/TORNADOES

OCTOBER 2019 SCALE: NOTED

Weston & Sampson

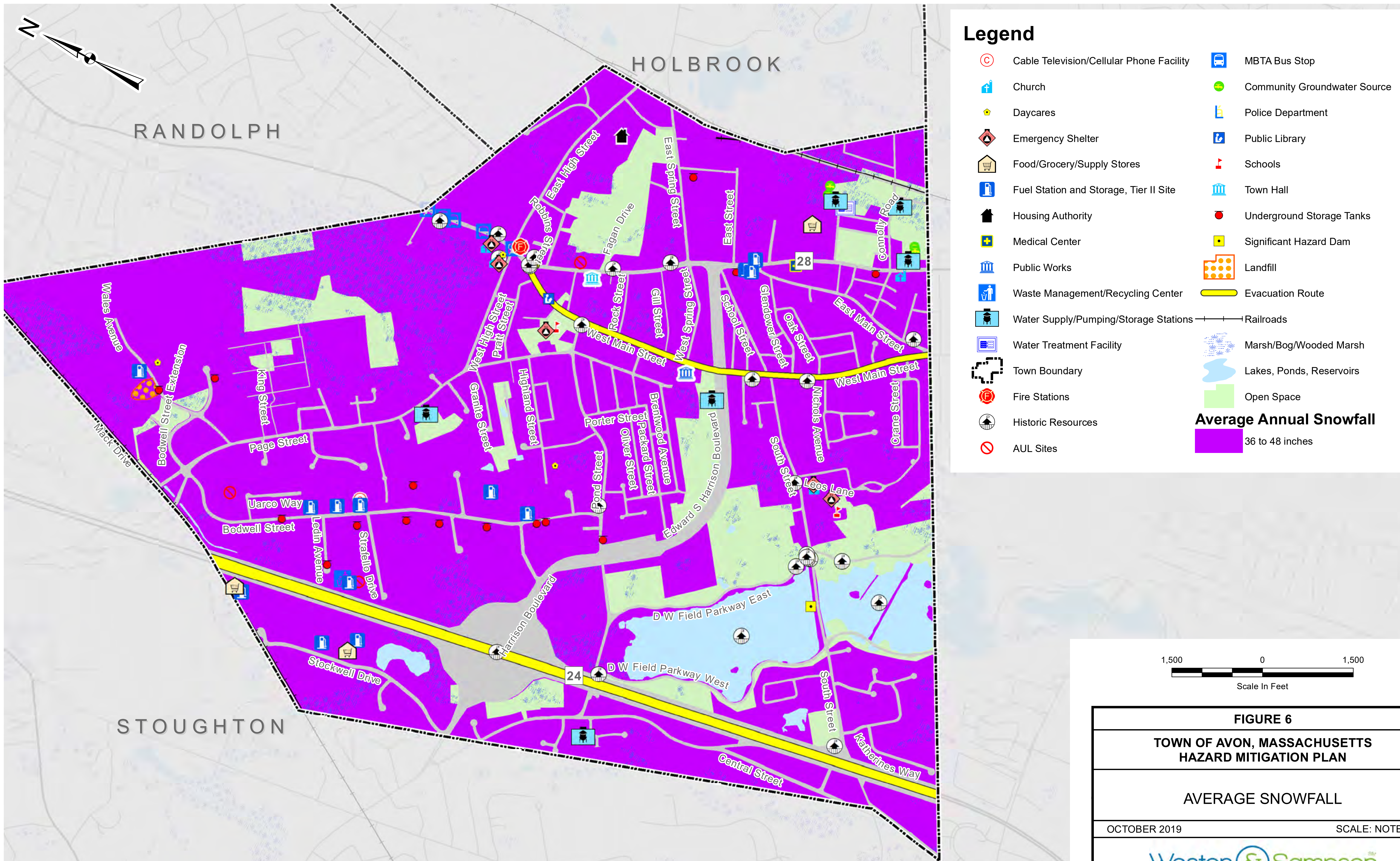


FIGURE 6

TOWN OF AVON, MASSACHUSETTS
HAZARD MITIGATION PLAN

AVERAGE SNOWFALL

OCTOBER 2019 | SCALE: NOTED

Weston & Sampson

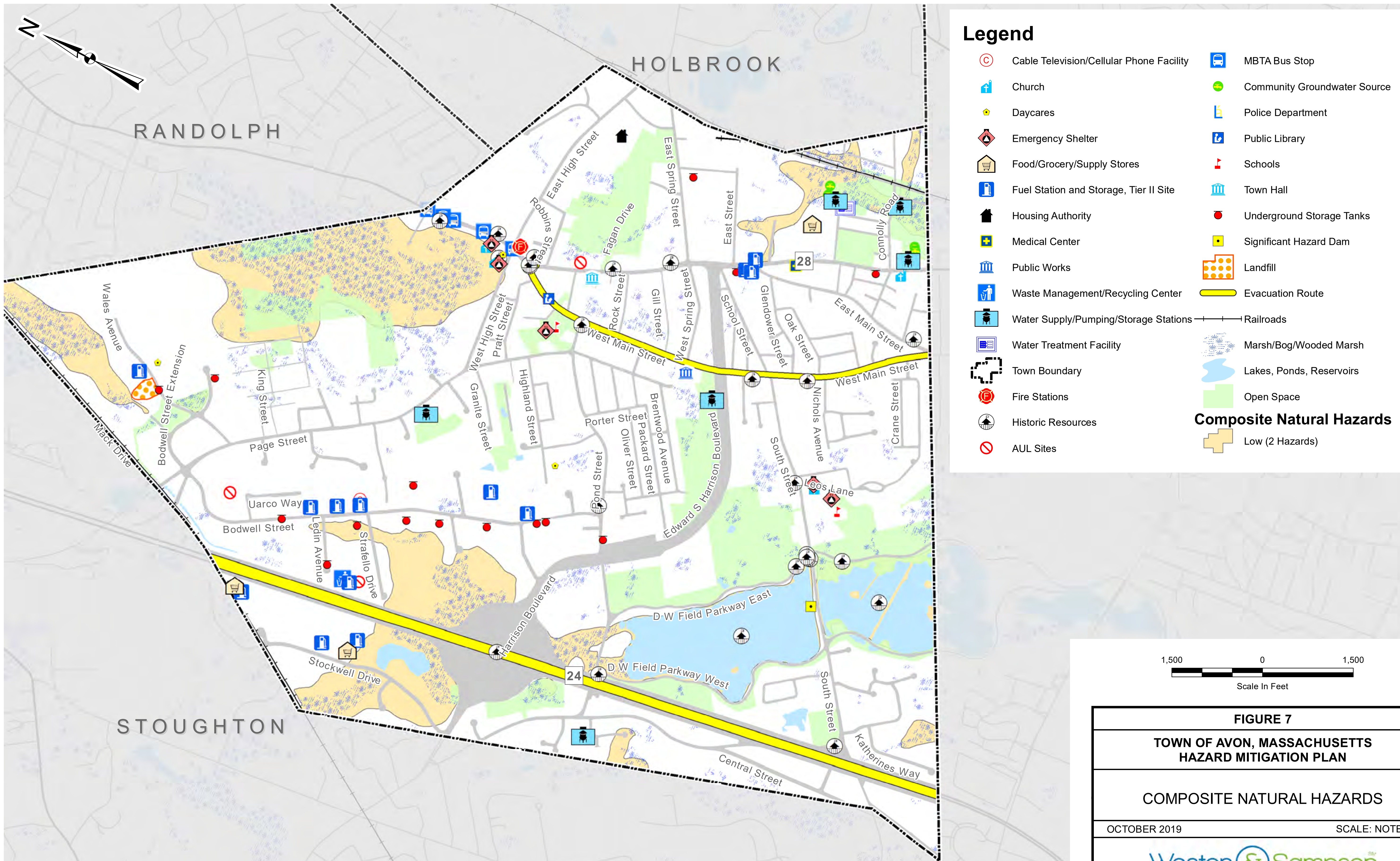


FIGURE 7

TOWN OF AVON, MASSACHUSETTS
HAZARD MITIGATION PLAN

COMPOSITE NATURAL HAZARDS

OCTOBER 2019 SCALE: NOTED

Weston & Sampson

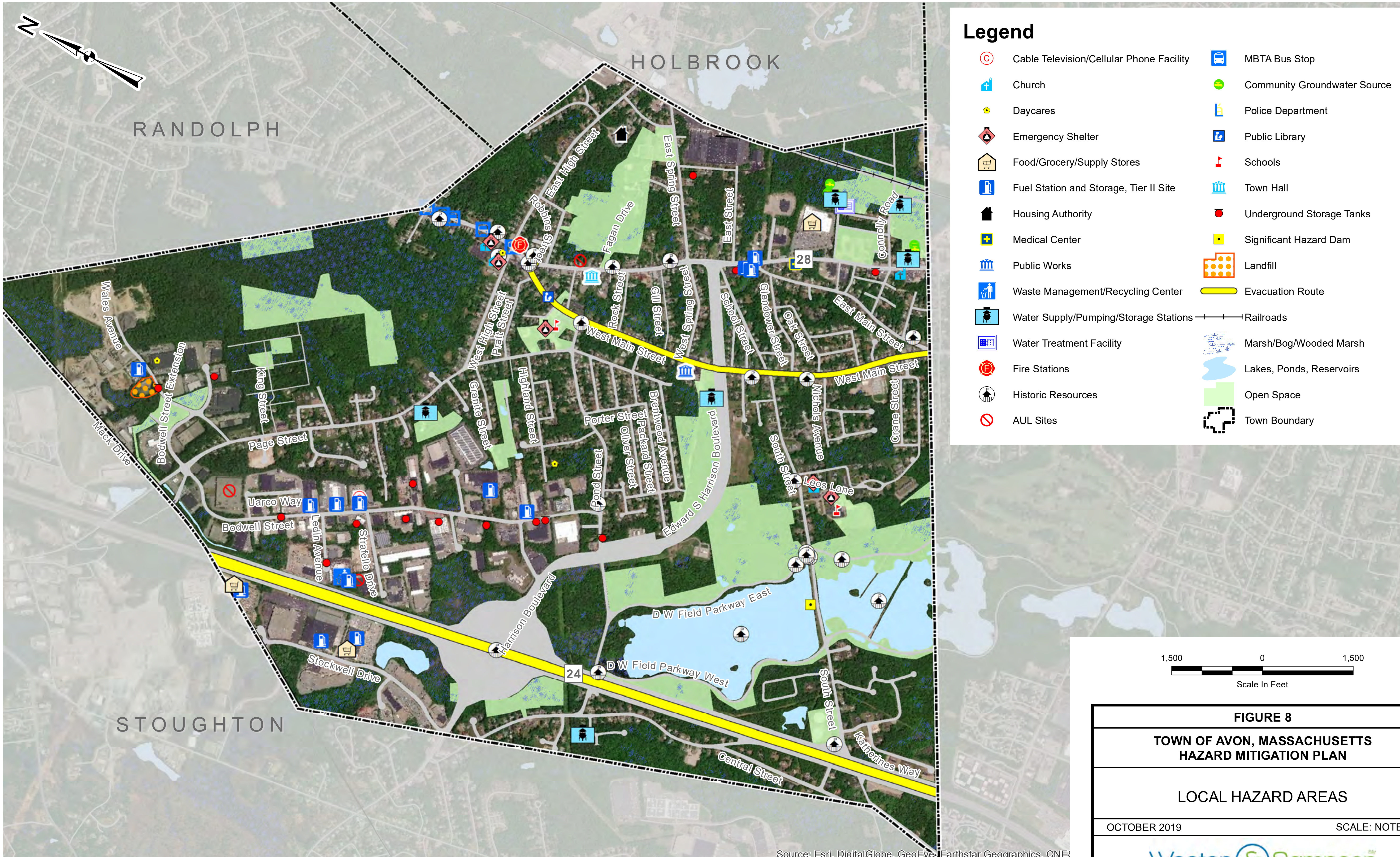


FIGURE 8

TOWN OF AVON, MASSACHUSETTS
HAZARD MITIGATION PLAN

LOCAL HAZARD AREAS

OCTOBER 2019 SCALE: NOTED

Weston & Sampson

Hazus: Hurricane Global Risk Report

Region Name: Avon

Hurricane Scenario: Probabilistic 100-year Return Period

Print Date: Wednesday, October 28, 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 4.54 square miles and contains 1 census tracts. There are over 1 thousand households in the region and a total population of 4,356 people (2010 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 1 thousand buildings in the region with a total building replacement value (excluding contents) of 1,197 million dollars (2014 dollars). Approximately 83% of the buildings (and 44% of the building value) are associated with residential housing.

Building Inventory

General Building Stock

Hazus estimates that there are 1,848 buildings in the region which have an aggregate total replacement value of 1,197 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.

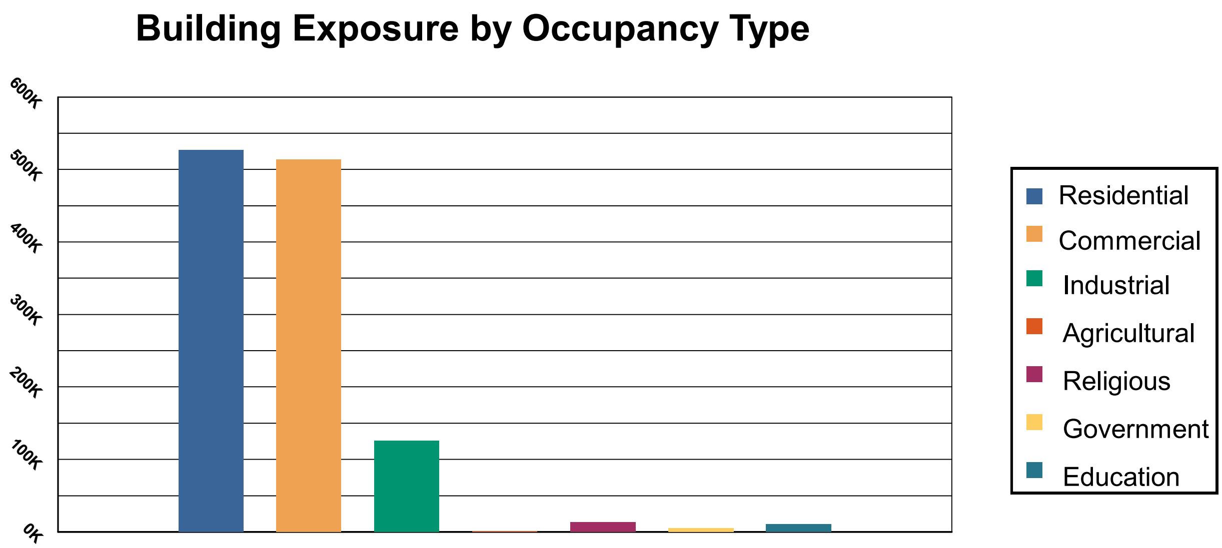


Table 1: Building Exposure by Occupancy Type

Occupancy	Exposure ($1000)	Percent of Tot
Residential	527,130	44.03 %
Commercial	513,610	42.90%
Industrial	125,615	10.49%
Agricultural	1,050	0.09%
Religious	13,882	1.16%
Government	5,366	0.45%
Education	10,444	0.87%
Total	**1,197,097**	**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, 1 police stations and 1 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 9 buildings will be at least moderately damaged. This is over 1% 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.

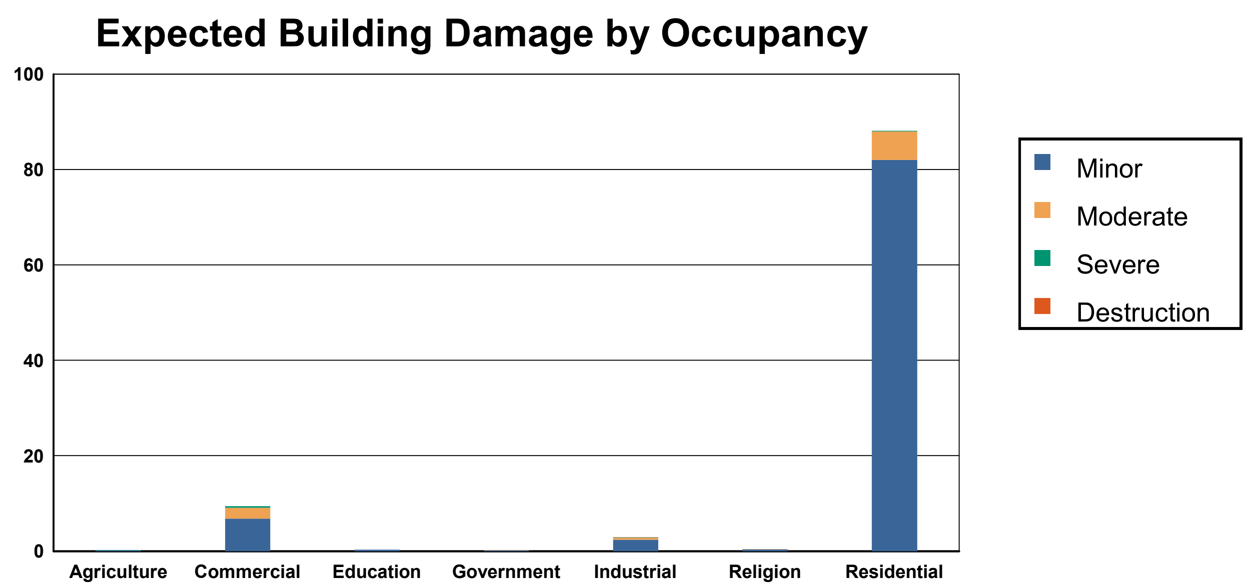


Table 2: Expected Building Damage by Occupancy : 100 - year Event

	None		Minor		Moderate		Severe		Destruction	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	3.78	94.54	0.18	4.43	0.03	0.73	0.01	0.29	0.00	0.01
Commercial	209.56	95.69	6.80	3.10	2.28	1.04	0.36	0.17	0.00	0.00
Education	8.67	96.34	0.31	3.48	0.02	0.18	0.00	0.00	0.00	0.00
Government	5.78	96.38	0.21	3.45	0.01	0.17	0.00	0.00	0.00	0.00
Industrial	59.10	95.33	2.41	3.89	0.36	0.58	0.12	0.19	0.00	0.01
Religion	10.58	96.19	0.40	3.63	0.02	0.17	0.00	0.01	0.00	0.00
Residential	1,448.88	94.27	82.02	5.34	5.95	0.39	0.15	0.01	0.01	0.00
Total	**1,746.36**		**92.33**		**8.66**		**0.64**		**0.01**	

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

Building Type	None		Minor		Moderate		Severe		Destruction	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	31	96.41	1	3.43	0	0.16	0	0.00	0	0.00
Masonry	164	94.76	8	4.34	1	0.76	0	0.13	0	0.00
MH	23	99.14	0	0.65	0	0.16	0	0.00	0	0.05
Steel	148	95.73	4	2.67	2	1.36	0	0.24	0	0.00
Wood	1,384	94.61	75	5.12	4	0.26	0	0.01	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.

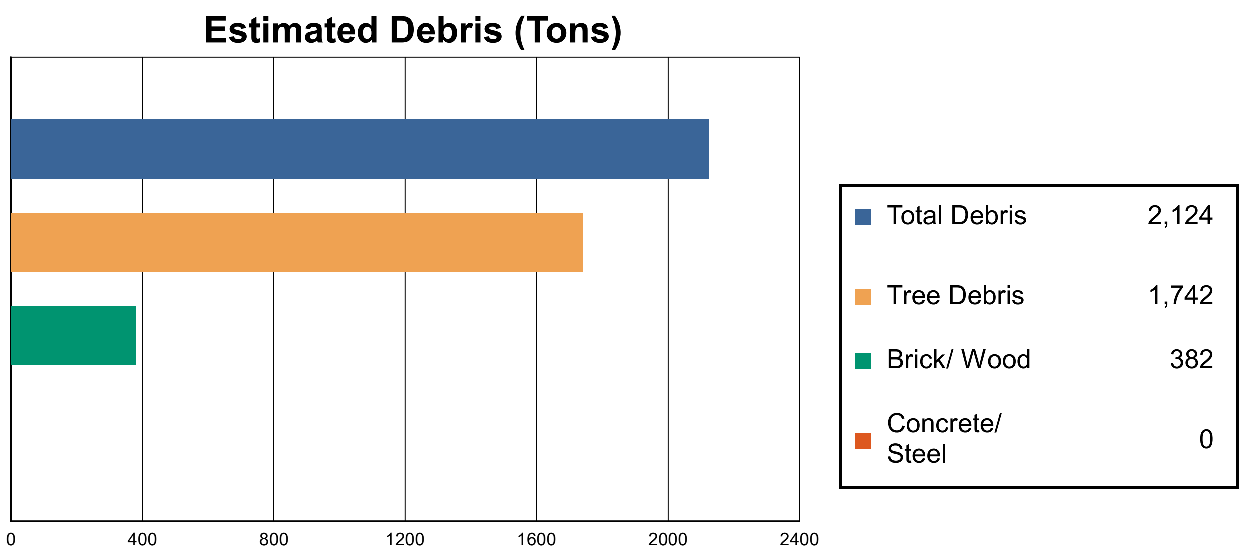
Thematic Map of Essential Facilities with greater than 50% moderate

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**
EOCs	1	0	0	1
Fire Stations	1	0	0	1
Police Stations	1	0	0	1
Schools	3	0	0	3

Induced Hurricane Damage

Debris Generation

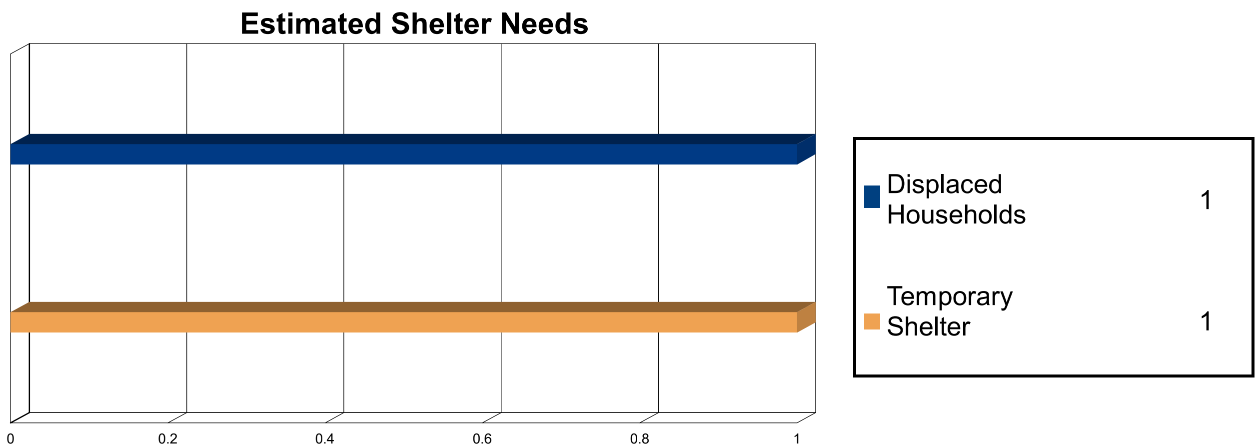


Hazus estimates the amount of debris that will be generated by the hurricane. The model breaks the debris into four general categories: a) Brick/Wood, b) Reinforced Concrete/Steel, c) Eligible Tree Debris, and d) Other Tree Debris. This distinction is made because of the different types of material handling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

The model estimates that a total of 2,124 tons of debris will be generated. Of the total amount, 1,010 tons (48%) is Other Tree Debris. Of the remaining 1,114 tons, Brick/Wood comprises 34% 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 15 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 732 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, 1 people (out of a total population of 4,356) will seek temporary shelter in public shelters.

Economic Loss

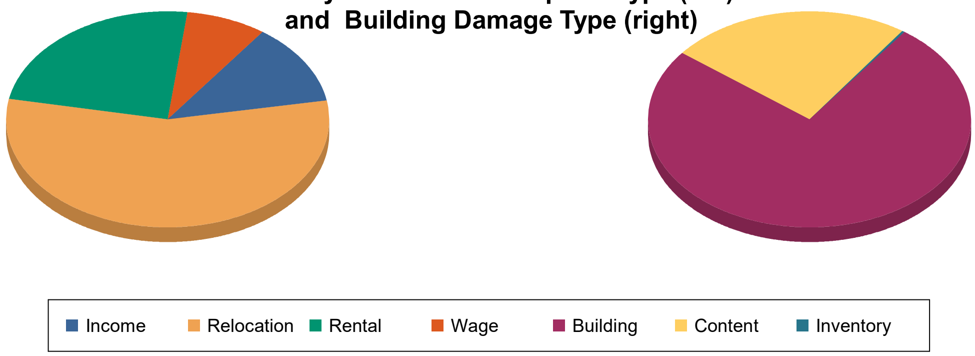
The total economic loss estimated for the hurricane is 6.6 million dollars, which represents 0.55 % of the total replacement value of the region's buildings.

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. 4% 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 80% 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

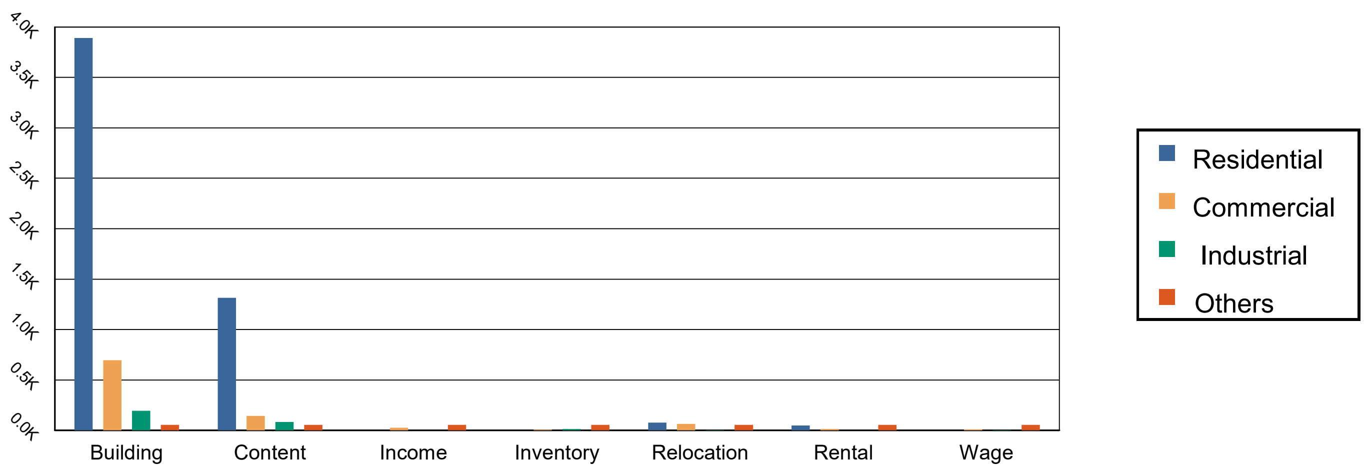


Table 5: Building-Related Economic Loss Estimates

(Thousands of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	3,891.24	694.34	193.54	36.41	4,815.53
	Content	1,314.15	144.85	82.48	1.91	1,543.39
	Inventory	0.00	7.15	12.94	0.05	20.14
	Subtotal	**5,205.39**	**846.34**	**288.96**	**38.37**	**6,379.06**
Business Interruption Loss						
	Income	0.00	27.03	1.47	3.81	32.31
	Relocation	76.00	62.85	4.86	2.62	146.33
	Rental	48.42	12.51	1.21	0.25	62.40
	Wage	0.00	9.61	2.43	8.93	20.97
	Subtotal	**124.42**	**112.00**	**9.97**	**15.62**	**262.01**

Total

Total	**5,329.80**	**958.34**	**298.93**	**53.98**	**6,641.06**

Appendix A: County Listing for the Region

Massachusetts
- Norfolk

Appendix B: Regional Population and Building Value Data

		Building Value (thousands of dollars)		
	Population	Residential	Non-Residential	Total
Massachusetts				
Norfolk	4,356	527,130	669,967	1,197,097
Total	**4,356**	**527,130**	**669,967**	**1,197,097**
Study Region Total	**4,356**	**527,130**	**669,967**	**1,197,097**

Hazus: Hurricane Global Risk Report

Region Name: Avon

Hurricane Scenario: Probabilistic 500-year Return Period

Print Date: Wednesday, October 28, 2020

Table of Contents

General Description of the Region

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Note:
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There are an estimated 1 thousand buildings in the region with a total building replacement value (excluding contents) of 1,197 million dollars (2014 dollars). Approximately 83% of the buildings (and 44% of the building value) are associated with residential housing.

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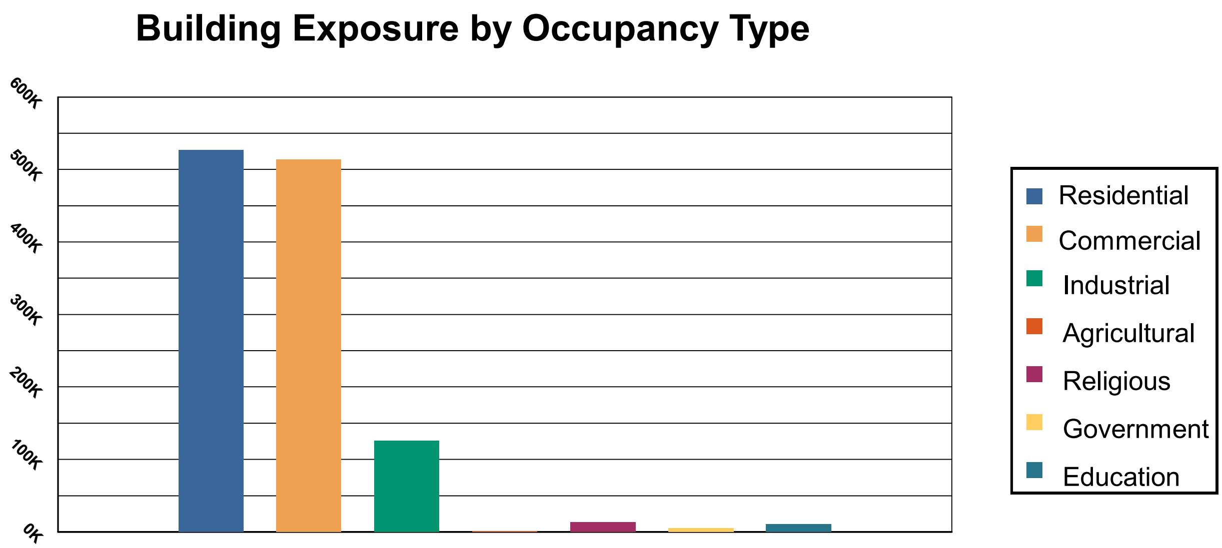

Table 1: Building Exposure by Occupancy Type

Occupancy	Exposure ($1000)	Percent of Tot
Residential	527,130	44.03 %
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Industrial	125,615	10.49%
Agricultural	1,050	0.09%
Religious	13,882	1.16%
Government	5,366	0.45%
Education	10,444	0.87%
Total	**1,197,097**	**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, 1 police stations and 1 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 91 buildings will be at least moderately damaged. This is over 5% of the total number of buildings in the region. There are an estimated 3 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.

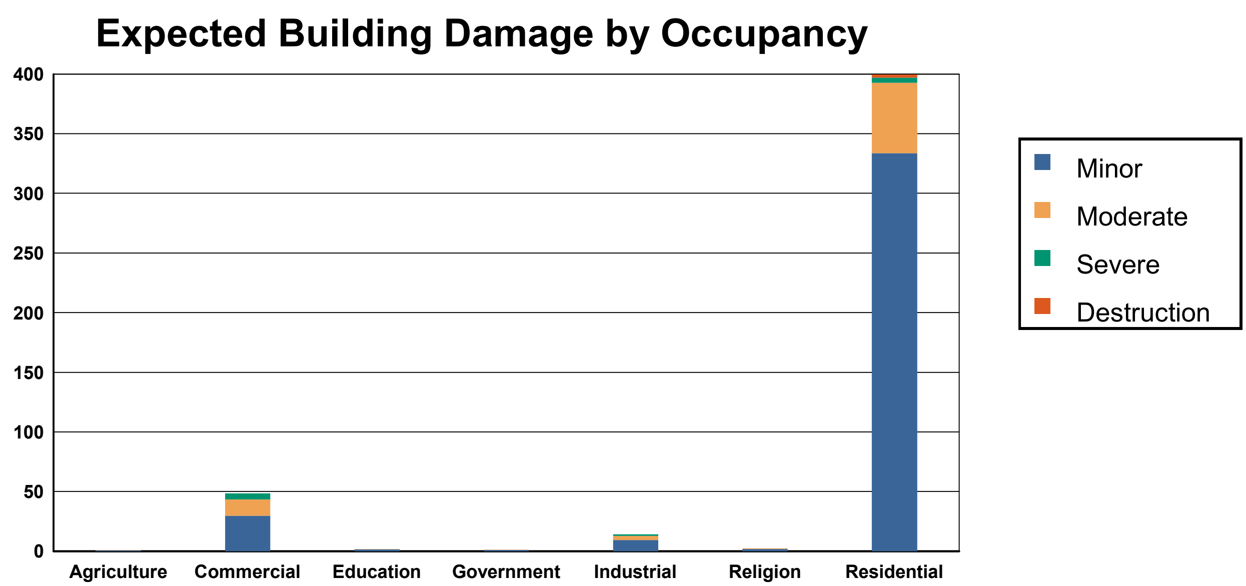


Table 2: Expected Building Damage by Occupancy : 500 - year Event

	None		Minor		Moderate		Severe		Destruction	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	2.94	73.51	0.73	18.16	0.22	5.39	0.10	2.60	0.01	0.34
Commercial	170.52	77.86	29.62	13.53	13.63	6.22	5.19	2.37	0.04	0.02
Education	7.19	79.94	1.41	15.62	0.37	4.13	0.03	0.31	0.00	0.00
Government	4.81	80.19	0.92	15.25	0.25	4.24	0.02	0.32	0.00	0.00
Industrial	47.77	77.05	9.24	14.91	3.59	5.79	1.26	2.03	0.14	0.22
Religion	8.67	78.83	1.90	17.23	0.40	3.68	0.03	0.26	0.00	0.00
Residential	1,137.47	74.01	333.77	21.72	58.85	3.83	4.28	0.28	2.62	0.17
Total	**1,379.38**		**377.58**		**77.32**		**10.90**		**2.81**	

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

Building Type	None		Minor		Moderate		Severe		Destruction	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	26	80.47	5	14.77	1	4.41	0	0.34	0	0.00
Masonry	132	76.32	27	15.78	11	6.40	2	1.36	0	0.16
MH	21	89.59	1	5.88	1	3.31	0	0.14	0	1.09
Steel	121	78.11	18	11.35	11	7.13	5	3.38	0	0.03
Wood	1,087	74.30	322	22.03	48	3.29	4	0.24	2	0.14

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.

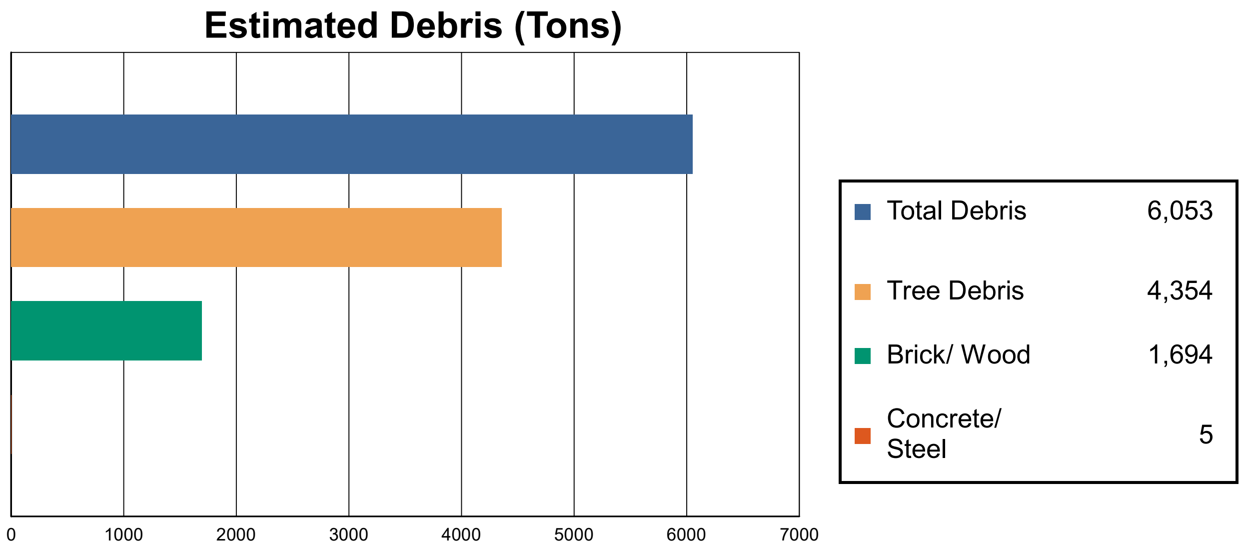
Thematic Map of Essential Facilities with greater than 50% moderate

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**
EOCs	1	0	0	1
Fire Stations	1	0	0	1
Police Stations	1	0	0	1
Schools	3	0	0	0

Induced Hurricane Damage

Debris Generation

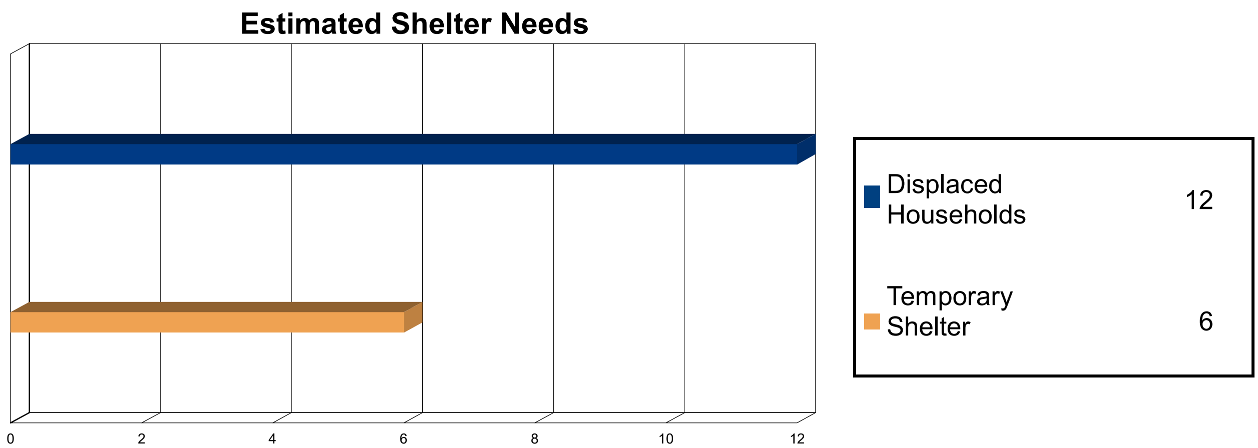


Hazus estimates the amount of debris that will be generated by the hurricane. The model breaks the debris into four general categories: a) Brick/Wood, b) Reinforced Concrete/Steel, c) Eligible Tree Debris, and d) Other Tree Debris. This distinction is made because of the different types of material handling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

The model estimates that a total of 6,053 tons of debris will be generated. Of the total amount, 2,525 tons (42%) is Other Tree Debris. Of the remaining 3,528 tons, Brick/Wood comprises 48% 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 68 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 1,829 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 12 households to be displaced due to the hurricane. Of these, 6 people (out of a total population of 4,356) will seek temporary shelter in public shelters.

Economic Loss

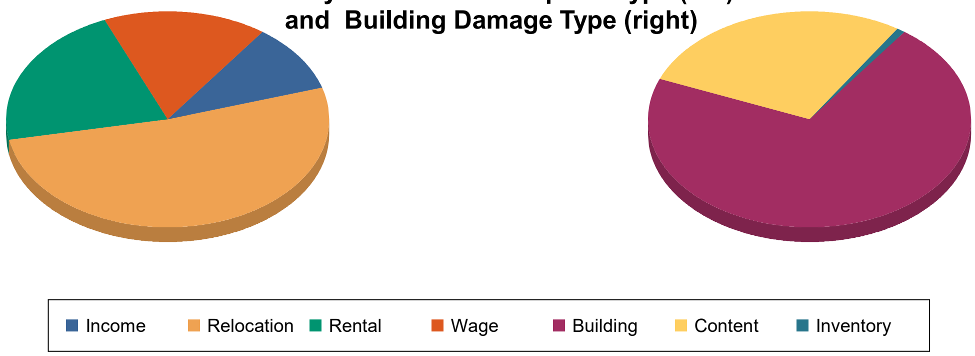
The total economic loss estimated for the hurricane is 30.1 million dollars, which represents 2.51 % of the total replacement value of the region's buildings.

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 30 million dollars. 9% 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 61% 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

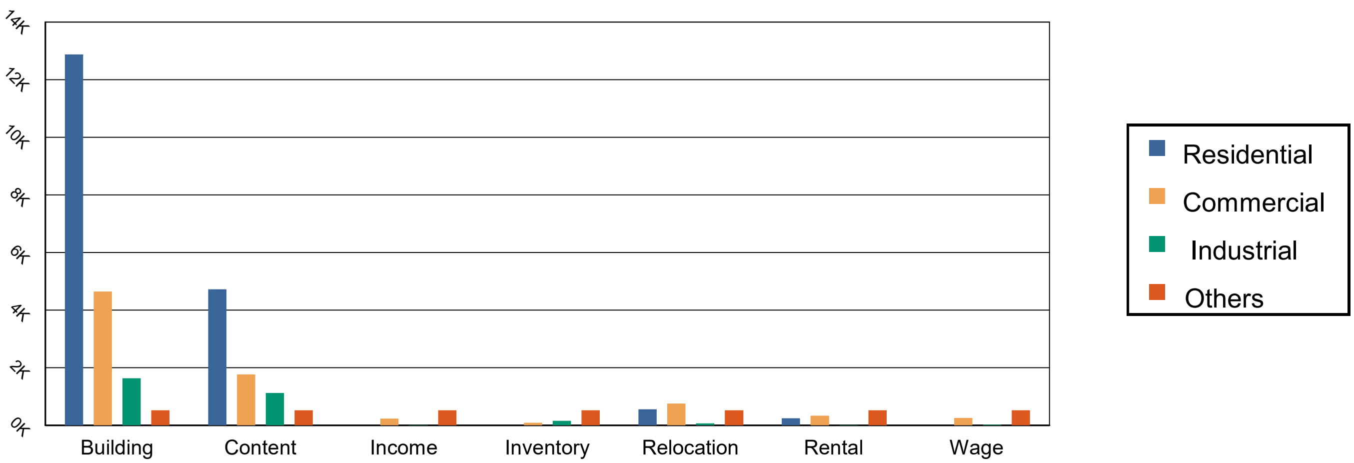


Table 5: Building-Related Economic Loss Estimates

(Thousands of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	12,881.75	4,641.08	1,633.28	228.19	19,384.31
	Content	4,718.52	1,773.16	1,120.37	54.97	7,667.02
	Inventory	0.00	86.78	161.91	0.66	249.35
	Subtotal	**17,600.27**	**6,501.02**	**2,915.56**	**283.83**	**27,300.68**
Business Interruption Loss						
	Income	0.00	239.15	17.24	26.07	282.46
	Relocation	554.32	755.76	71.31	38.07	1,419.46
	Rental	243.33	335.66	15.14	3.37	597.50
	Wage	0.00	254.31	28.76	167.53	450.60
	Subtotal	**797.65**	**1,584.88**	**132.45**	**235.03**	**2,750.02**

<u>Total</u>

Total	**18,397.92**	**8,085.90**	**3,048.01**	**518.86**	**30,050.70**

Appendix A: County Listing for the Region

Massachusetts
- Norfolk

Appendix B: Regional Population and Building Value Data

	Population	Building Value (thousands of dollars)		
		Residential	Non-Residential	Total
Massachusetts				
Norfolk	4,356	527,130	669,967	1,197,097
Total	**4,356**	**527,130**	**669,967**	**1,197,097**
Study Region Total	**4,356**	**527,130**	**669,967**	**1,197,097**

Hazus: Earthquake Global Risk Report

Region Name: Avon

Earthquake Scenario: Magnitude 5 Earthquake

Print Date: October 28, 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 4.54 square miles and contains 1 census tracts. There are over 1 thousand households in the region which has a total population of 4,356 people (2010 Census Bureau data). The distribution of population by Total Region and County is provided in Appendix B.

There are an estimated 1 thousand buildings in the region with a total building replacement value (excluding contents) of 1,197 (millions of dollars). Approximately 83.00 % of the buildings (and 44.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 365 and 19 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 1 thousand buildings in the region which have an aggregate total replacement value of 1,197 (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 79% 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, 1 police stations and 1 emergency operation facilities. With respect to high potential loss facilities (HPL), there are no dams identified within the inventory. The inventory also includes 3 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 384.00 (millions of dollars). This inventory includes over 27.96 miles of highways, 2 bridges, 123.65 miles of pipes.

Table 1: Transportation System Lifeline Inventory

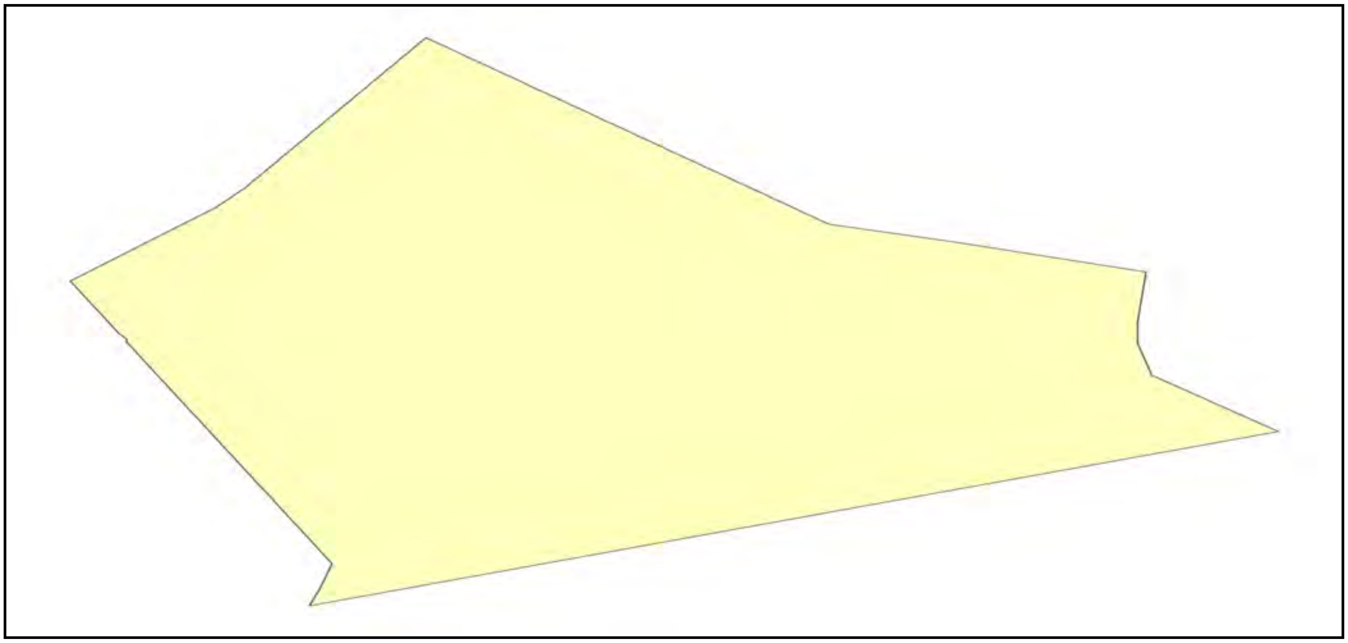
System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	2	12.6915
	Segments	15	321.0334
	Tunnels	0	0.0000
		Subtotal	**333.7249**
Railways	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	5	13.1081
	Tunnels	0	0.0000
		Subtotal	**13.1081**
Light Rail	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	2	18.3503
	Tunnels	0	0.0000
		Subtotal	**18.3503**
Bus	Facilities	0	0.0000
		Subtotal	**0.0000**
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	**365.20**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	2.2288
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**2.2288**
Waste Water	Distribution Lines	NA	1.3373
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**1.3373**
Natural Gas	Distribution Lines	NA	0.8915
	Facilities	0	0.0000
	Pipelines	2	15.5041
		Subtotal	**16.3956**
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	**20.00**

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	Magnitude 5 Earthquake
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-71.05
Latitude of Epicenter	42.13
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 461 buildings will be at least moderately damaged. This is over 25.00 % 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

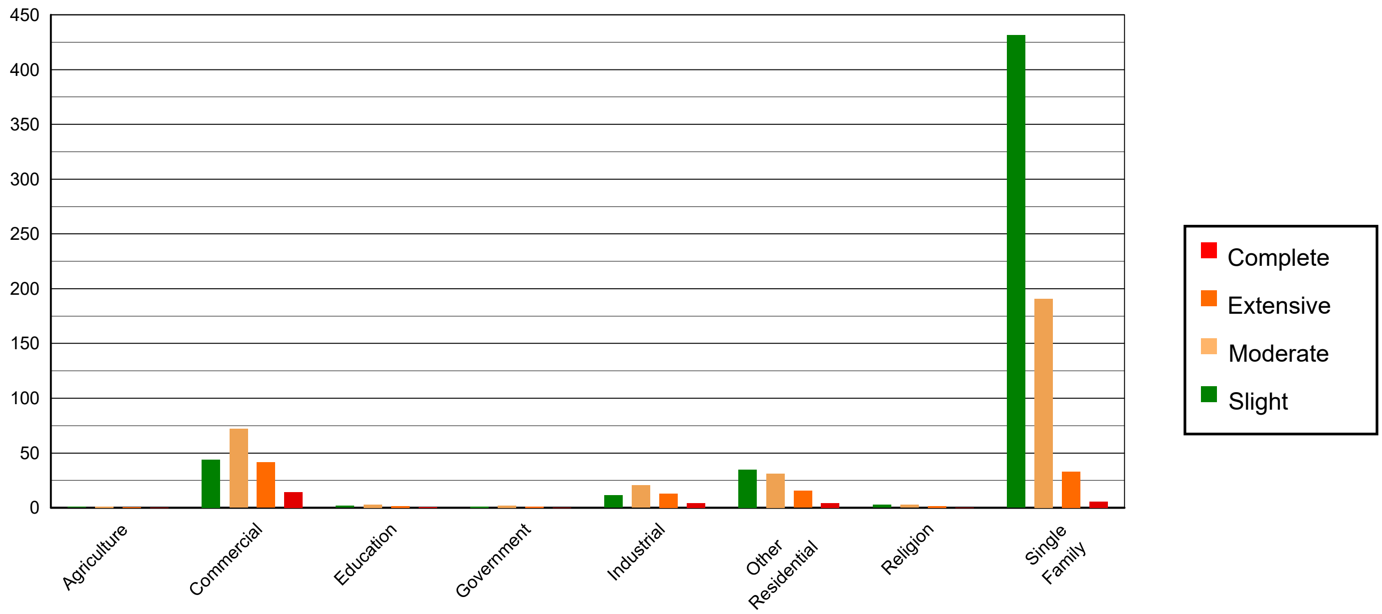


Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0.86	0.10	0.96	0.18	1.34	0.41	0.62	0.58	0.21	0.70
Commercial	47.10	5.49	44.03	8.33	72.02	22.25	41.48	38.53	14.37	47.45
Education	2.08	0.24	1.82	0.34	2.94	0.91	1.62	1.50	0.54	1.79
Government	1.25	0.15	1.11	0.21	2.00	0.62	1.22	1.14	0.42	1.38
Industrial	12.74	1.48	11.33	2.15	20.57	6.36	12.90	11.98	4.45	14.71
Other Residential	52.83	6.16	35.14	6.65	31.21	9.64	15.48	14.38	4.34	14.32
Religion	3.84	0.45	2.60	0.49	2.65	0.82	1.44	1.33	0.48	1.58
Single Family	737.42	85.94	431.30	81.64	190.90	58.99	32.91	30.56	5.47	18.06
Total	**858**		**528**		**324**		**108**		**30**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	774.80	90.29	456.61	86.43	200.74	62.03	28.42	26.39	2.43	8.04
Steel	29.38	3.42	25.31	4.79	53.39	16.50	34.49	32.03	12.38	40.89
Concrete	3.93	0.46	3.55	0.67	8.48	2.62	5.57	5.18	1.70	5.61
Precast	1.39	0.16	1.05	0.20	2.77	0.86	2.87	2.67	0.94	3.09
RM	9.45	1.10	4.69	0.89	10.03	3.10	8.27	7.68	1.54	5.09
URM	36.21	4.22	32.95	6.24	39.70	12.27	22.13	20.55	9.79	32.35
MH	2.93	0.34	4.13	0.78	8.52	2.63	5.92	5.50	1.49	4.93
Total	**858**		**528**		**324**		**108**		**30**	

*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	2	0	1
EOCs	1	1	0	0
PoliceStations	1	1	0	0
FireStations	1	1	0	0

Transportation Lifeline Damage

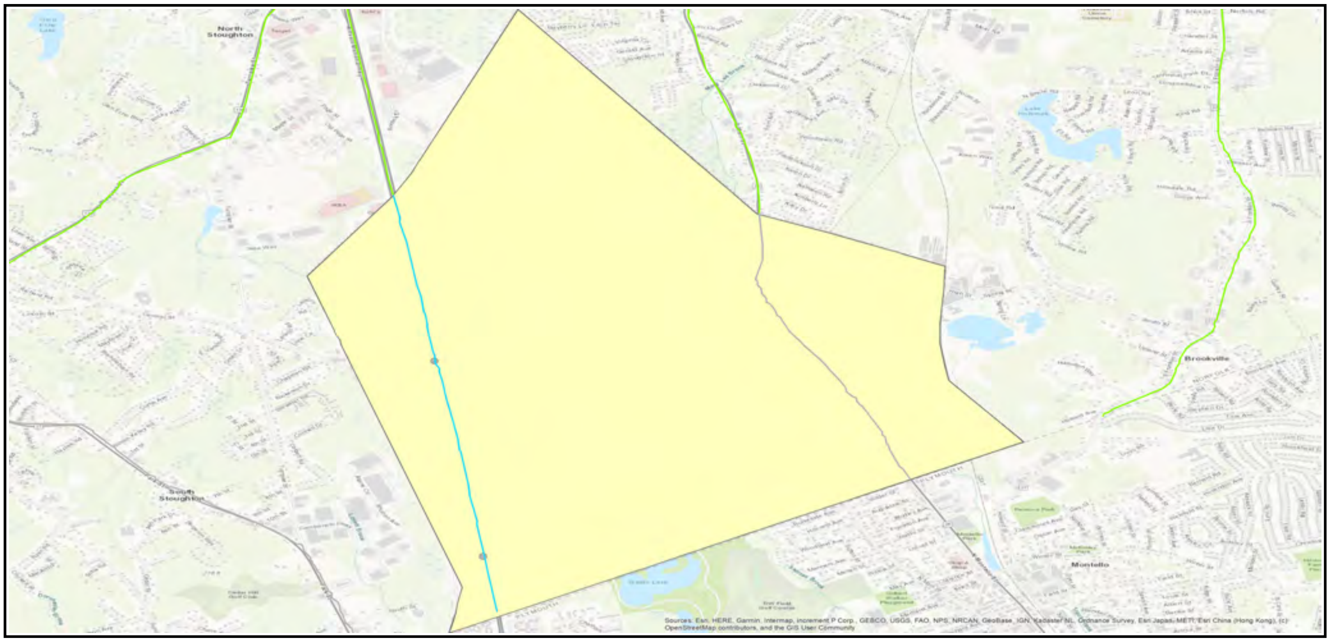


Table 6: Expected Damage to the Transportation Systems

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	15	0	0	2	2
	Bridges	2	0	0	2	2
	Tunnels	0	0	0	0	0
Railways	Segments	5	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	2	0	0	2	2
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	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	0	0	0	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	69	18	5
Waste Water	42	9	2
Natural Gas	13	0	0
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	1,709	0	0	0	0	0
Electric Power		1,446	971	414	75	2

Induced Earthquake Damage

Fire Following Earthquake

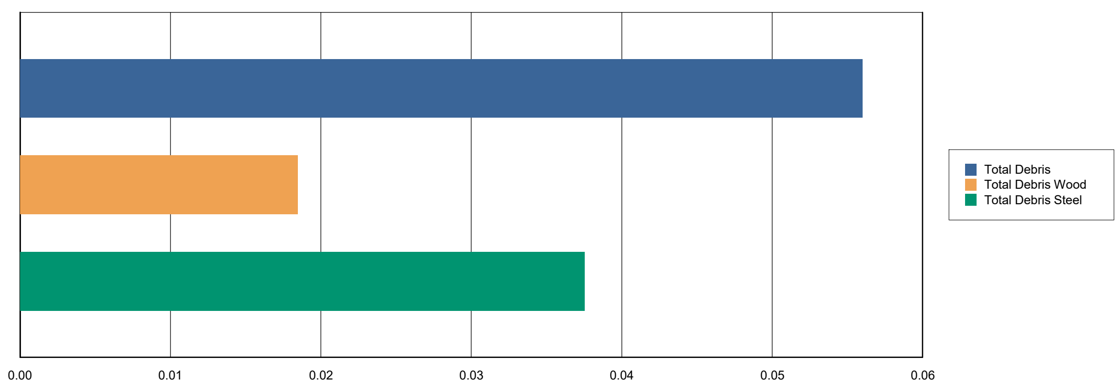
Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there 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 56,000 tons of debris will be generated. Of the total amount, Brick/Wood comprises 33.00% 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 2,240 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Earthquake Debris (millions of tons)



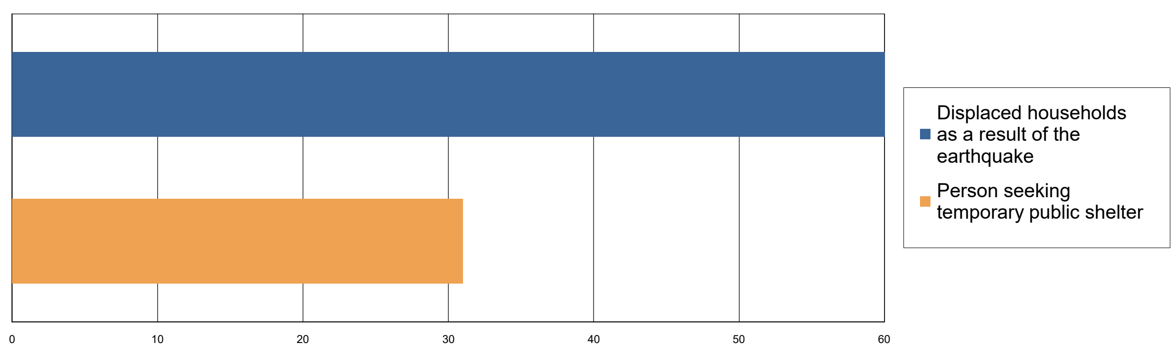
Brick/ Wood	Reinforced Concrete/Steel	Total Debris	Truck Load
0.02	0.04	0.06	2,240 (@25 tons/truck)

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 60 households to be displaced due to the earthquake. Of these, 31 people (out of a total population of 4,356) 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
60	31

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	0.31	0.08	0.01	0.02
	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	0.29	0.07	0.01	0.02
	Other-Residential	3.26	0.78	0.11	0.21
	Single Family	4.42	0.77	0.08	0.15
	Total	**8**	**2**	**0**	**0**
2 PM	Commercial	17.31	4.31	0.60	1.17
	Commuting	0.00	0.00	0.00	0.00
	Educational	6.63	1.70	0.25	0.49
	Hotels	0.00	0.00	0.00	0.00
	Industrial	2.13	0.54	0.08	0.15
	Other-Residential	0.67	0.16	0.02	0.04
	Single Family	0.91	0.16	0.02	0.03
	Total	**28**	**7**	**1**	**2**
5 PM	Commercial	11.92	2.98	0.42	0.81
	Commuting	0.04	0.06	0.09	0.02
	Educational	0.80	0.20	0.03	0.06
	Hotels	0.00	0.00	0.00	0.00
	Industrial	1.33	0.34	0.05	0.09
	Other-Residential	1.28	0.31	0.04	0.08
	Single Family	1.74	0.31	0.03	0.06
	Total	**17**	**4**	**1**	**1**

Economic Loss

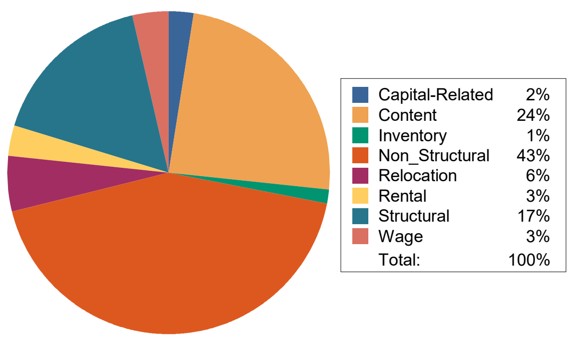
The total economic loss estimated for the earthquake is 228.77 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

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 228.43 (millions of dollars); 15 % 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 22 % 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)

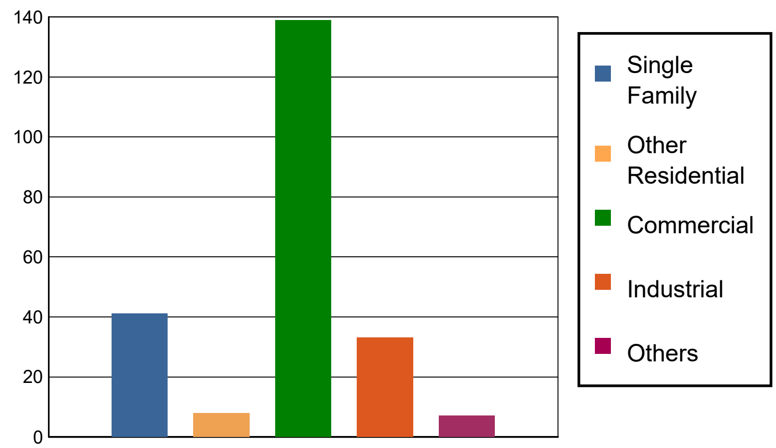


Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.0000	0.0000	6.9775	0.6871	0.3077	7.9723
	Capital-Related	0.0000	0.0000	5.2190	0.4099	0.0418	5.6707
	Rental	0.4664	0.4298	5.7637	0.2091	0.0805	6.9495
	Relocation	1.6710	0.3695	9.3028	0.9258	0.7343	13.0034
	Subtotal	**2.1374**	**0.7993**	**27.2630**	**2.2319**	**1.1643**	**33.5959**
Capital Stock Losses							
	Structural	3.9179	0.7748	28.2833	4.2410	1.0111	38.2281
	Non_Structural	23.7139	4.8528	51.9030	14.4904	3.1819	98.1420
	Content	11.4666	1.5177	29.7887	10.4505	1.8288	55.0523
	Inventory	0.0000	0.0000	1.6349	1.7718	0.0068	3.4135
	Subtotal	**39.0984**	**7.1453**	**111.6099**	**30.9537**	**6.0286**	**194.8359**
	Total	**41.24**	**7.94**	**138.87**	**33.19**	**7.19**	**228.43**

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	321.0334	0.0000	0.00
	Bridges	12.6915	0.1993	1.57
	Tunnels	0.0000	0.0000	0.00
	Subtotal	**333.7249**	**0.1993**	
Railways	Segments	13.1081	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	**13.1081**	**0.0000**	
Light Rail	Segments	18.3503	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	**18.3503**	**0.0000**	
Bus	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
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	**365.18**	**0.20**	

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	0.0000	0.0000	0.00
	Distribution Lines	2.2288	0.0828	3.72
	Subtotal	**2.2288**	**0.0828**	
Waste Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Lines	1.3373	0.0416	3.11
	Subtotal	**1.3373**	**0.0416**	
Natural Gas	Pipelines	15.5041	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Lines	0.8915	0.0142	1.59
	Subtotal	**16.3956**	**0.0142**	
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	**19.96**	**0.14**	

Appendix A: County Listing for the Region

Norfolk,MA

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Massachusetts					
	Norfolk	4,356	527	669	1,197
Total Region		**4,356**	**527**	**669**	**1,197**

Hazus: Earthquake Global Risk Report

Region Name Avon

Earthquake Scenario: Magnitude 7 Earhtquake

Print Date: October 28, 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:
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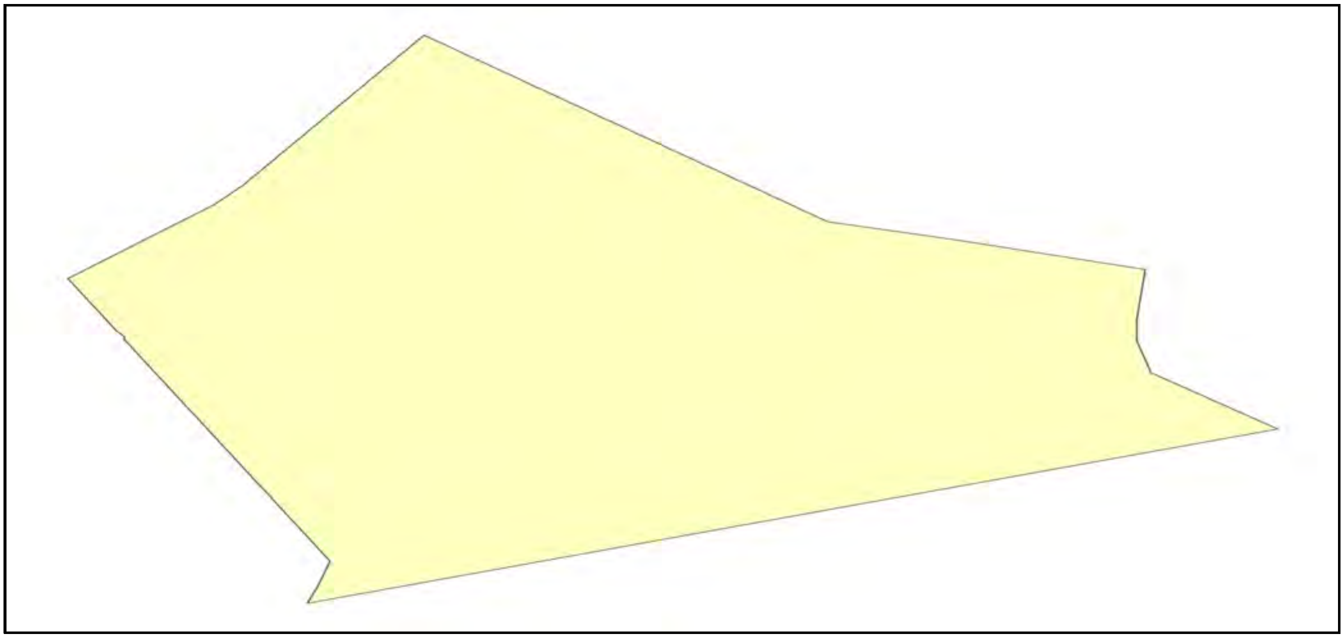
		Subtotal	**0.0000**
Ferry	Facilities	0	0.0000
		Subtotal	**0.0000**
Port	Facilities	0	0.0000
		Subtotal	**0.0000**
Airport	Facilities	0	0.0000
	Runways	0	0.0000
		Subtotal	**0.0000**
		Total	**365.20**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	2.2288
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**2.2288**
Waste Water	Distribution Lines	NA	1.3373
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**1.3373**
Natural Gas	Distribution Lines	NA	0.8915
	Facilities	0	0.0000
	Pipelines	2	15.5041
		Subtotal	**16.3956**
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	**20.00**

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	Magnitude 7 Earhtquake
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-71.05
Latitude of Epicenter	42.13
Earthquake Magnitude	7.00
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 1,679 buildings will be at least moderately damaged. This is over 91.00 % of the buildings in the region. There are an estimated 677 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

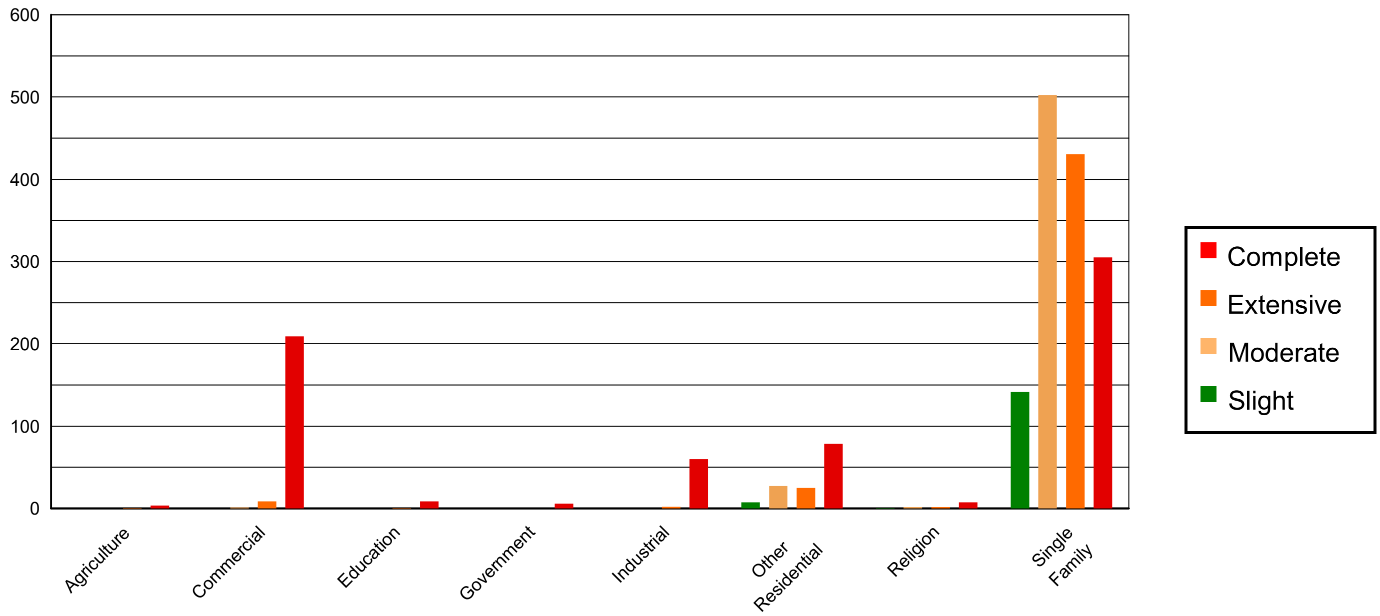


Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0.00	0.00	0.00	0.00	0.03	0.01	0.27	0.06	3.70	0.55
Commercial	0.02	0.10	0.07	0.05	1.07	0.20	8.74	1.87	209.10	30.84
Education	0.00	0.00	0.00	0.00	0.04	0.01	0.35	0.07	8.60	1.27
Government	0.00	0.00	0.00	0.00	0.02	0.00	0.18	0.04	5.80	0.86
Industrial	0.00	0.03	0.01	0.01	0.22	0.04	1.91	0.41	59.85	8.83
Other Residential	0.97	5.06	7.56	5.05	27.09	5.09	24.98	5.33	78.39	11.56
Religion	0.05	0.28	0.42	0.28	1.52	0.29	1.48	0.32	7.52	1.11
Single Family	18.13	94.52	141.63	94.61	502.56	94.37	430.69	91.91	304.99	44.99
Total	**19**		**150**		**533**		**469**		**678**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	19.14	99.80	149.56	99.91	530.81	99.67	457.82	97.70	305.67	45.09
Steel	0.01	0.04	0.01	0.01	0.17	0.03	3.17	0.68	151.60	22.36
Concrete	0.00	0.01	0.00	0.00	0.04	0.01	0.37	0.08	22.83	3.37
Precast	0.00	0.00	0.00	0.00	0.02	0.00	0.08	0.02	8.91	1.31
RM	0.01	0.05	0.01	0.01	0.21	0.04	0.63	0.13	33.13	4.89
URM	0.02	0.10	0.10	0.07	1.23	0.23	5.75	1.23	133.68	19.72
MH	0.00	0.00	0.01	0.00	0.09	0.02	0.76	0.16	22.15	3.27
Total	**19**		**150**		**533**		**469**		**678**	

*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

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

Transportation Lifeline Damage

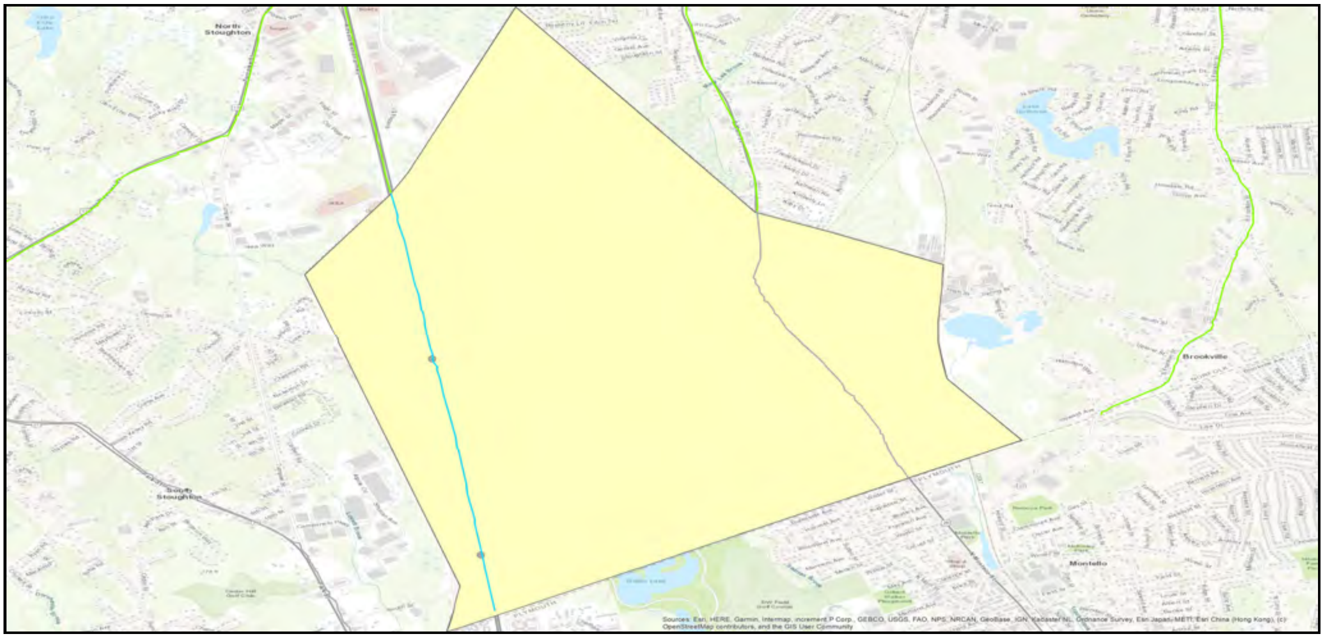


Table 6: Expected Damage to the Transportation Systems

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	15	0	0	2	2
	Bridges	2	2	2	0	0
	Tunnels	0	0	0	0	0
Railways	Segments	5	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	2	0	0	2	2
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	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	0	0	0	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	69	496	124
Waste Water	42	249	62
Natural Gas	13	0	0
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	1,709	1,700	1,639	0	0	0
Electric Power		1,641	1,524	1,210	484	2

Induced Earthquake Damage

Fire Following Earthquake

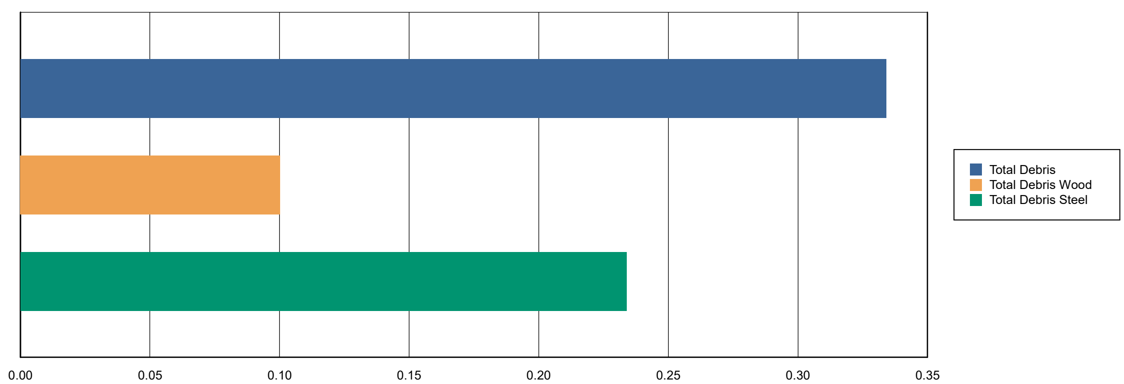
Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there 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 334,000 tons of debris will be generated. Of the total amount, Brick/Wood comprises 30.00% 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 13,360 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Earthquake Debris (millions of tons)



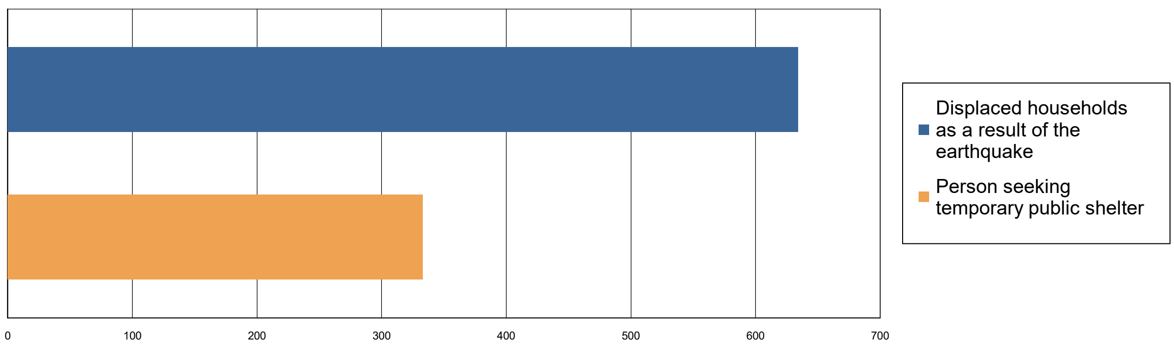
Brick/ Wood	Reinforced Concrete/Steel	Total Debris	Truck Load
0.10	0.23	0.33	13,360 (@25 tons/truck)

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 634 households to be displaced due to the earthquake. Of these, 333 people (out of a total population of 4,356) 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
634	333

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	2.92	0.94	0.15	0.30
	Commuting	0.02	0.03	0.04	0.01
	Educational	0.00	0.00	0.00	0.00
	Hotels	0.00	0.00	0.00	0.00
	Industrial	2.60	0.85	0.14	0.27
	Other-Residential	34.98	10.84	1.65	3.22
	Single Family	70.64	17.38	1.64	2.99
	Total	**111**	**30**	**4**	**7**
2 PM	Commercial	164.64	52.81	8.47	16.61
	Commuting	0.14	0.27	0.35	0.07
	Educational	65.77	21.52	3.60	7.02
	Hotels	0.00	0.00	0.00	0.00
	Industrial	19.28	6.29	1.04	2.02
	Other-Residential	7.24	2.26	0.36	0.66
	Single Family	14.83	3.69	0.39	0.64
	Total	**272**	**87**	**14**	**27**
5 PM	Commercial	114.05	36.60	5.93	11.42
	Commuting	2.97	5.78	7.55	1.57
	Educational	7.88	2.58	0.43	0.84
	Hotels	0.00	0.00	0.00	0.00
	Industrial	12.05	3.93	0.65	1.26
	Other-Residential	13.89	4.34	0.68	1.27
	Single Family	28.45	7.07	0.75	1.23
	Total	**179**	**60**	**16**	**18**

Economic Loss

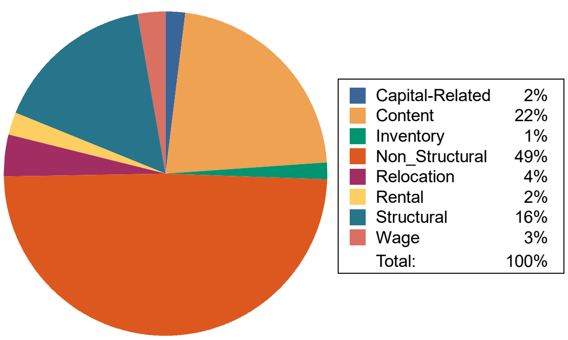
The total economic loss estimated for the earthquake is 1,322.15 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

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 1,309.66 (millions of dollars); 11 % 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 25 % 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)

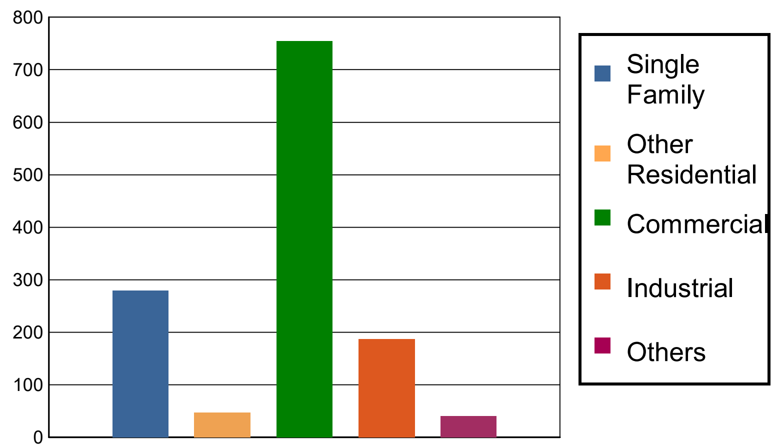


Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.0000	0.0000	30.8664	2.5531	1.1871	34.6066
	Capital-Related	0.0000	0.0000	24.1649	1.5132	0.1927	25.8708
	Rental	4.9746	2.8643	19.9610	0.6989	0.3505	28.8493
	Relocation	16.7662	1.9856	28.7146	2.7184	3.1466	53.3314
	Subtotal	**21.7408**	**4.8499**	**103.7069**	**7.4836**	**4.8769**	**142.6581**
Capital Stock Losses							
	Structural	44.9674	5.1371	138.1942	19.3617	5.3572	213.0176
	Non_Structural	170.2907	31.1017	332.7025	91.5316	20.4329	646.0594
	Content	42.1171	6.8434	170.5938	59.0342	9.8943	288.4828
	Inventory	0.0000	0.0000	9.3401	10.0600	0.0407	19.4408
	Subtotal	**257.3752**	**43.0822**	**650.8306**	**179.9875**	**35.7251**	**1167.0006**
	Total	**279.12**	**47.93**	**754.54**	**187.47**	**40.60**	**1309.66**

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	321.0334	0.0000	0.00
	Bridges	12.6915	8.7520	68.96
	Tunnels	0.0000	0.0000	0.00
	Subtotal	**333.7249**	**8.7520**	
Railways	Segments	13.1081	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	**13.1081**	**0.0000**	
Light Rail	Segments	18.3503	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	**18.3503**	**0.0000**	
Bus	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
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	**365.18**	**8.75**	

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	0.0000	0.0000	0.00
	Distribution Line	2.2288	2.2323	100.16
	Subtotal	**2.2288**	**2.2323**	
Waste Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	1.3373	1.1213	83.85
	Subtotal	**1.3373**	**1.1213**	
Natural Gas	Pipelines	15.5041	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	0.8915	0.3842	43.10
	Subtotal	**16.3956**	**0.3842**	
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	**19.96**	**3.74**	

Appendix A: County Listing for the Region

Norfolk,MA

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Massachusetts					
	Norfolk	4,356	527	669	1,197
Total Region		**4,356**	**527**	**669**	**1,197**

APPENDIX C

Public Meetings

Listening Session Invitation

Greetings,

The Town of Avon was awarded a grant from the Commonwealth's Municipal Vulnerability Preparedness Program to identify priority action items that will improve our community's resilience to climate change. A Listening Session has been planned to present the plan and collect your feedback as a valued member of the community.

We hope you can join the Town at this important workshop. By participating in this program, Avon will be designated as an MVP Community and be eligible for future grants that promote resilience. Following the workshop, we will be hosting a meeting open to public to receive broader input on the planning process.

Mitigation Action	Geographic Coverage	Implementation Responsibility	Time Frame	Priority
FLOODING				
Improve drainage system maintenance	Townwide	Public Works	Ongoing	High
Flood control measures for structures	Townwide	Public Works	Short-term	High
Flood proofing for pumping stations	Townwide	Public Works	Long-term	High
Cloudburst mitigation measures for roadways	Townwide	Public Works	Short and Long-Term	Medium
Assessment and major cleaning of drainage system	Townwide	Public Works	Short and Long-Term	Medium
Convert to sewer system or upgrade septic systems.	Industrial/Commercial Areas (Stockwell and Memorial Drive)	Town Council Public Works Private Parties	Ongoing, Short and Long-Term	Medium to High
Implement green infrastructure and improve existing BMPs.	Townwide	Public Works	Ongoing	Medium
Implement individual stormwater project retrofits.	Townwide	Public Works	Long-Term	Medium
Complete stormwater mapping and make it accessible to emergency personnel.	Townwide	Public Works	Short-term	High

Mitigation Action	Geographic Coverage	Implementation Responsibility	Time Frame	Priority
WIND				
Distributed generation	Townwide	Town Council Public Works	Long-term	
Tree assessment and maintenance plan	Townwide	Public Works Utility Company	Short-term and Ongoing	High
Mobile chipper for post-storm fallen branch and debris management	Townwide	Public Works	Short-term	High
Repeater site antenna replacement/repair	Page Street Water Tank	Police Department Public Works	Short-term	High
Provide backup power sources	Townwide	Town Council Public Works	Ongoing	High
Convert to fiber optic lines	Townwide	Town Council Public Works Public Safety	Long-term	High
Provide a radio control option for communications	Townwide	Public Safety Public Works	Short-term	High

Mitigation Action	Geographic Coverage	Implementation Responsibility	Time Frame	Priority
MULTI-HAZARD				
Work with schools to improve communication with foreign born.	Townwide	School Department Town Council	Short-term and Ongoing	Medium
Identify translators to assist with dissemination of information.	Townwide		Short-term and Ongoing	Medium
Establish a website or call center for translation services.	Townwide	Town Council	Short-term and Ongoing	Medium
Provide variable message boards in strategic locations.		Town Council Public Safety	Long-term	Medium
DROUGHT				
Provide a water supply interconnection for purchase of water.	Townwide	Town Council Public Works	Long-term	High
Repair existing water storage tanks	Page Street Central Street	Public Works	Short-term	High
WINTER STORMS				
Add storage and implement improvements and regular maintenance at snow compost site	Downtown	Public Works	Short-term and Ongoing	Low

TOWN OF AVON

Listening Session

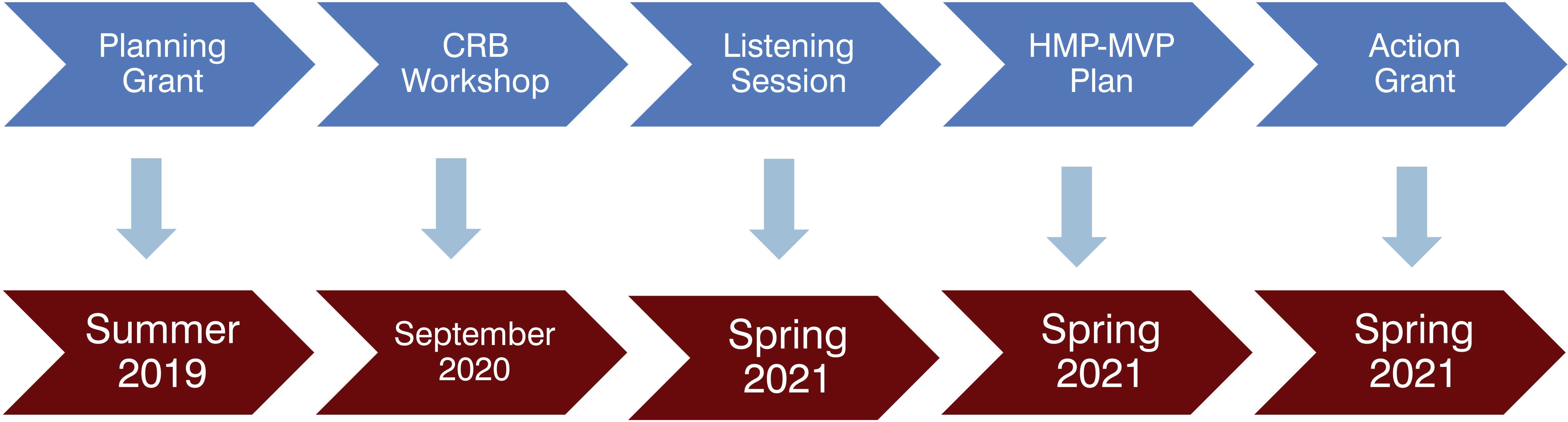
Hazard Mitigation Plan & Municipal Vulnerability Preparedness

April 13, 2021

PROJECT CORE TEAM

Robert Spurr
Jeffrey J. Bukunt
Kathleen Waldron
Brian Martin

Patricia Bessette
William Fitzgerald
Gregory Enos


Planning Grant
CRB Workshop
Listening Session
HMP-MVP Plan
Action Grant
Summer 2019
September 2020
Spring 2021
Spring 2021
Spring 2021

MVP IN AVON

- Increase resilience of community
- Raise awareness of climate threats
- Identify priority actions to move forward
- Create implementation pathways

Weston & Sampson

HAZARDS & CLIMATE CHANGE

IN AVON AND NEW ENGLAND

Weston & Sampson

HAZARDS IN AVON

FLOOD HAZARDS

WIND HAZARDS

WINTER STORMS

EARTHQUAKES, LANDSLIDES, ETC.

FIRE

EXTREME TEMPERATURES

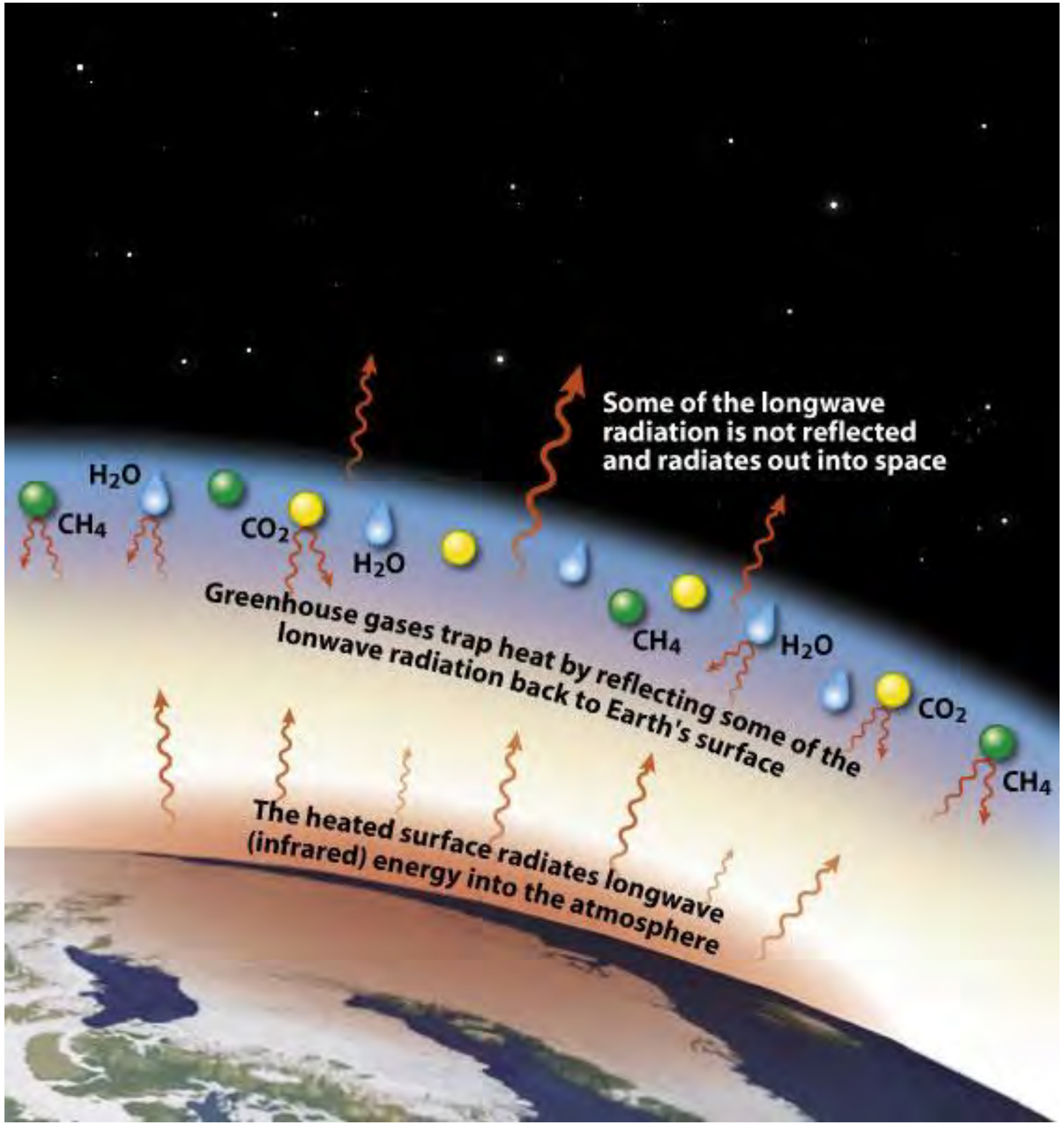
DROUGHT

CLIMATE CHANGE

GREENHOUSE GASES (GHG)

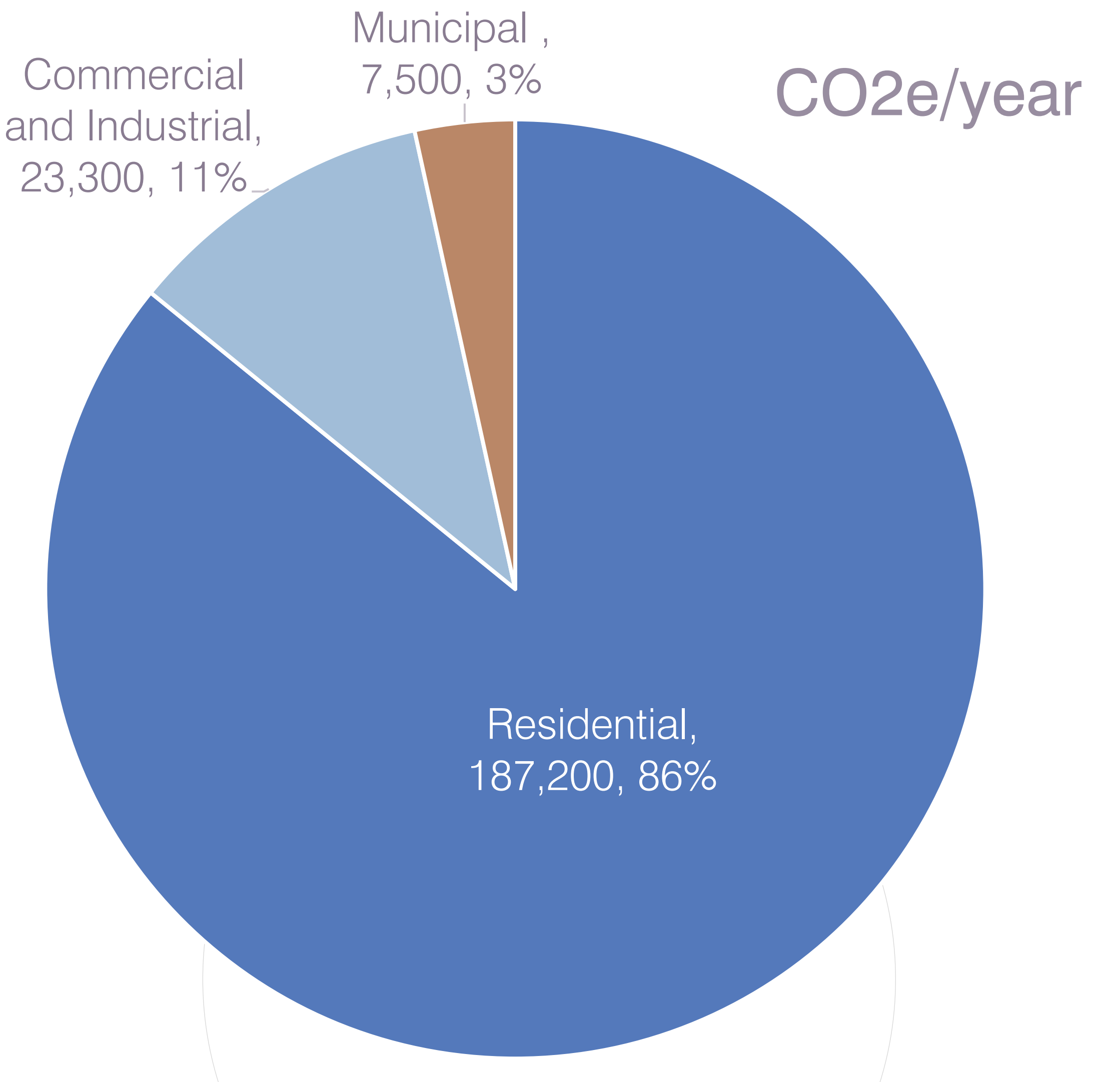
- Naturally occurring
- Act as a blanket
- Examples: carbon dioxide and methane

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

2006 GHG EMISSIONS



Hazards in Avon

Hazard	Frequency (in Avon)	Severity (in Avon)
Flooding	High	Minor to Serious
Dam Failures	Very Low	Minor
Snow and Blizzard	High	Minor to Extensive
Ice Storms	High	Minor to Extensive
Hurricanes	Medium	Serious
Nor'easters	High	Minor To Extensive
Thunderstorms	High	Minor to Extensive
Brush Fires	Medium	Minor to Extensive
Earthquakes	Very Low	Minor to Catastrophic
Landslides	Low	Minor
Extreme Temperatures	High	Minor to Serious
Drought	High	Minor to Serious

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

Weston & Sampson

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

Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "ResilientMA Datagrapher." Massachusetts Climate Change Clearinghouse. Resilientma.org/datagrapher/?c=Temp/state/tx90/ANN/MA/
Notes: Mid-century projected annual averages use a 2040-2069 time range. End-of-century project annual averages use a 2080-2097 time range.

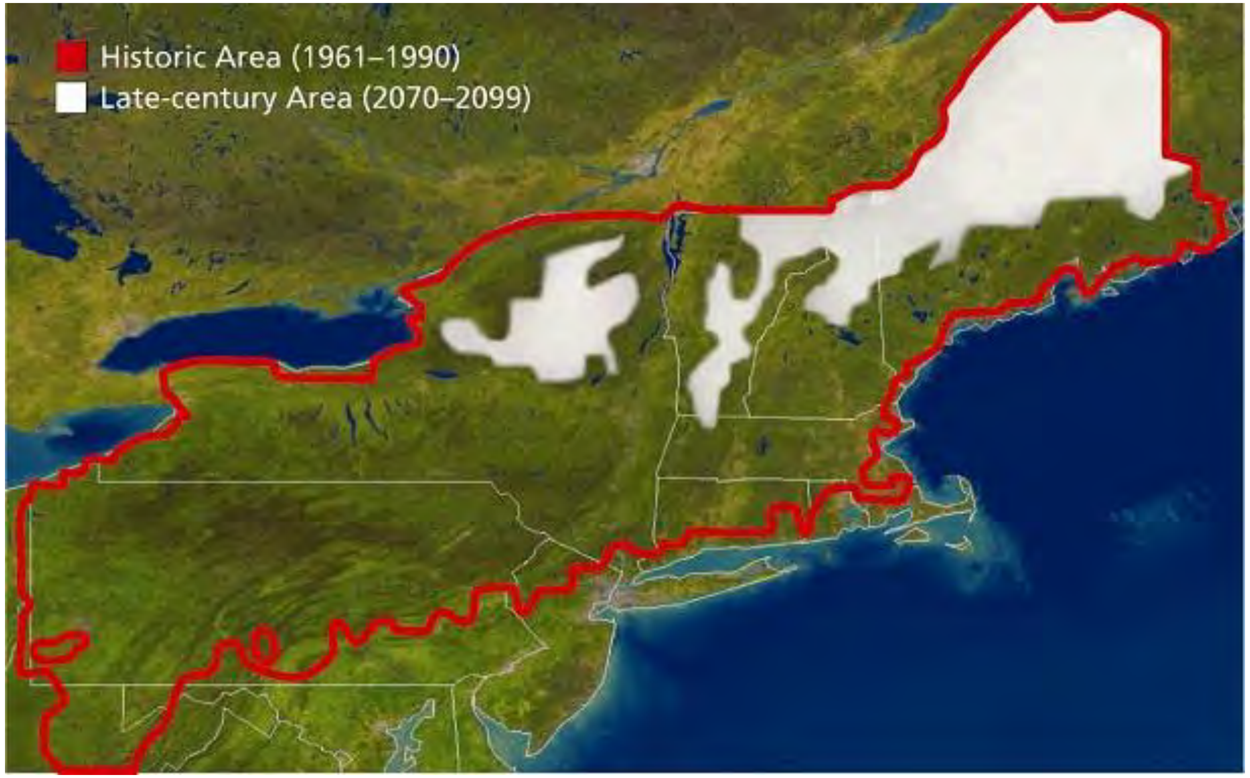


Photo: UCSUSA “Confronting Climate Change in the U.S. Northeast”.

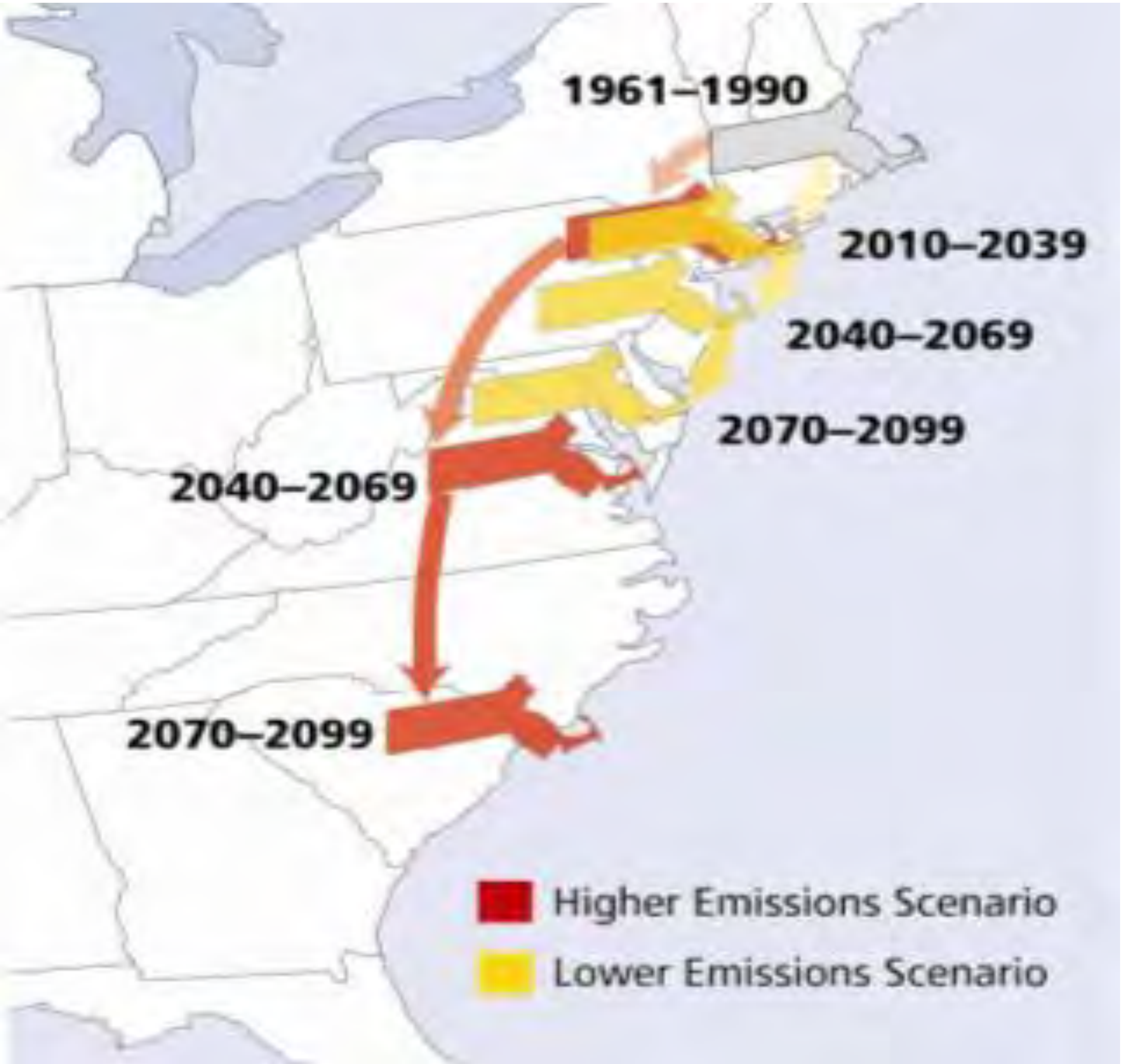
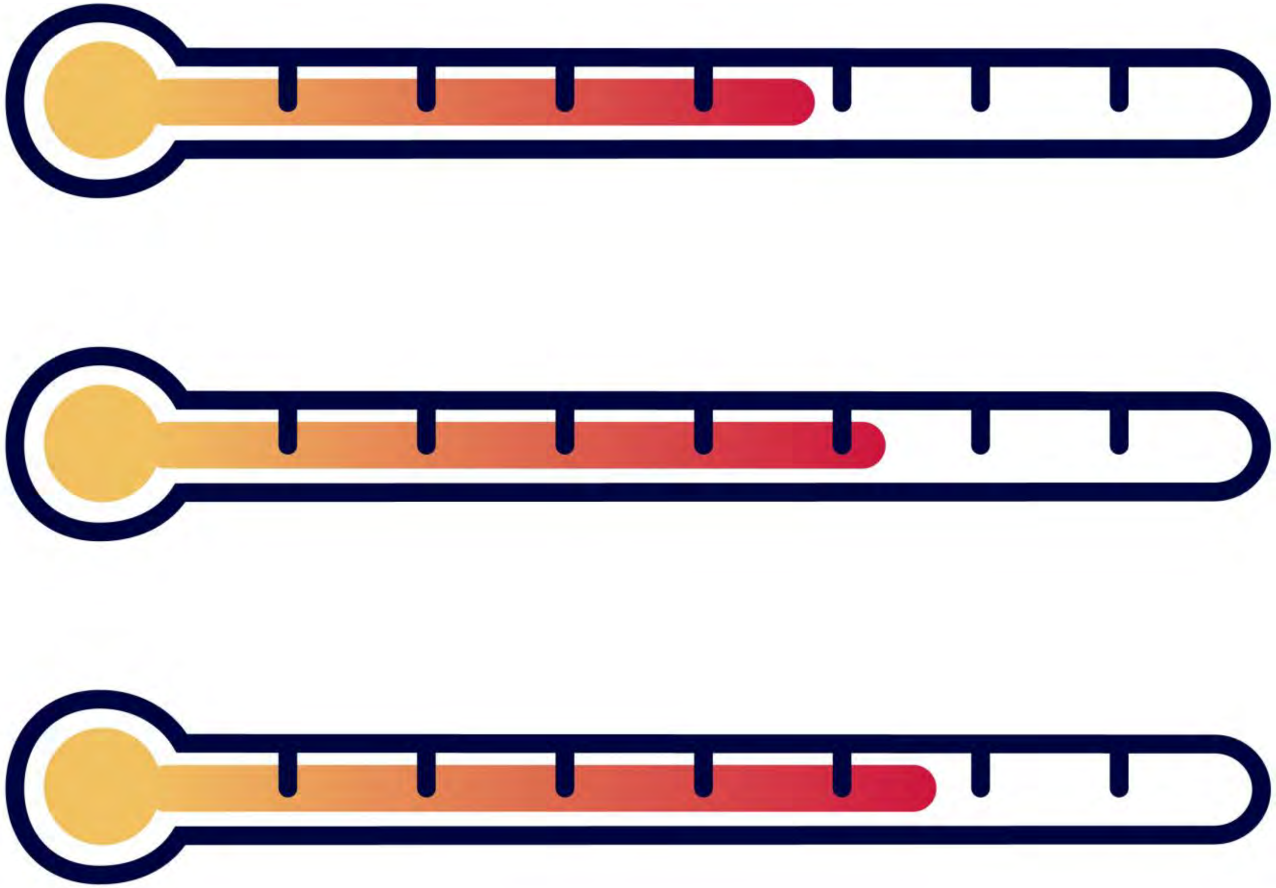


Photo: NECIA/UCS, 2007.

INCREASING AVERAGE **TEMPERATURE**

IN MASSACHUSETTS (°F)



48.13

2005
OBSERVED
ANNUAL AVERAGE

53.43

MID-CENTURY
PROJECTED
ANNUAL AVERAGE

55.32

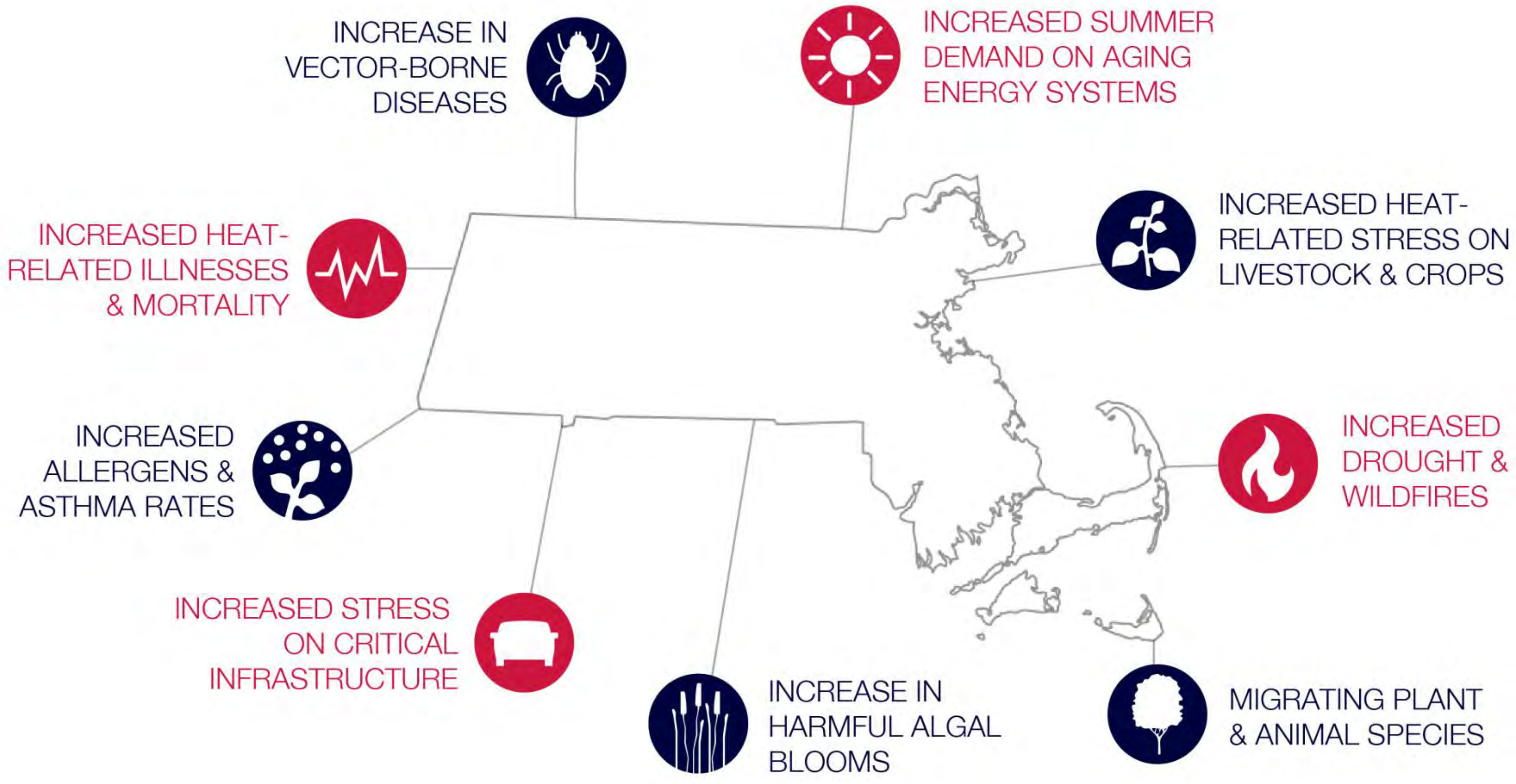
END-OF-CENTURY
PROJECTED
ANNUAL AVERAGE

Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "ResilientMA Datagrapher." Massachusetts Climate Change Clearinghouse. Resilientma.org/datagrapher/?c=Temp/state/tx90/ANN/MA/
Notes: Mid-century projected annual averages use a 2040-2069 time range. End-of-century project annual averages use a 2080-2097 time range.

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



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Rising Temperatures." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/rising-temperatures

BOSTON
MOSQUITO SEASON GROWING
THEN
96
DAYS
On average per year
1980-1989
NOW
119
DAYS
On average per year
since 2006
CLIMATE CENTRAL

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

EXTREME PRECIPITATION

8%

Increase in extreme precipitation events by midcentury

13%

Increase in extreme precipitation events by 2100

Weston & Sampson

PROJECTED CHANGES IN PRECIPITATION

ANNUAL TOTAL PRECIPITATION
IN MASSACHUSETTS (IN INCHES)

56.51
2005
OBSERVED
ANNUAL AVERAGE

58.70
MID-CENTURY
PROJECTED
ANNUAL AVERAGE

59.71
END-OF-CENTURY
PROJECTED
ANNUAL AVERAGE

EXTREME RAIN EVENTS WITH MORE THAN 2" OF RAIN PER DAY IN MASSACHUSETTS

<1
DAY/YEAR
CURRENT

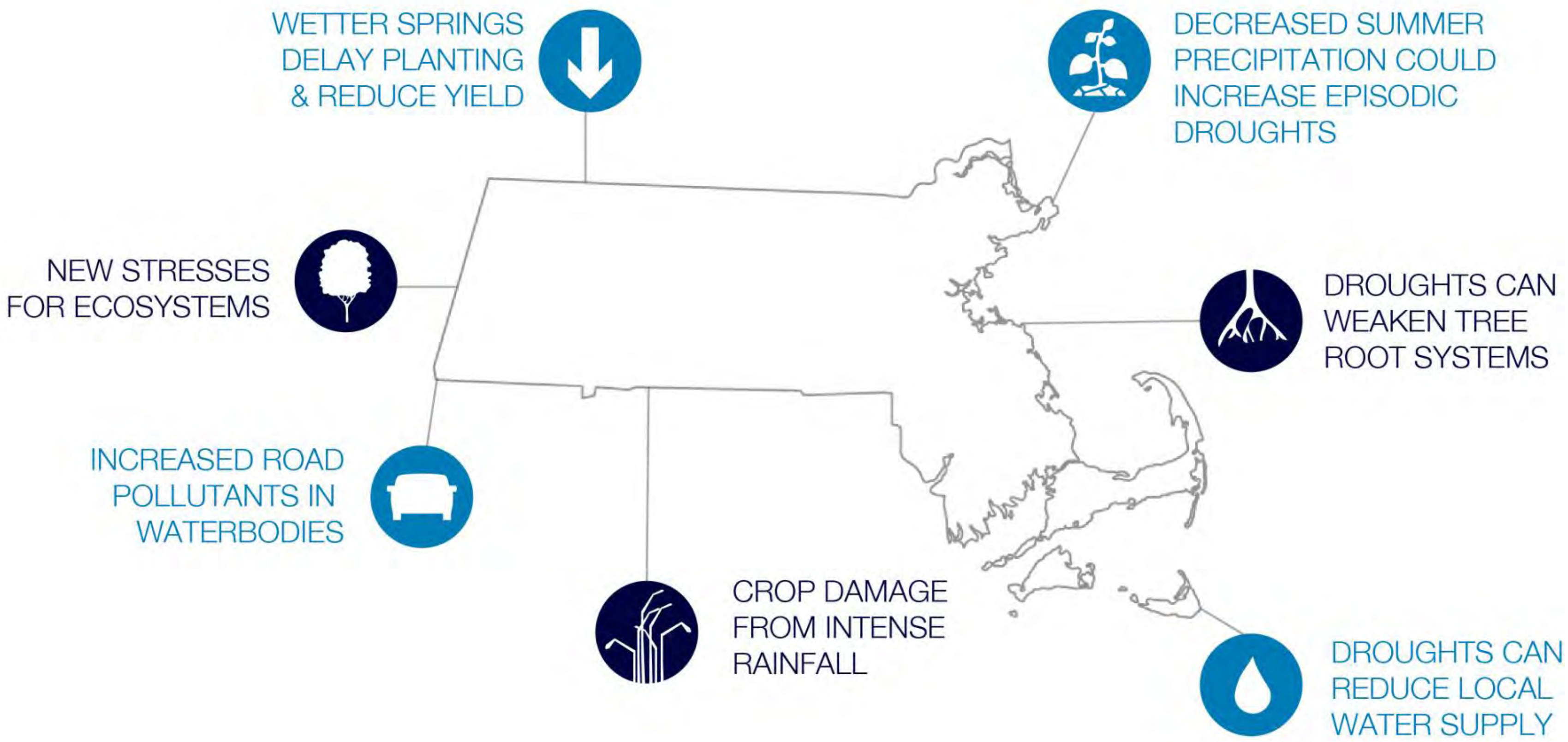
0.9-1.5
DAYS/YEAR
2100

Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "ResilientMA Datagrapher." Massachusetts Climate Change Clearinghouse. Resilientma.org/datagrapher/?c=Temp/state/pcpn/ANN/MA/
Notes: Mid-century projected annual averages use a 2040-2069 time range. End-of-century project annual averages use a 2080-2097 time range.

IMPACTS OF CHANGING **PRECIPITATION**

HIGHER AVERAGE ANNUAL PRECIPITATION

INCREASED BY ABOUT 10% IN THE NORTHEAST INTHE LAST 50 YEARS



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

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"

FLOODING

Vulnerable Areas

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

75 events reported by NOAA since 1998 for Norfolk County:

- No reported deaths or injuries
- Just over $41M in property damage
- March 2010 accounts for just over 80% of total damage

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."

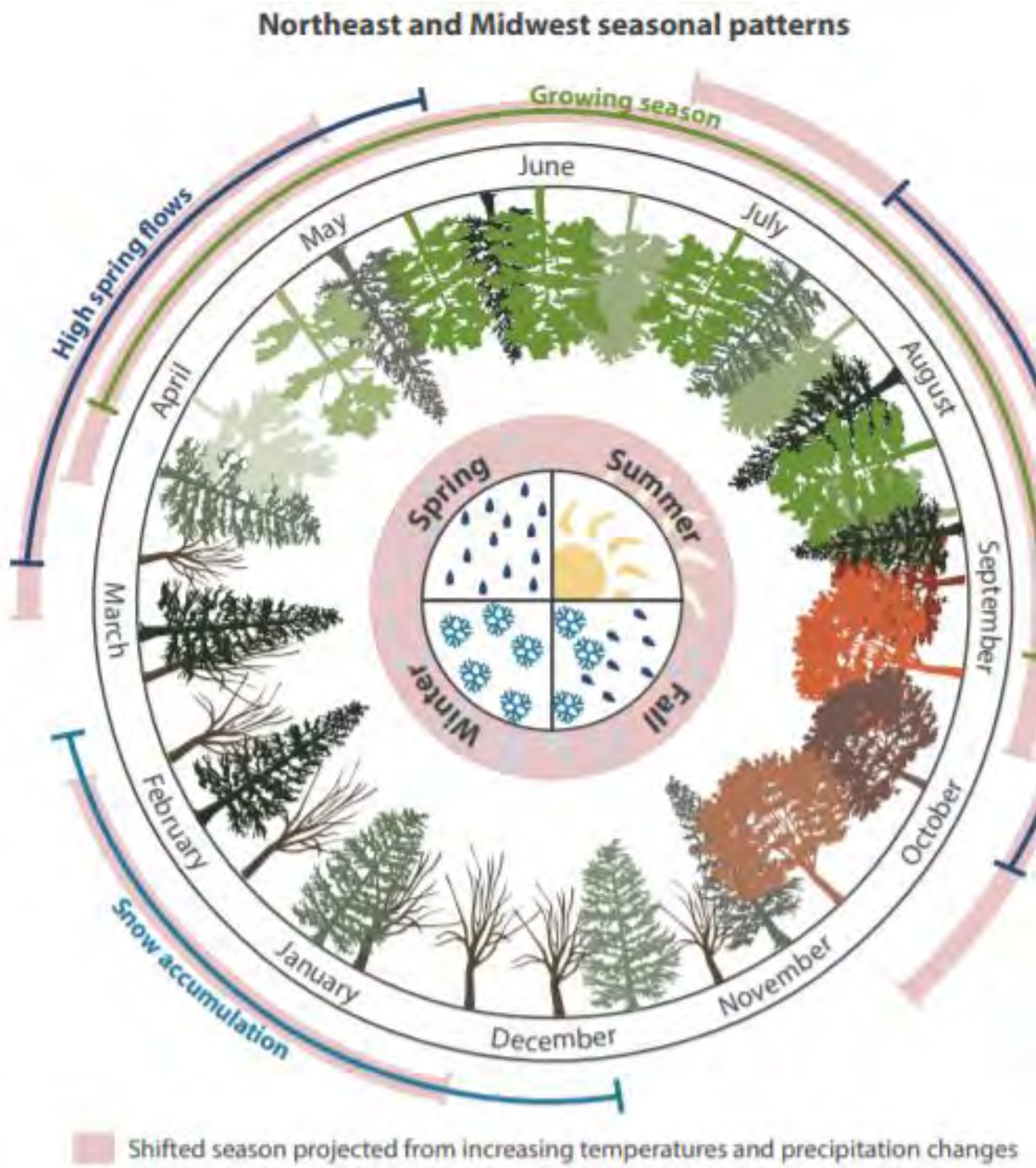


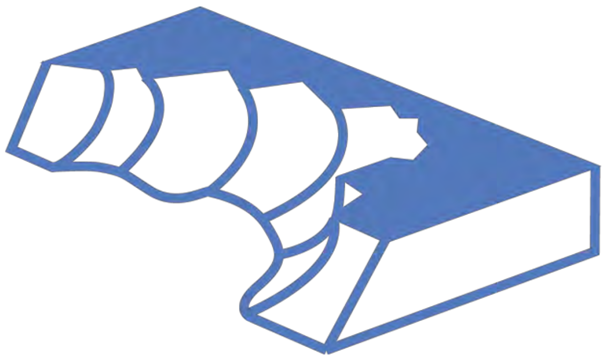
Image credit: Northeast Climate Science Center, University of Maryland Center for Environmental Science

The most notable recent drought event was in

2016 - 17

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

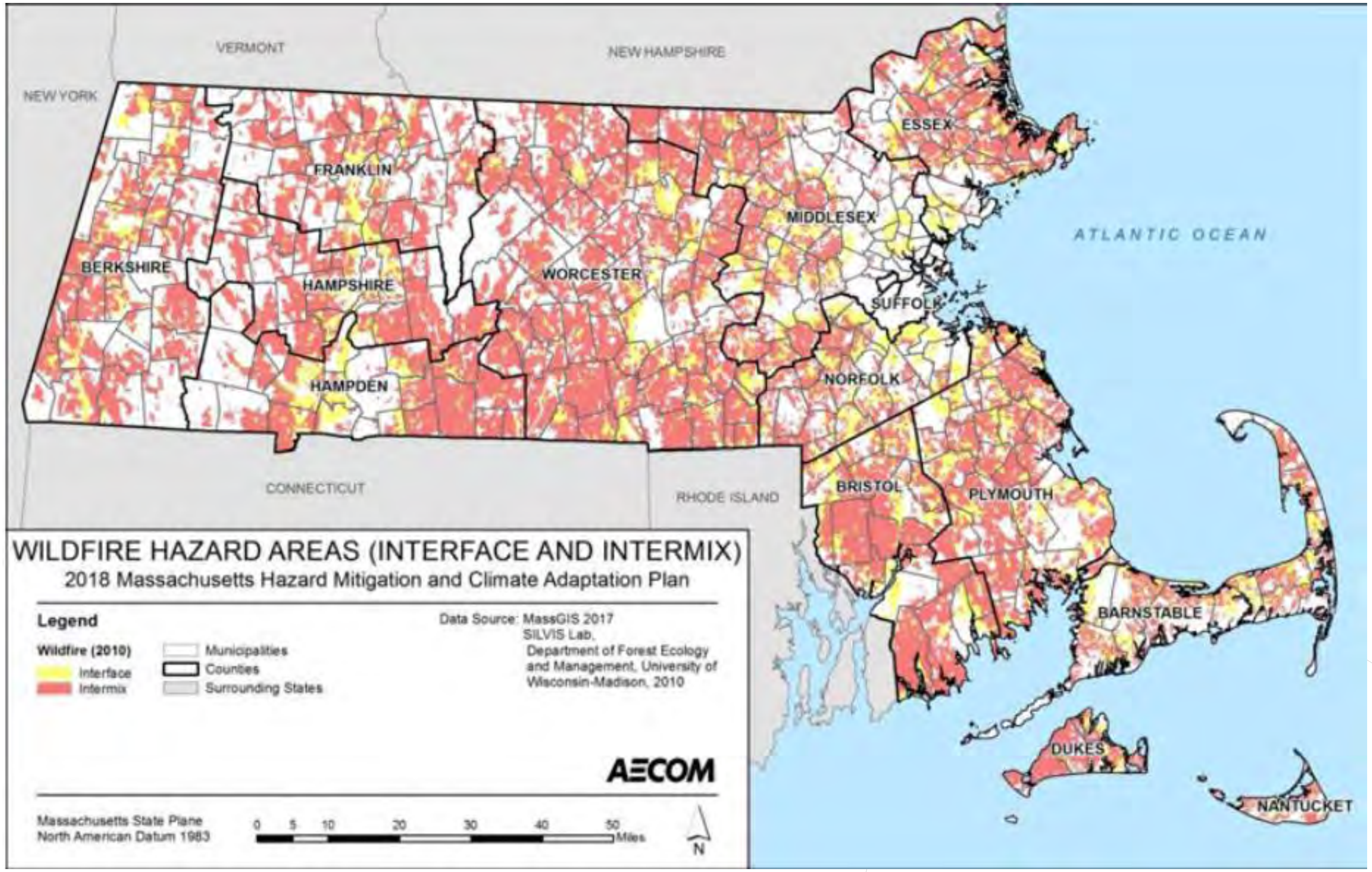
EROSION



- Caused by riverine flow & stormwater[1]
- Increased precipitation, including winter rains, could increase erosion[1]
- Drier soils will reduce resistance to erosion

1. Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 42.

FIRE



VERMONT
NEW HAMPSHIRE
NEW YORK
ESSEX
FRANKLIN
MIDDLESEX
ATLANTIC OCEAN
BERKSHIRE
HAMPSHIRE
WORCESTER
SUFFOLK
NORFOLK
HAMPDEN
CONNECTICUT
RHODE ISLAND
BRISTOL
PLYMOUTH
BARNSTABLE
DUKES
NANTUCKET
WILDFIRE HAZARD AREAS (INTERFACE AND INTERMIX)
2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan
Legend
Wildfire (2010)
Interface
Intermix
Municipalities
Counties
Surrounding States
Data Source: MassGIS 2017
SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin-Madison, 2010
AECOM
Massachusetts State Plane
North American Datum 1983
0 5 10 20 30 40 50 Miles
N

HURRICANES AND EARTHQUAKES

HURRICANE

Sandy
and nor'easters
cause downed trees and power lines

Upward trend in North Atlantic hurricane activity since 1970

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

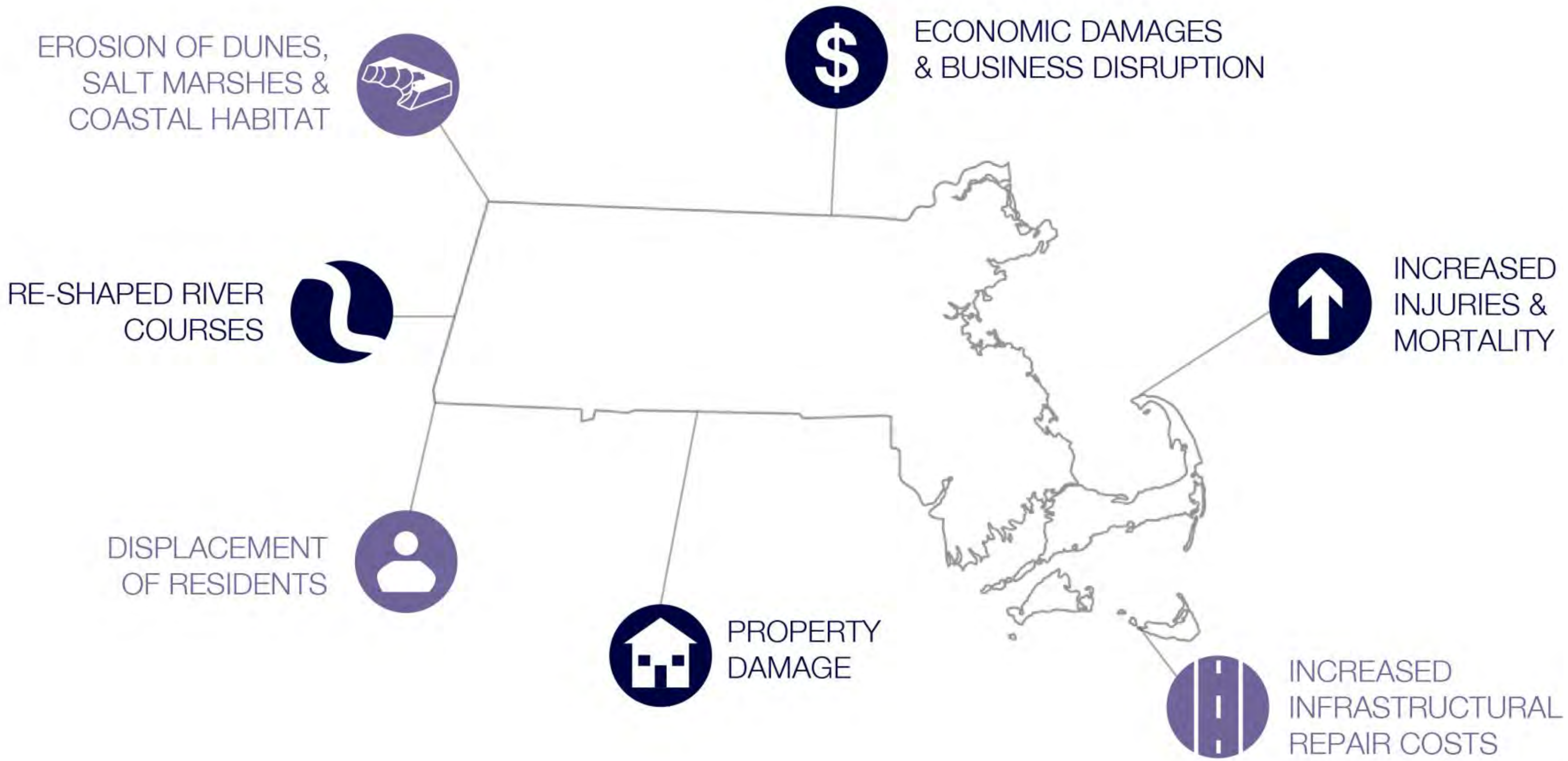
EARTHQUAKE

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

Source: Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)Northern Middlesex Council of Governments. 2015. "Hazard Mitigation Plan for the Northern Middlesex Region," 159-160.

IMPACTS OF **EXTREME WEATHER**

STORMS ARE BECOMING MORE INTENSE AND DAMAGING



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Extreme Weather." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/extreme-weather

HAZARD POTENTIAL OF DAMS

Dam Name	Ownership	Hazard Potential
Brockton Reservoir Dam	Town of Avon	Significant

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

Increased coastal flooding

Permanently inundated low-lying coastal areas

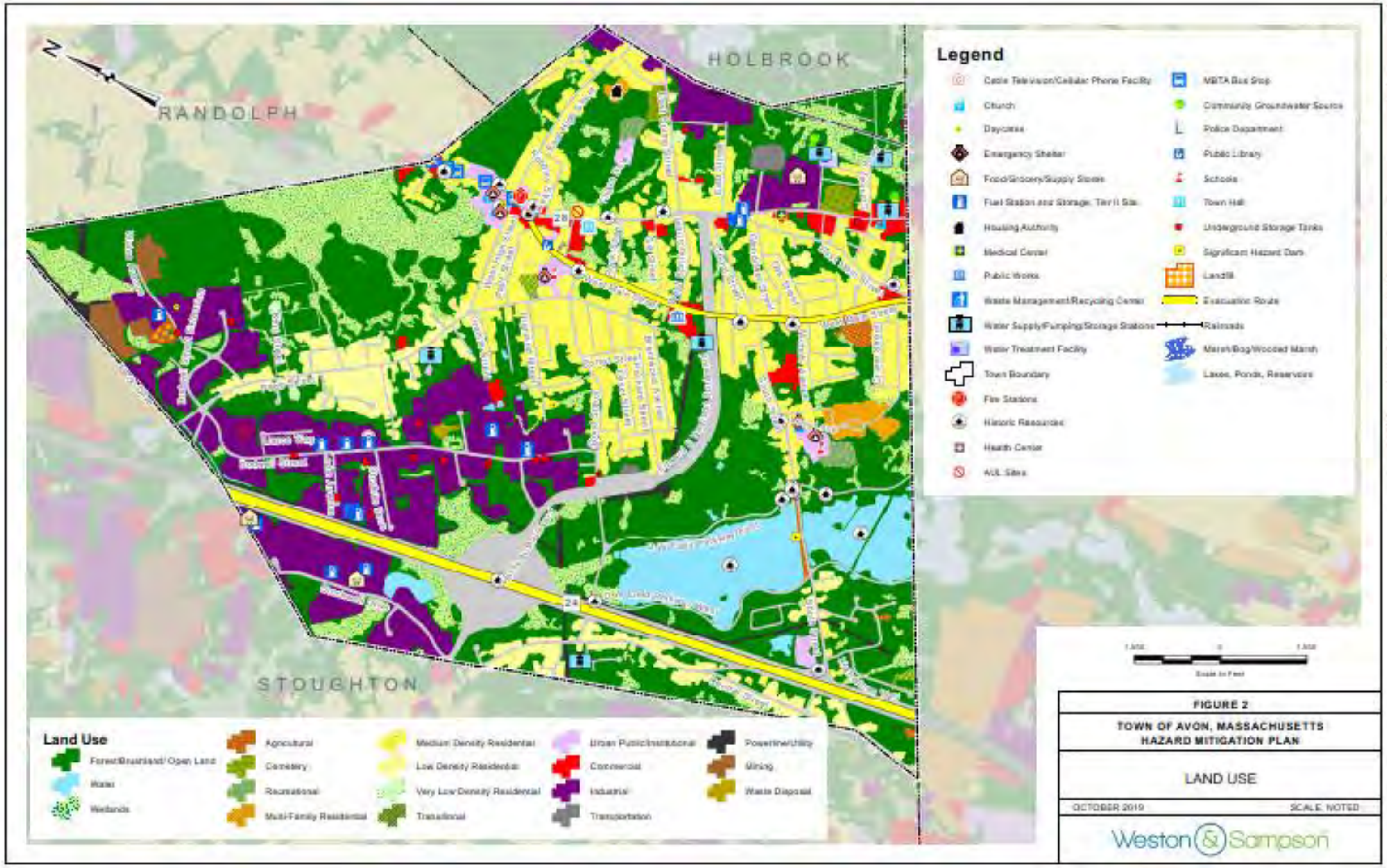
Increased shoreline erosion

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)

PLANNING CONTEXT

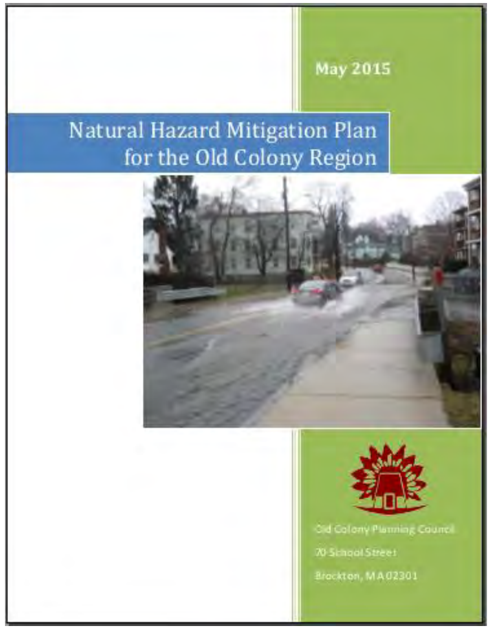
Avon’s Land Use



Avon’s Land Use

- 4,096 Acres (6.4 sq mi)

DATA RESOURCES



Within Avon and Throughout Massachusetts

Massachusetts Climate Change Projections, 2018)

Massachusetts State Hazard and Climate Adaptation Plan, 2018

Massachusetts Climate Change Adaptation Report, 2011

Old Colony Region Hazard Mitigation Plan

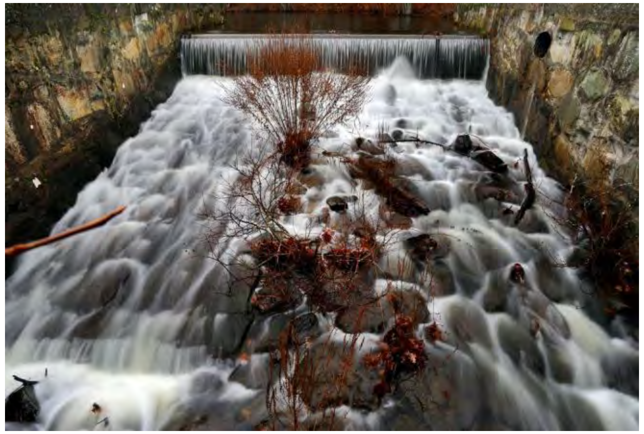
US Census, American Community Survey, 2013-2017

INFRASTRUCTURAL FEATURES

Police Department

Fire Department

Wastewater



Dams

Roadways

Water Supply

SOCIETAL FEATURES

Population	Avon	Massachusetts
2010	4,364	6,547,790
2017	4,468	6,902,149
Age		
Under 18 years:	16.9%	20%
65+ years:	16.0%	17%
Education		
Bachelor’s degree or higher:	27%	42.1%
Additional Information		
Median household income:	$74,225	$74,167
Persons in poverty:	8.5%	10.5%

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

ENVIRONMENTAL FEATURES

Avon's Open Space

Brockton Reservoir

Demarco Park

PROPOSED ACTIONS

SYNOPSIS of ACTIONS

Mitigation Action	Geographic Coverage	Implementation Responsibility	Time Frame	Priority
		FLOODING		
Improve drainage system maintenance	Townwide	Public Works	Ongoing	High
Flood control measures for structures	Townwide	Public Works	Short-term	High
Flood proofing for pumping stations	Townwide	Public Works	Long-term	High
Cloudburst mitigation measures for roadways	Townwide	Public Works	Short and Long-Term	Medium
Assessment and major cleaning of drainage system	Townwide	Public Works	Short and Long-Term	Medium
Convert to sewer system or upgrade septic systems.	Industrial/Commercial Areas (Stockwell and Memorial Drive)	Town Council Public Works Private Parties	Ongoing, Short and Long-Term	Medium to High
Implement green infrastructure and improve existing BMPs.	Townwide	Public Works	Ongoing	Medium
Implement individual stormwater project retrofits.	Townwide	Public Works	Long-Term	Medium
Complete stormwater mapping and make it accessible to emergency personnel.	Townwide	Public Works	Short-term	High

SYNOPSIS of ACTIONS

Mitigation Action	Geographic Coverage	Implementation Responsibility	Time Frame	Priority
		WIND		
Distributed generation	Townwide	Town Council Public Works	Long-term	
Tree assessment and maintenance plan	Townwide	Public Works Utility Company	Short-term and Ongoing	High
Mobile chipper for post-storm fallen branch and debris management	Townwide	Public Works	Short-term	High
Repeater site antenna replacement/repair	Page Street Water Tank	Police Department Public Works	Short-term	High
Provide backup power sources	Townwide	Town Council Public Works	Ongoing	High
Convert to fiber optic lines	Townwide	Town Council Public Works Public Safety	Long-term	High
Provide a radio control option for communications	Townwide	Public Safety Public Works	Short-term	High

SYNOPSIS of ACTIONS

Mitigation Action	Geographic Coverage	Implementation Responsibility	Time Frame	Priority
MULTI-HAZARD				
Work with schools to improve communication with foreign born.	Townwide	School Department Town Council	Short-term and Ongoing	Medium
Identify translators to assist with dissemination of information.	Townwide		Short-term and Ongoing	Medium
Establish a website or call center for translation services.	Townwide	Town Council	Short-term and Ongoing	Medium
Provide variable message boards in strategic locations.		Town Council Public Safety	Long-term	Medium
DROUGHT				
Provide a water supply interconnection for purchase of water.	Townwide	Town Council Public Works	Long-term	High
Repair existing water storage tanks	Page Street Central Street	Public Works	Short-term	High
WINTER STORMS				
Add storage and implement improvements and regular maintenance at snow compost site	Downtown	Public Works	Short-term and Ongoing	Low

WESTON & SAMPSON

Jim Riordan, Team Leader

riordanj@wseinc.com

APPENDIX D

Plan Adoption

{Mayor's Letterhead}

{Date}

To Whom it May Concern:
Please be advised that on behalf of the Town of Avon, and as the Chief Executive of the Town, I hereby adopt the attached Municipal Vulnerability Preparedness and Hazard Mitigation Plan 2020.

Thank you.

Sincerely,

NAME

APPENDIX E

Plan Approval

APPENDIX F

Stormwater Green Infrastructure Analysis

TOWN OF AVON
INCORPORATED FEB. 21, 1888

TOWN OF
AVON
MASSACHUSETTS

Municipal Vulnerability Planning Project

Stormwater Nature-Based Solutions
Outside of Trout Brook Watershed

Prepared by:

Weston & Sampson

June 2021

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Town of Avon (the "Town") has undertaken a study of stormwater retrofits to address flooding that is predicted to come with climate change and the increased intensity of precipitation that it is bringing.

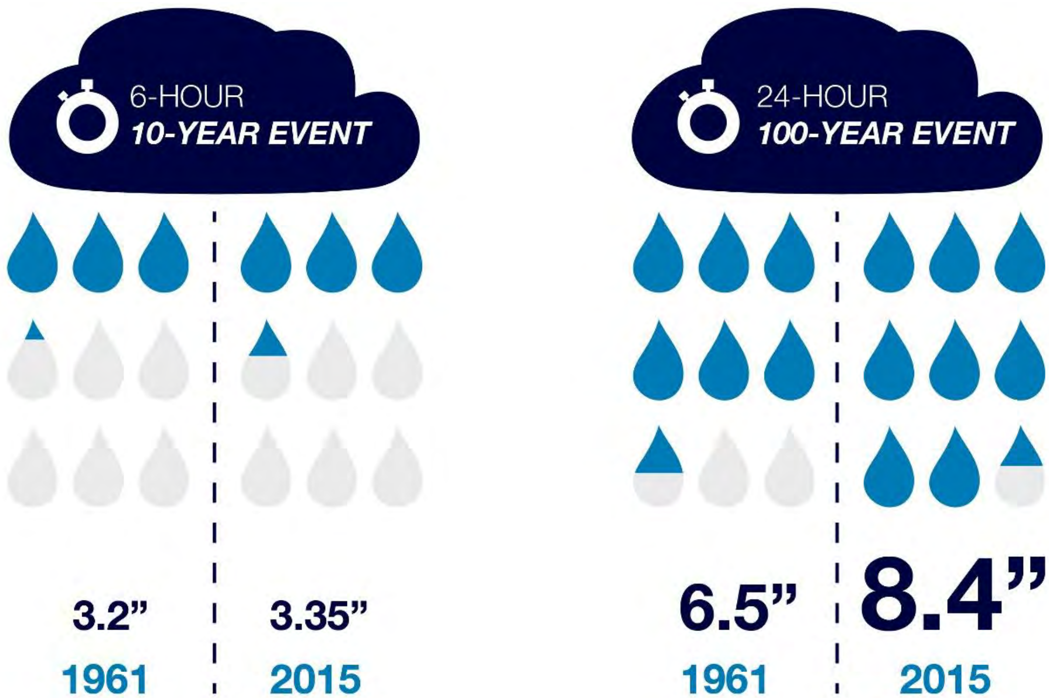


Figure ES.1 Increased Precipitation in Massachusetts from 1961 to 2015
Climate change is affecting both the severity and frequency of storm events which has caused areas previously unknown to flooding issues, to become more susceptible during these events.

This study compliments similar work completed for the Trout Brook Watershed by addressing stormwater concerns in the remainder of the Town. The ultimate goal of the current study is to develop conceptual stormwater best management practice (BMPs) designs with an approach for prioritizing BMPs and next steps for implementation.

This draft report represents the first step in the development of the study and focuses on current conditions in the study area related to stormwater along with methods for assessing BMP priorities. Next steps will include desktop assessment to locate BMPs, field assessment of locations, and development of a final with conceptual designs for potential BMPs.

\\wse03.local\WSE\Projects\MA\Avon\MVP Grant Project\Stormwater\Desktop Assessment Methods and Mapping 20200517.docx

1.0 AVAILABLE DATA AND CURRENT STUDY AREA CONDITIONS

This section discusses watershed data including land use, cultural resources and habitat and soils. This section also discusses stormwater infrastructure data that is available from the Town. The purpose of this discussion is to provide information to support the conceptual design of structural BMPs.

1.1 Relationship between Land Use and Stormwater

Stormwater runoff is a part of the hydrologic cycle (the movement of water between the Earth's atmosphere, land, and waterbodies). (See Figure 1.1.) When land is developed with buildings and roads, that development interrupts the natural hydrologic cycle by blocking absorption of water into soil and uptake by plants. Pavement and other surfaces that prevent precipitation from draining into the soil are collectively referred to as impervious surface. Figure 1.1 below illustrates how increasing degrees urbanization may disrupt the natural water cycle and reduce the land's capacity to retain stormwater.

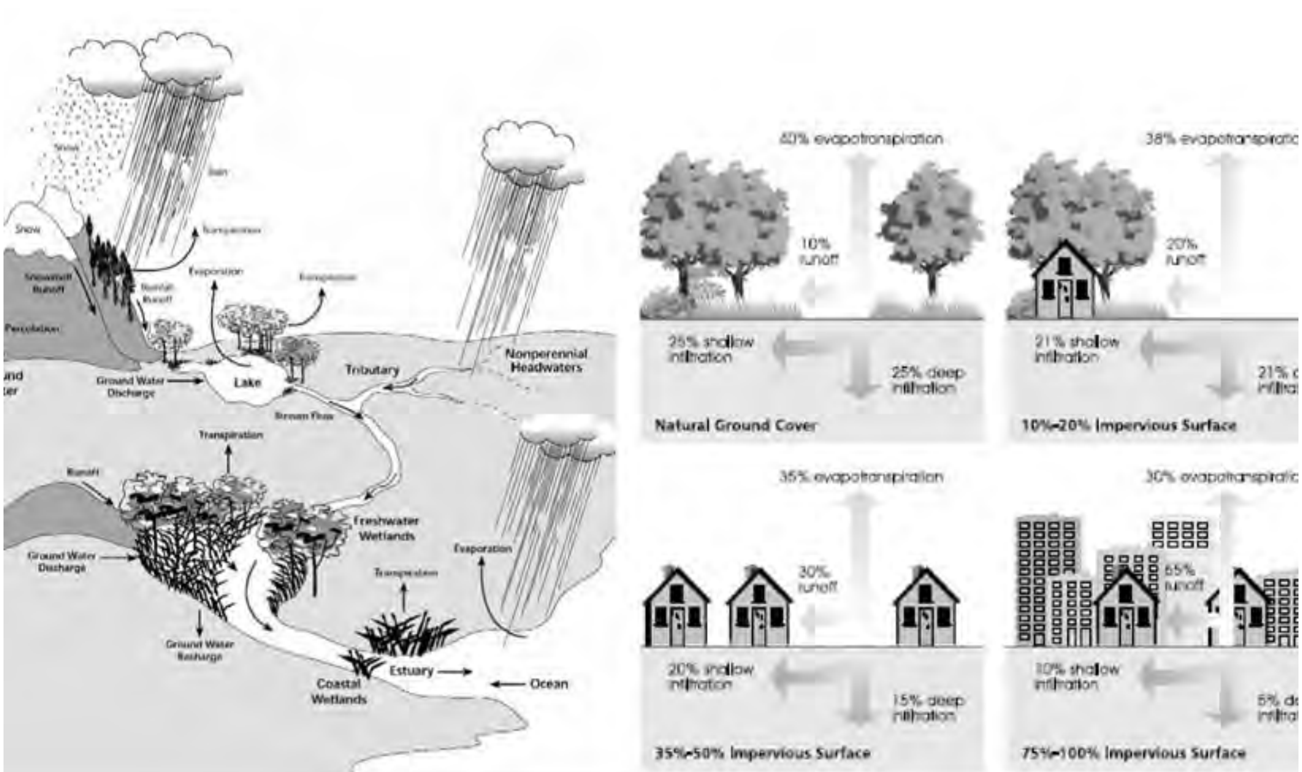


Figure 1.1 Stormwater Runoff and Urban Development
Stormwater runoff is a natural part of the hydrologic (i.e., water) cycle, but urban development and dense areas of impervious surface increase stormwater runoff to the extent that it causes floods and degrades water resources.

Impervious cover and intensity of development provide good metrics for the expected adverse effect of stormwater and the overall health of a watershed. Numerous studies have documented the cumulative effects of urbanization on stream and watershed ecology (Schueler et al., 1992; Schueler, 1994; Schueler, 1995; Booth and Reinelt, 1993, Arnold and Gibbons, 1996; Brant, 1999; Shaver and Maxted, 1996). Research has shown that when impervious cover in a watershed reaches between 10 and 25 percent, ecological stress becomes clearly apparent. Beyond 25 percent impervious cover, stream stability is reduced, habitat is lost, water quality becomes degraded, and biological diversity decreases (NRDC, May 1999).

Land use within in Avon was obtained from the most recent MassGIS land use layer. Land use describes how the natural environment has been modified into a built environment. Impervious surface covers approximately 22.8% of land in the study area and is denser in more developed areas of Town. Figure 1.2 on the following page shows the extent of impervious surface and urban land development throughout the Town.

Table 1.1
Land Use in the Study Area

Land Use Classification	Percentage of Study Area
Commercial	7.7%
Industrial	12.7%
Open land	42.4%
Residential - multi-family	3.3%
Residential - single family	15.8%
Right-of-way	15.8%
Tax exempt	2.1%
Unknown	0.2%
Total	**100.0%**

In recent years, Avon, like most of Southern New England has experienced an increase in severe weather and intense rain and snow events. Climate data indicates this trend will probably continue as will the challenge of managing stormwater. Avon finds itself at particular risk due to a particularly high density of development and the condition of its stormwater system, most of which was developed many years ago.

1.2 Municipally Owned Land

Municipally owned land is an ideal location for structural stormwater BMPs to reduce the volume of runoff and associated pollutant loads, as the Town already owns these parcels and, therefore, does not have to acquire land rights or request permission to install BMPs. The Town provided a municipally owned parcel layer and a municipally owned open space layer. The total area of municipally owned land in the study area is 337 acres. Municipally owned land is shown in figures 1.3 and 1.4.

1.3 Soils

To determine soil types within the watershed area, MassGIS publishes a layer from the U.S. Department of Agriculture, Natural Resources Conservation Service. To be practical, stormwater BMPs must be selected to fit in with the conditions of the watershed. We reviewed hydrologic soil groups (HSG) to determine whether infiltration would be feasible. We assumed HSG soil types A, B and C could reasonably support some volume of infiltration; however, HSG types A and B are generally preferred as they will more readily infiltrate.

Table 1.2, on the following page, breaks down the distribution of hydrologic soil types.

Table 1.2
Hydrologic Soil Groups in the Study Area

Hydrologic Group	Percentage	General Distribution in Watershed
A	3.10%	Primarily in the south part of the study area
B	41.68%	Dominant hydrologic soil throughout the study area
C	16.34%	Primarily in the northern part of the study area
D	11.93%	Isolated pockets within the B and C areas
Urban Fill	24.34%	Isolated pockets throughout watershed

HSG A and B, which make up approximately 45% of the soils in the study area are generally appropriate for infiltration BMPs, which are ideal for treatment and removal of bacteria. Figure 1.3 shows general distribution of HSG soil types within Avon focusing on A, B, and C soils since these are the only appropriate soils for infiltration BMPs.

1.4 Stormwater Infrastructure

Figures 1.3 and 1.4 depict stormwater drainage elements. Stormwater infrastructure in Avon consists primarily of catch basins, manholes, drainage piping, and some detention basins. Table 1.3 provides a general summary of stormwater system elements in the study area.

Table 1.3
Stormwater System Elements in the Study Area

Stormwater System Element Type	Amount
Catch Basins	870
Manholes	361
Outfalls	234
Miles of Pipe	2.89 miles

Avon, like most municipalities, generally manages stormwater with gravity fed systems as it is typically impractical to pump stormwater. Retrofits proposed under this report also rely on gravity conveyance. Understanding the location of existing stormwater infrastructure and its elevation is essential to developing a strategy for retrofits.

2.0 IDENTIFICATION AND EVALUATION OF CATCHMENTS

The following section discusses the selection of locations for development of conceptual BMP designs.

2.1 Selection of Areas for Conceptual Design Work

A primary objective of this study is to select sites for conceptual BMP design. Structural stormwater BMP alternatives were considered throughout the Avon-owned properties of the study area. Management practices for flooding focus on increasing the capacity of existing stormwater drainage networks with the addition and enlargement of pipes and addition of relief mechanisms. Retrofits will be sited using best engineering judgement.

To be practical, stormwater BMPs must be selected to fit in with the conditions of the watershed. Conditions considered should include land use, cultural resources, and environmental constraints such as wetlands, soil type and proximity to groundwater. Candidate BMPs in this study are intended to be appropriate for open spaces and roadways in residential areas. These BMPs include vegetated BMPs (e.g., bioretention) and buried BMPs (e.g., drainage structure and pipe networks, subsurface infiltration). BMP locations were selected using the following siting criteria:

When identifying locations to site BMPs, we used MassGIS and Town data.

- Site BMPs on Town- or publicly owned property to the extent practicable with a strong preference for areas of Town-owned land.
- Maximize potential stormwater capture and treatment based on impervious surface within stormwater catchments, hydrologic location, availability of public land, and existing drainage patterns.
- Avoid disturbance of cultural and historic resources as well as wetlands and other sensitive receptors.
- Assume HSG soil types A, B and C could reasonably support some volume of infiltration but focus on HSG soil types A and B since they provide better infiltration capacity.
- Prioritize management of significant flood risk by siting BMPs in hydrologic proximity to the 100-year floodplain.

3.0 STRUCTURAL ALTERNATIVES

A primary objective of this study is to select suitable sites for conceptual BMP design. Structural stormwater BMP alternatives were considered throughout Avon.

3.1 Identification of Preferred BMP Locations and their Capacity to Treat Stormwater

BMP locations were selected using the following siting criteria:

- Site BMPs on Town or publicly owned land to the extent practicable.
- Maximize potential stormwater capture and treatment based on hydraulic location and existing drainage patterns.
- Avoid disturbances of cultural and historic resources as well as wetlands and other sensitive receptors.

The Massachusetts Department of Environmental Protection (MassDEP) wetlands layer was used, along with the Massachusetts Historic Commission and National Register of Historic Places cultural resources database to identify potential BMP locations and selected preferred locations using the process described in sections 3.1.1 through 3.1.4. The four figures on the pages that follow depict the BMP locations the approximate area of imperious surface that can conceptually be routed to the BMP locations.

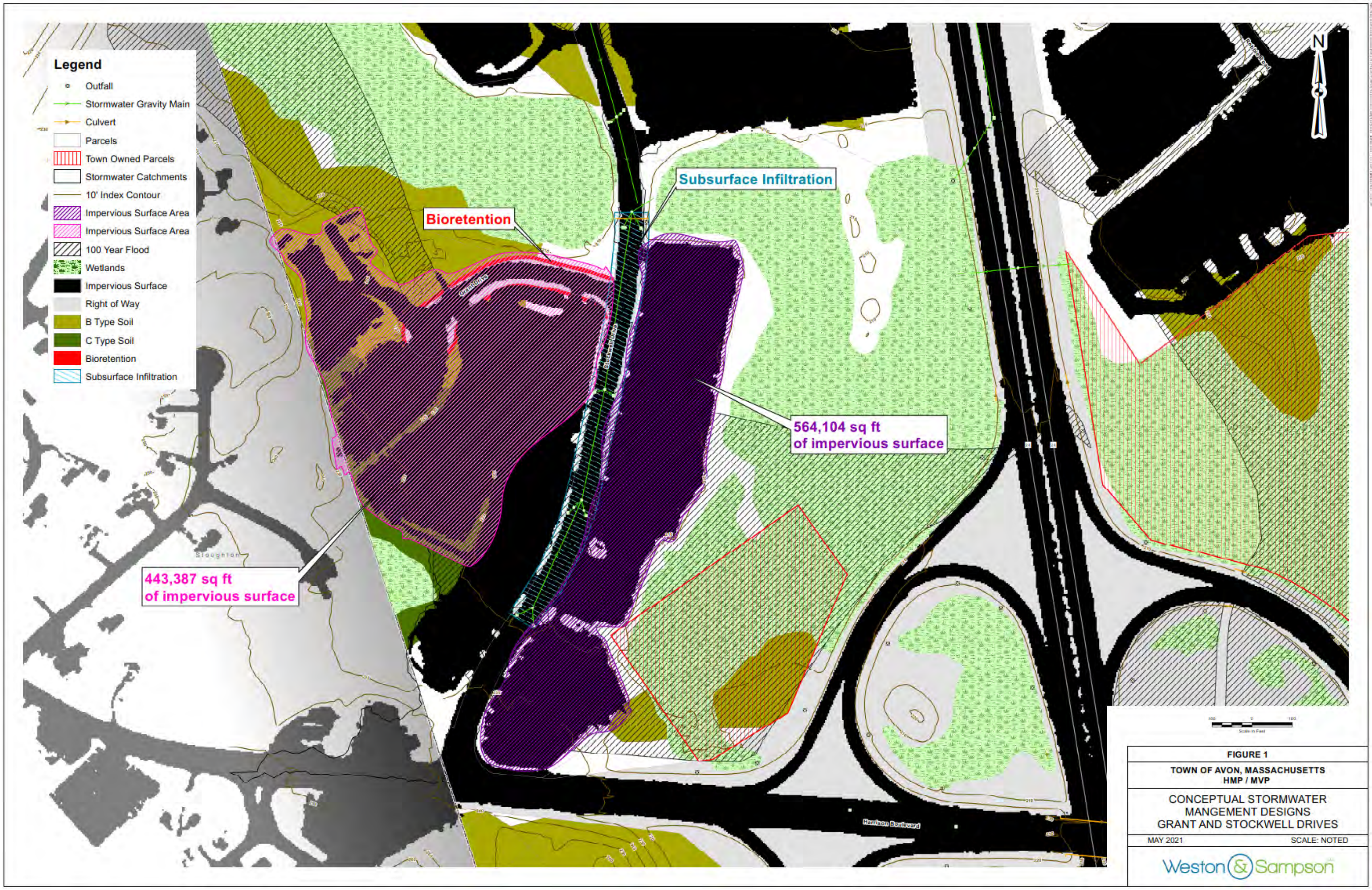


Figure 3.1 BMP Siting Grant Drive and Stockwell Drive

Figure 3.2 BMP Siting Criteria Analysis South Street

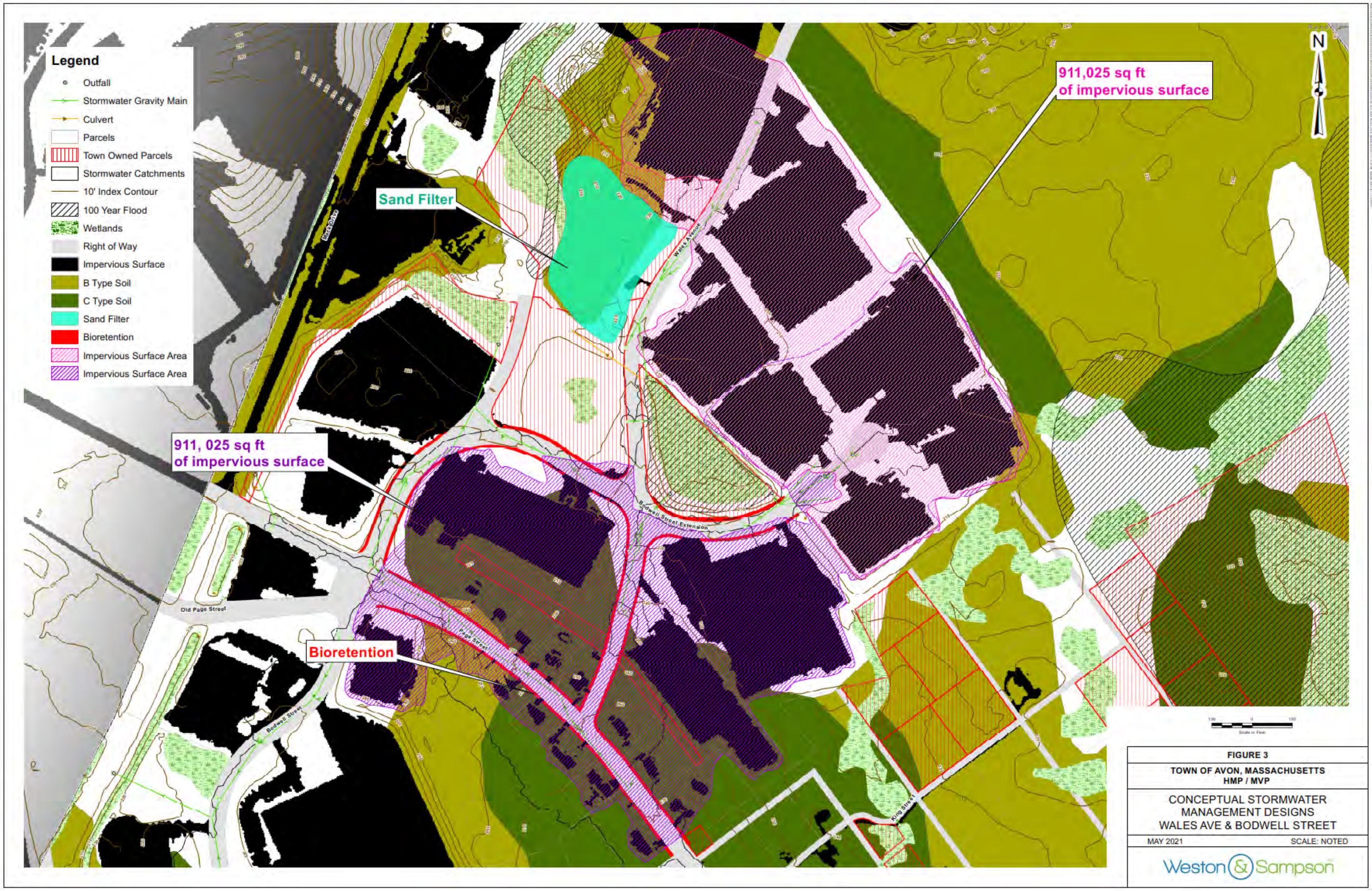


Figure 3.3 BMP Siting Criteria Analysis Wales Ave & Bodwell Street

Figure 3.4 BMP Siting North Main Street

3.1.1 Selection of Candidate Locations Based on Property Ownership

Assessor parcel data from MassGIS, as well as stormwater infrastructure data supplied by the Town and LIDAR were used to select candidate sites for conceptual BMPs. The general approach began with identification of the following:

- Town-owned properties in Avon with green space. Town-owned properties were focused on because they are under Town control and will not require purchase or transfer of development rights. This simplifies the implementation process and eliminates significant potential expense.

- Other public owned lands near outfalls and privately owned vacant lots contiguous to Town-owned properties with green space. Additional space typically improves the feasibility of BMP implementation. It is anticipated that the Town might wish to acquire the property rights to implement BMPs in locations where hydrologic capacity of Town-owned property is limited, but siting feasibility is otherwise favorable.

3.1.2 Analysis Based on Hydrology and Hydraulic Location

Feasibility of BMP installation at a given site relies significantly on hydrologic location, which can be determined by reviewing topography. Available LIDAR data was used to develop topographic mapping. It was assumed that both surface and subsurface flow direction generally followed surface topography. A flow-to analysis was conducted, which approximately determined the catchment areas of hydrologic low points on candidate BMP sites. MassGIS impervious surface coverage data layer was overlaid to determine the approximate area of impervious surface that would be expected to drain to the candidate sites.

3.1.3 Connectivity to Town-Owned Outfalls

The area of impervious surface within the drainage catchment of each candidate site was used as a measure of its potential capacity to treat stormwater. Impervious surface is considered to be a primary source of pollutants in urban runoff. As such, it is commonly used as a unit of measure to determine the capacity of treatment elements in stormwater management practice design.

3.1.4 Environmental and General Land-Use Constraints

To be practical, BMPs must be selected to fit in with the conditions of the surrounding area. Conditions considered should include land use, cultural resources, and environmental constraints such as wetlands, soil type, and proximity to groundwater. All candidate BMPs are intended to be appropriate for open spaces and roadways in residential areas. These BMPs include vegetated BMPs (e.g., bioretention) and buried BMPs (e.g., surface infiltration). When identifying locations to site BMPs, MassGIS data was used to avoid wetland areas and areas near sensitive historic and cultural resources. Hydrologic soil groups (HSG) were reviewed to determine whether infiltration would be feasible. It was assumed that soil types A and B would support infiltration and HSG type C soils would require nonfiltrating BMPs (e.g., wet vegetated treatment systems and sand filters).

3.2 Candidate Best Management Practices

For this conceptual design study, BMPs with significant capacity to treat bacteria were considered and based on information available in the *Massachusetts Stormwater Handbook,* which was supplemented with data from the *Rhode Island Stormwater Design and Installation Standards Manual* when data was insufficient. Stormwater treatment mechanisms that work well to remove these pollutants include vegetated treatment, filtration, and infiltration. The use of BMPs that treat stormwater primarily by detention and sedimentation were considered but generally avoided since a number of field studies have shown such BMPs to export pollutants such as bacteria and nutrients. Appendix B provides a description of each type of BMP considered for this study as well as a discussion of their general application, advantages, and limitations. Appendix B also provides schematics and photographs of the candidate BMPs. The tables below provide a summary of information in Appendix B.

Since water quality treatment BMPs all provide good flood attenuation capacity (a principal focus of this study), BMPs were primarily selected for their water quality improvement capacity, which can vary quite substantially from BMP type to BMP type. Capacity to remove pathogens and phosphorus are key stormwater pollutants for freshwater resources and were used for this purpose of selecting BMP preferences. BMP types were also considered for their capacity to function appropriately in the subject setting (e.g., residential versus industrial). Low-end limits for preferred BMPs were 70 percent removal of pathogens and 30 percent removal of phosphorus. BMPs with vegetative treatment processes and infiltrative capacity were considered to be preferred as these processes are generally more reliable for nutrient removal. Selection of preferred BMPs was limited to those that have the capacity to treat large areas (i.e., five acres or more) or roadways since we are focusing on retrofits to address community areas as opposed to individual private properties.

The following BMPs were selected as preferred for further consideration. This is not intended to preclude the use of other BMPs, but instead to provide guidance in selecting BMPs for conceptual consideration and further study:

Table 3-1
Candidate BMPs Selected for Further Consideration

Preferred BMPs (Any Setting)	Secondary Consideration (Any Setting)	BMPs (Roadways Only)	Removed from Consideration in this Study
• Bioretention • Infiltration Basin	• Water Quality Swale • Sand Filter	• Subsurface Infiltration	• Dry Wells • Green Roofs et al • Constructed Stormwater Wetland[a] • Wet Retention Pond[a] • Vegetated Filter Strip • Vegetated Drainage Ways • Planter and Tree Box • Porous Pavement • Proprietary Media Filter • Infiltration Trenches

Notes

a. Removed due to the presence of standing water, which is inappropriate for this application.

Table 3-2
Summary of Candidate Best Management Practices for Selection of Retrofits

BMP Type	Peak Flow Control	Pollutant Removal Capacity		Treatment Process		Application		
		Bacteria (+70%)	TP (+30%)	Infiltration Filtration	Vegetative Treatment	Common Areas	Roads	Drainage Area (+5 acres)
Bioretention	✓	✓	✓	✓	✓	Appropriate	Appropriate	Appropriate
Constructed Stormwater Wetland	✓		✓		✓	Appropriate	Appropriate	Appropriate
Dry Wells		✓	✓	✓				
Green Roofs		✓	✓		✓			
Impervious Surface Disconnection				✓	✓	Appropriate	Appropriate	
Infiltration Basin	✓	✓	✓	✓	✓	Appropriate	Appropriate	Appropriate
Infiltration Trenches	✓	✓	✓	✓		Appropriate	Appropriate	Appropriate
Planter and Tree Box Filters		✓	✓	✓	✓	Appropriate	Appropriate	
Porous Pavement		✓	✓	✓			Appropriate	
Proprietary Media Filter		✓	✓	✓			Appropriate	
Sand Filters	✓	✓	✓	✓	✓	Appropriate	Appropriate	Appropriate
Subsurface Infiltration	✓	✓	✓	✓			Appropriate	Appropriate
Vegetated Filter Strip				✓	✓	Appropriate	Appropriate	
Vegetated Drainage Ways					✓	Appropriate	Appropriate	Appropriate
Water Quality Swale	✓	✓	✓	✓	✓	Appropriate	Appropriate	Appropriate

Table 3-3
Proposed Locations and Preferred BMPs

Proposed Location	General Land Use	HSG Soil Type	Preferred BMP
Grant Drive and Stockwell Drive	• Commercial • Roads	• Unclassified • HSG B	• Bioretention • Subsurface infiltration
South Street	• Institutional • Residential • Roads	• HSG A • HSG B	• Grassed sand filter • Subsurface infiltration
Wales Avenue and Bodwell Street	• Commercial • Industrial • Roads	• Unclassified • HSG B • HSG C	• Bioretention • Grassed sand filter
North Main Street	• Institutional • Residential • Commercial • Roads	• Unclassified • HSG B	• Subsurface sand filter • Subsurface infiltration

3.3 BMP Sizing

Retrofit BMPs are typically sized based on required water quality volume and available space. The Massachusetts Stormwater Handbook was used as a design standard and water quality volume was determined using a standard of one inch depth over the impervious area in each catchment. In the case of this study, limitations on available space prevent sizing BMPs to meet the water quality volume. Therefore, BMPs have been made as large as reasonably possible given space constraints. Area of imperviousness was determined from the MassGIS impervious area coverage.

The storage volume of stormwater BMPs was calculated on the available area and constraints associated with each BMP type. The following assumptions were made:

- Nonlinear bioretention will have 3:1 side slopes.
- Subsurface infiltration provides 30 cubic feet of water quality storage per linear foot based on three-foot storage depth, 30-foot bottom width on a road shoulder or up to 80% of a property footprint and storage bed material porosity of 0.30.
- Subsurface sand filters will be 1.5 feet deep. Surface sand filters will be three feet deep. Both will be sized at approximately 80% of the footprint of the available space and with a storage bed material porosity of 0.30.

For further analysis, Table 3.7 on the following page summarizes the treatment and treatment capacity that was identified in each of the subject catchments.

3.4 Opinions of Cost

Order of magnitude opinions of cost have been developed based on unit treatment values (i.e., cost per cubic foot of treatment capacity) of each of the preferred BMP types. Table 3.8 provides cost on a per catchment basis for the alternatives recommended for each catchment. Table 3.8 also provides cost per a unit of treat volume (i.e., water quality volume), which can be used as a measure of cost-benefit reflecting both water quality and peak flow management benefits. Unit costs for preferred BMPs in dollars per cubic foot (cu ft) area listed in Table 3.6 below.

Table 3-4.
Unit Costs for Preferred BMP Types

BMP Type	Unit Cost (Dollars/cu ft)[a]
Bioretention	$14
Subsurface Infiltration	$16
Sand Filter	$17

Notes
a. Unit cost was determined based on empirical data and observations from previous projects

Table 3-5
Capacity of Proposed BMPs

Proposed Location	WQV[a] (cu ft) for Drainage Area of Proposed BMPs	Capacity of BMPs			Treatment Capacity (cu ft)
		Bioretention (cu ft)	Subsurface Infiltration (cu ft)	Sand Filter (cu ft)	
Grant Drive and Stockwell Drive	83,958	3,699	28,701	N/A	32,400
South Street	60,574	N/A	41,688	22,874	64,562
Wales Avenue and Bodwell Street	75,919	28,440	N/A	130,867	159,307
North Main Street	220,723	N/A	11,070	10,790	21,860

Note

a. Water quality volume of the area draining to the proposed BMP location

Table 3-6
Construction Cost of Selected BMPs and Probable Cost Based on Unit Pricing

Proposed Location	Treatment Capacity (cu ft)	Cost of BMPs			Cost per Treatment Site Based on Unit Price[a]	Cost per Unit of Treatment (Total Cost/Treatment Capacity)
		Bioretention ($14/cu ft)	Subsurface Infiltration ($16/cu ft)	Sand Filter ($17/cu ft)		
Grant Drive and Stockwell Drive	32,400	$51,786	$459,216	N/A	$511,002	$15.77
South Street	64,562	N/A	$667,008	$388,858	$1,055,866	$16.35
Wales Avenue and Bodwell Street	159,307	$398,160	N/A	$2,224,739	$2,622,899	$16.46
North Main Street	21,860	N/A	$177,120	$183,430	$360,500	$16.49
Total Costs		$449,946	$1,303,344	$2,797,027	$4,550,267	

Note

a. Actual cost may vary by approximately – 30% to + 50% from the conceptual design costs provided. Additionally, costs provided do not include design, permitting, or construction oversight.

4.0 RECOMMENDATIONS FOR PRIORITIZATON

We recommend prioritizing application of BMPs based on their cost benefit as shown in Table 3.8. We also generally recommend completing BMP implementation in one drainage area at a time in order to maximize cost benefit (e.g., construction mobilization for a single area per construction project). Therefore, we recommend the following order of priorities:

- Grant Drive and Stockwell Drive
- South Street
- Wales Avenue and Bodwell Street
- North Main Street

For each of the four areas listed above, we would anticipate three phases of implementation as follows:

- Year 1 Design and Permitting
- Year 2 – 3 Construction

APPENDIX E

Plan Approval

INTRODUCTION

The following text provides a description of best management practices (BMPs) that are used to treat stormwater at end-of-pipe and in the upland areas of drainage catchments. The text provides a general description of each BMP as well as an assessment of pollutant removal capacity, treatment processes provided, and applications, advantages and limitations. The following BMPs are included in alphabetical order:

- Bioretention, Rain Gardens, Stormwater Planters
- Constructed Stormwater Wetland (Including Gravel Wetlands)
- Dry Wells
- Green Roofs, Blue Roofs and Facades
- Infiltration Basin
- Infiltration Trenches
- Planter and Tree Box Filters
- Porous Pavement
- Proprietary Media Filter
- Sand Filters
- Subsurface Infiltration (Including Leaching Catch Basins)
- Vegetated Drainage Ways
- Water Quality Swale

For the most part, BMP types are based on BMPs listed in the Rhode Island Stormwater Design and Installation Standards Manual (RIDEM, 2010). In certain instances (e.g., leaching catch basins), we have adapted BMPs from other standards documents such as the Boston Water and Sewer Commission's Stormwater Best Management Practices: Guidance Document (2013).

Knowledge of pollutant removal capacity in conjunction with BMP treatment mechanisms is important to understanding the capacity of BMPs to improve stormwater quality. Removal capacities have been adapted from the Rhode Island Stormwater Design and Installation Standards Manual and were taken from either Appendix H or the "Key Considerations" text boxes. Treatment processes have been adapted from the Boston Water and Sewer Commission's Stormwater Best Management Practices: Guidance Document. Percent removal data is not available for metals in either of these documents; however, Rhode Island Stormwater Design and Installation Standards Manual qualifies BMPs as to whether they are able to achieve "good" metals removal or not.

A tabular summary of BMP application, advantages and limitations is provided to help ensure that BMPs selected are appropriately suited to the surrounding land use and other watershed conditions. This information was taken from several sources including the Rhode Island Stormwater Design and Installation Standards Manual and the Stormwater Best Management Practices: Guidance Document. We have also included our general knowledge of BMPs.

BIORETENTION, RAIN GARDENS, STORMWATER PLANTERS

Bioretention and rain gardens are shallow landscaped depressions designed to manage and treat stormwater runoff. Bioretention systems are a variation of a surface sand filter, where the sand filtration media is replaced with a planted soil bed designed to remove pollutants through physical and biological processes. The concept of bioretention originated with the Prince George's County, Maryland, Department of Environmental Resources in the early 1990s as an alternative to more traditional management practices. Stormwater flows into the bioretention area, ponds on the surface, and gradually infiltrates into the soil bed. Treated water is allowed to infiltrate into the surrounding soils or is collected by an underdrain system and discharged to the storm drain system or receiving waters. Small-scale bioretention applications (i.e., residential yards, median strips, parking lot islands) are commonly referred to as rain gardens. Tree box filters are essentially mini bioretention systems installed in concrete vaults. They are most often designed to fit in urban landscapes (e.g., sidewalks as part of street tree systems) where space is at a premium.

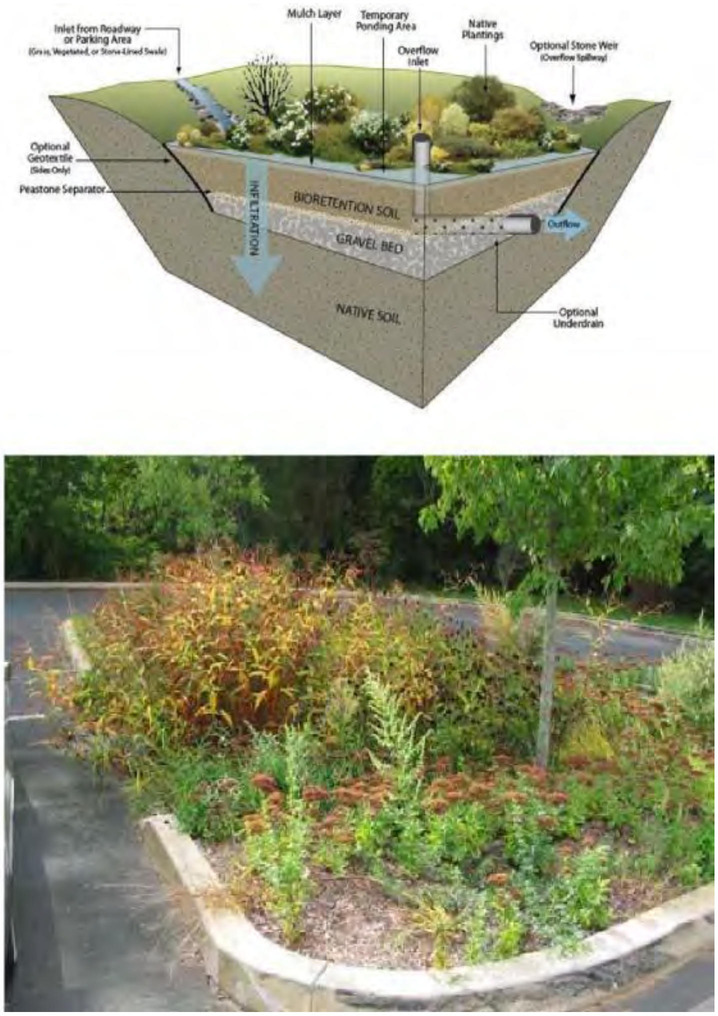


Figure B.1 Picture and schematic of bioretention

Table B-1
Pollutant Removal Capacity
Bioretention, Rain Gardens, Stormwater Planters

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards*
Bacteria	70%
Total Phosphorus	30%
Total Nitrogen	55%
TSS	90%
Metals	Good

Notes:

a. Percent removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs and "Key Considerations" text boxes of the *Rhode Island Stormwater Design and Installation Standards Manual.*

Table B-2
Treatment Processes Provided by Bioretention, Rain Gardens, Stormwater Planters

Treatment Processes[a]	Process Provided?
Biological Processes	✓
Infiltration	✓ (if designed to infiltrate)
Filtration	✓
Sedimentation	✓
Vegetated Treatment	✓
Volume Reduction	✓

Notes:

a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-3
Advantages, Disadvantages and Limitations of Bioretention, Rain Gardens, Stormwater Planters

Applications	Advantages	Limitations
• May be used in a wide variety of settings including residential, commercial, and industrial areas. • May be decentralized (e.g., as rain gardens on individual lots) or centralized in common areas to manage multiple • May be lined and underdrained; or designed to infiltrate and recharge groundwater.	• Highly versatile and adaptable to size of watershed and type of land use. • High solids, metals, and bacteria removal efficiency. • Infiltrating bioretention can provide groundwater recharge. • Helps to mimic predevelopment runoff conditions. • Reduces need for end-of-pipe treatment.	• Bottom of the filter must be at or above the seasonal high groundwater table if • Generally requires approximately 3-foot depth for soil bed and ponding area.

Figure B.2—Photograph of tree box filter.

CONSTRUCTED STORMWATER WETLAND

A constructed stormwater wetland is a system designed to maximize pollutant removal through vegetative uptake, retention, and settling. A typical constructed wetland consists of a sediment forebay to provide pretreatment and dissipate energy, a base with shallow pockets planted with diverse emergent vegetation, deeper areas or micro-pools and a water quality outlet structure. In addition to water quality treatment, constructed wetlands are designed to control peak flow rates from the 2-and 10-year storm through extended detention above the permanent pool elevation. The interactions between the incoming stormwater runoff, aquatic vegetation, wetland soils, and associated physical, chemical, and biological processes are a fundamental part to reducing suspended soils, nutrients, metals, oils and grease, and trash. Site investigations must be conducted prior to design and construction to ensure proper soils, depth to groundwater and suitable land.

Figure B.3—Photograph of constructed stormwater wetland.

There are several types of Constructed Stormwater Wetlands. Common types of constructed stormwater wetland include shallow marsh, basin/wetland, extended detention, and pocket.

Table B-4
Pollutant Removal Capacity
Constructed Stormwater Wetland

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	60%
Total Phosphorus	48%
Total Nitrogen	30%
TSS	85%
Metals	Fair

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-5
Treatment Processes Provided by Constructed Stormwater Wetland

Treatment Processes[a]	Process Provided?
Biological Processes	
Infiltration, if designed as such	
Filtration	✓
Sedimentation	✓
Vegetated Treatment	✓
Volume Reduction	

Notes:

a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-6
Advantages, Disadvantages and Limitations of Constructed Stormwater Wetland

Applications	Advantages	Limitations
• May be used as regional detention and treatment • May be best for sites without space constraints	• Low maintenance cost • Treatment of large tributary areas • Provides wildlife habitat • Aesthetically pleasing	• High land requirement • High capital cost • Design affected by depth to groundwater and bedrock • Additional restrictions apply in cold-water fishery watershed based on distance from discharge point to streams (and any contiguous wetlands)

DRY WELLS

A dry well is a small, excavated pit, backfilled with stone aggregate. Dry wells function like infiltration systems to control roof runoff and are applicable for most types of buildings.

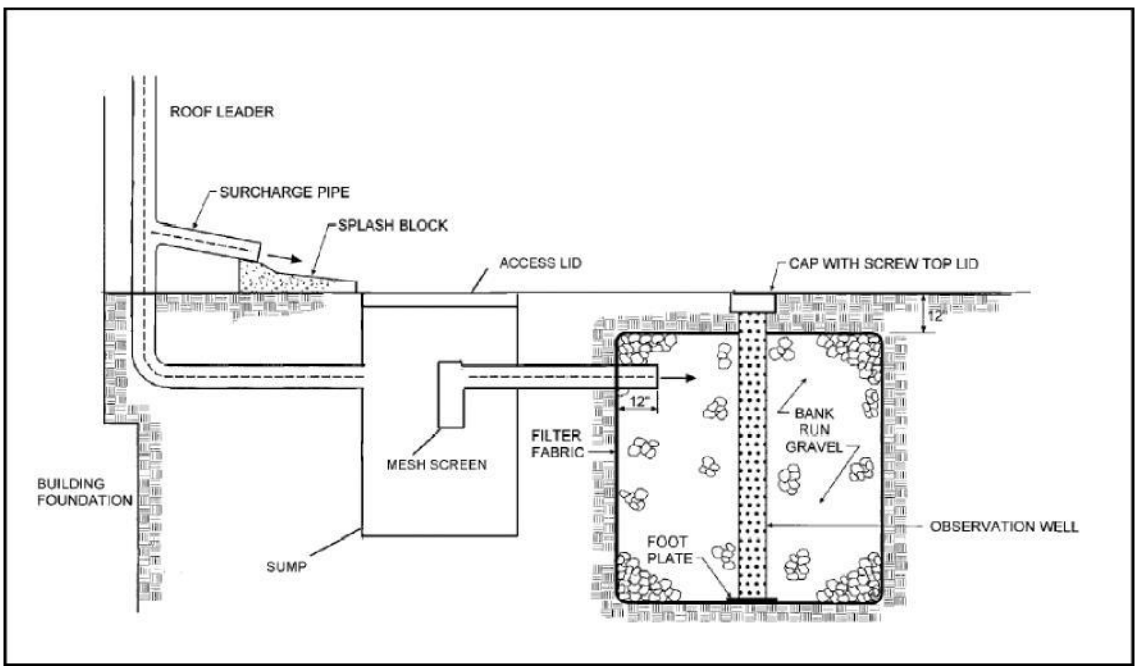


Figure B.4—Photograph and schematic of dry wells.

Table B-7
Pollutant Removal Capacity
Dry Wells

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	90%
Total Phosphorus	55%
Total Nitrogen	40%
TSS	90%
Metals	Good

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-8
Treatment Processes Provided by
Dry Wells

Treatment Processes[a]	Process Provided?
Biological Processes	
Infiltration	✓
Filtration	✓
Sedimentation	✓
Vegetated Treatment	
Volume Reduction	✓

Notes:

a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-9
Advantages, Disadvantages and Limitations of
Dry Wells

Applications	Advantages	Limitations
• Can be useful for disposing of roof runoff and reducing the overall runoff volume from a variety of building sites. (e.g., residential, commercial industrial, etc.).	• Low cost. • Provides retention of runoff from roofs. • Recharges groundwater. • Reduces need for end-of- pipe treatment.	• Clogging likely when used for runoff other than from rooftops • Only applicable in small drainage areas • When located near buildings, potential issues with water seeping into cellars or inducing • Two-foot minimum separation to groundwater • Minimum soil infiltration rate of 0.5 inches per hour • Infiltration of rooftop runoff from commercial or industrial buildings with pollution control, heating, cooling, or venting equipment may require UIC review and approval.

GREEN ROOFS, BLUE ROOFS AND FACADES

Figure B.5—Photograph of green roofs.

Green roofs are vegetated roof covers designed to reduce stormwater volumes through storage of precipitation in a soil media layer and increased evapotranspiration. Green roofs decrease the impervious footprint of buildings and help mimic pre-development hydrology. They are applicable in highly urbanized locations where land is limited and expensive. Due to an observed increase in nitrogen and phosphorous discharged from green roofs, they should not be used in nutrient sensitive waters, or locations where groundwater recharge is a priority due to low base flows. There are two types of green roofs: intensive green roofs and extensive green roofs. Extensive green roofs are lightweight systems requiring minimal maintenance and a shallow soil media, while intensive green roofs are larger and deeper systems requiring regular maintenance (irrigation, fertilizing, mowing) throughout the year.

Rooftop runoff management structures are modifications to conventional building design that attenuate runoff originating from roofs. The modifications include:

- Vegetated roof covers
- Roof gardens
- Vegetated building facades
- Roof ponding areas (e.g., blue roofs)

Roofs are significant sources of runoff from developed sites. If runoff is controlled at the source, the size of other BMPs throughout the site can be reduced. Rooftop runoff management practices influence the runoff hydrograph in two ways:

- Intercept rainfall during the early part of a storm.
- Limit the maximum release rate.

In addition to achieving specific stormwater runoff management objectives, rooftop runoff management can also be aesthetically and socially beneficial.

Design Variations

- Vegetated roof cover – Vegetated roof covers, also called green roofs and extensive roof gardens, involve blanketing roofs with a veneer of living vegetation. Vegetative roof covers are particularly effective when applied to extensive roofs, such as those that typify commercial and institutional buildings. The filtering effect of vegetated roof covers results in a roof discharge that is free of leaves and roof litter. Therefore, it is recommended where roof runoff will be directed to infiltration devices (see Standards for Infiltration Practices and Dry Wells).
- Because of recent advances in synthetic drainage materials, vegetated covers now are feasible on most conventional flat roofs. An efficient drainage layer is placed between the growth media and the roof surface. This layer rapidly conveys water off of the roof surface

and prevents water from "lying" on the roof. In fact, vegetated roof covers can be expected to protect roof materials and prolong their life.

- If materials are selected carefully to reduce the weight of the system, vegetated roof covers generally can be created on existing flat roofs without additional structural support. Drainage nets or sheet drains constructed from lightweight synthetic materials can be used as underlayments to carry away water and prevent ponding. The total load of a fully vegetated and saturated roof cover system can be less than the design load computed for gravel ballast on conventional tar roofs.
- Although vegetative roof covers are most effective during the growing season, they also are beneficial during the winter months as additional insulation if the vegetative matter from the dead or dormant plants is left in place and intact.
- Roof Gardens – Vegetated roof covers blanket an entire roof area and, although presenting an attractive vista, generally are not intended to accommodate routine traffic by people. Roof gardens, on the other hand, are landscaped environments, which may include planters and potted shrubs and trees. Roof gardens can be tailor-made natural areas, designed for outdoor recreation, and perched above congested city streets. Because of the special requirements for access, structural support, and drainage, roof gardens are found most frequently in new construction.
- Roof gardens generally are designed to achieve specific architectural objectives. The load and hydraulic requirements for roof gardens will vary according to the intended use of the space.
- Intensive roof gardens typically include design elements such as planters filled with topsoil, decorative gravel or stone, and containers for trees and shrubs. Complete designs also may detain runoff ponding in the form of water gardens or storage in gravel beds. A wide range of hydrologic principles may be exploited to achieve stormwater management objectives, including runoff peak attenuation and runoff volume control.
- Vegetated Building Facades – Vegetated facades provide many of the same benefits as vegetated roof covers and roof gardens, including the interception of precipitation and the retardation of runoff. However, their effectiveness is limited to small rainfall events.
- Vertical facades and walls of houses can be covered with the foliage of self-climbing plants that are rooted in the ground and reach heights in excess of 80 feet. Vines can be evergreen or prolific deciduous flowering plants. As for roof gardens, the designer must be judicial in selecting plant species that will prosper in the constructed environment. Planters and trellises can be installed so that vegetation can be placed strategically.
- Roof Ponding – Roof ponding, also known as blue roofs, is applicable where the increased load of impounded water on a roof will not increase the building costs significantly or require extensive reinforcement. Roof ponding generally is not viable for large-area commercial buildings where clear spans are required. Special consideration must be given to ensuring that the roof will remain watertight under a range of adverse weather conditions. Low-cost plastic membranes can be used to construct an impermeable lining for the containment area.

Table B-10
Pollutant Removal Capacity
Extensive and Intensive Green Roofs

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	70%
Total Phosphorus	30%
Total Nitrogen	55%
TSS	90%
Metals	Good

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

There is no available data on pollutant removal capacity on blue roofs or facades.

Table B-11
Treatment Processes Provided by
Extensive and Intensive Green Roofs

Treatment Processes[a]	Process Provided?
Biological Processes	
Infiltration	
Filtration	
Sedimentation	✓
Vegetated Treatment	✓
Volume Reduction	✓

Notes:

a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-12
Treatment Processes Provided by
Blue Roofs

Treatment Processes	Process Provided?
Biological Processes	
Infiltration	
Filtration	
Peak Flow Reduction	✓
Plant Uptake	✓
Sedimentation	✓
Vegetated Treatment	
Volume Reduction	✓

Notes:

a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-13
Treatment Processes Provided by Facades

Treatment Processes	Process Provided?
Biological Processes	✓
Infiltration	
Filtration	
Sedimentation	
Vegetated Treatment	✓
Volume Reduction	

Notes:

a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-14
Advantages, Disadvantages and Limitations of Extensive and Intensive Green Roofs

Applications	Advantages	Limitations
• Can use vegetative roofs on residential, commercial and light industrial buildings. • Vegetative roof systems are most appropriate on roofs with slopes of 12:1 to 4:1. • Vegetative roofs may be used on flatter slopes if an underdrain is installed.	• Rooftop runoff management techniques can be retrofitted to most constructed buildings. • Reduces energy consumption for heating cooling. • Conserves space. • Reduces wear on roofs caused by UV damage, wind, and extremes of temperature. Vegetative roof covers can reduce bare roof temperatures in summer by as much as 40 • Roof gardens, vegetated roof covers, and vegetated facades add aesthetic value to residential and commercial property that attract songbirds, bees, and butterflies. • Benefit water quality by reducing the acidity of runoff and trapping airborne particulates. • May reduce the size of onsite runoff attenuation	• Maximum 20% roof slope, unless specific measures are provided to retain the on steeper slopes. • Needs to be designed in accordance with weight and aesthetics and consideration of thermal performance.

INFILTRATION BASIN

An infiltration practice that stores the water in a surface depression before it is infiltrated into the underlying soils or substratum. Infiltration basins are stormwater impoundments, over permeable soils with vegetated bottoms and side slopes. Infiltration basins are designed to reduce stormwater volumes through exfiltration and groundwater recharge. Pretreatment is vital to ensuring successful performance. There are 2 types of infiltration basins: full exfiltration and partial or off-line exfiltration. Full exfiltration basins are designed to store, treat, and exfiltrate the full required water quality volume and attenuate peak flows. Partial or off-line exfiltration basins are designed to exfiltrate a portion of the runoff (usually the “first flush” or runoff from first 0.5 inches of precipitation), while diverting the remaining runoff to another BMP through flow splitters or weirs. The type of infiltration basin is chosen based upon site conditions and limitations.

Table B-15
Pollutant Removal Capacity
Infiltration Basin

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	95%
Total Phosphorus	65%
Total Nitrogen	65%
TSS	90%
Metals	Good

Notes:
a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-16
Treatment Processes Provided by
Infiltration Basin

Treatment Processes[a]	Process Provided?
Biological Processes	✓
Infiltration	✓
Filtration	✓
Sedimentation	✓
Vegetated Treatment	✓
Volume Reduction	✓

Notes:
a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-17
Advantages, Disadvantages and Limitations of Infiltration Basin

Applications	Advantages	Limitations
• Contributing drainage area should be between 2 and 15 acres • Suitable for sites with gentle slopes, permeable soils, and relatively deep groundwater table	• Reduces local flooding • Can use near cold-water fisheries	• Requires pretreatment • Requires large pervious • Clogging potential is high so high level of maintenance is necessary • Not suitable for treating high loads of sediment or other pollutants

INFILTRATION TRENCHES

Gravel trenches are long, narrow, gravel-filled trenches, which treat stormwater runoff from small drainage areas. Gravel trenches remove stormwater pollutants through infiltration, sedimentation and filtration. Reactive media (e.g., zeolite, activated carbon, oxide-coated sand, etc.) may be incorporated into the design to increase sorption capacity and target specific pollutants. Pretreatment may be provided to prevent clogging of the gravel bed and sub-grade.

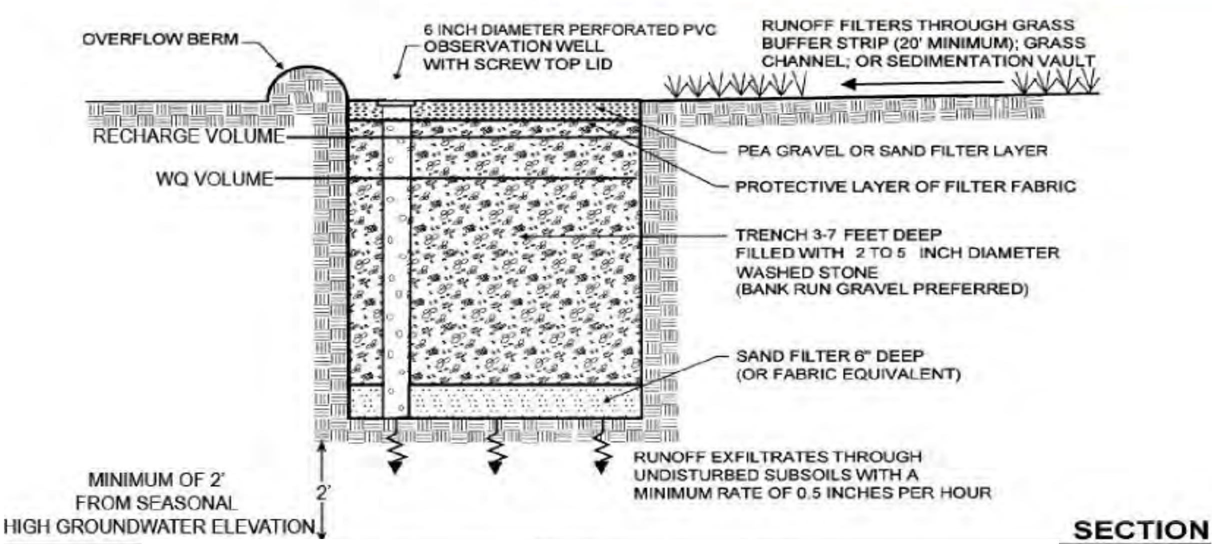


Figure B.6 – Photograph and schematic of infiltration trench

Table B-18
Pollutant Removal Capacity
Infiltration Trenches

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	95%
Total Phosphorus	65%
Total Nitrogen	65%
TSS	90%
Metals	Good

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-19
Treatment Processes Provided by Infiltration Trenches

Treatment Processes[a]	Process Provided?
Biological Processes	
Infiltration	✓
Filtration	✓
Sedimentation	✓
Vegetated Treatment	
Volume Reduction	✓

Notes:

a. Treatment processes are assumed to be same as Dry Wells and are identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-20
Advantages, Disadvantages and Limitations of Infiltration Trenches

Applications	Advantages	Limitations
• Infiltration may be useful for disposing of roof runoff (e.g., dry wells), or runoff from parking lots and • Infiltration trenches generally have a longer life cycle when hydrologically proceeded by pretreatment such as a vegetated filter strip. • Infiltration generally requires UIC review and approval.	• Appropriate for installation directly adjacent to parking lots or other impervious • Applicable to small drainage areas, stormwater retrofits and highly developed sites. • High bacteria removal efficiency. • Infiltration provides groundwater recharge. • Helps to mimic predevelopment runoff conditions. • Reduces need for end-of-pipe treatment.	• Susceptible to clogging by sediment • Maintenance required approximately every six months • Minimum soil infiltration rate of 0.5 inches per • Natural slope less than 15% • Cannot accept LUHPPL runoff • Separation to high groundwater minimum of 2 feet

LEACHING CATCH BASINS

Leaching catch basins are pre-cast concrete structures with openings within the structure walls and an open bottom. The openings allow water to infiltrate into the surrounding soils. Preferable design of a leaching catch basin involves an offline system with a deep sump catch basin upstream for pretreatment.

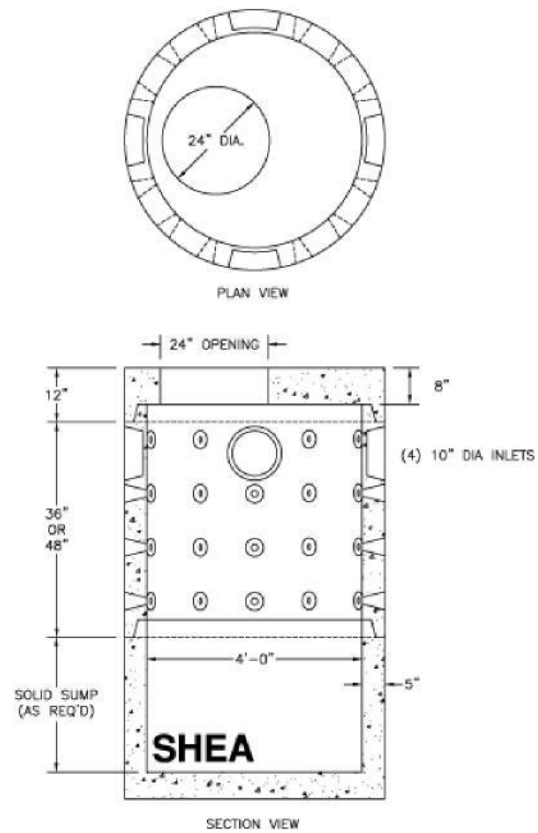


Figure B.7—Schematic of leaching catch basins.

Table B-21
Pollutant Removal Capacity

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	90%
Total Phosphorus	55%
Total Nitrogen	40%
TSS	90%
Metals	Good

Notes:
a. Removal rates assumed to be the same as Dry Wells and taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-22
Treatment Processes Provided by
Leaching Catch Basins

Treatment Processes[a]	Process Provided?
Biological Processes	
Infiltration	✓
Filtration	✓
Sedimentation	✓
Vegetated Treatment	
Volume Reduction	✓

Notes:
a. Treatment processes are assumed to be same as Dry Wells and are identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-23
Advantages, Disadvantages and Limitations of Leaching Catch Basins

Applications	Advantages	Limitations
• Can be implemented as a retrofit • May be useful in urban areas with land	• Low cost per unit of treatment • Especially suitable retrofit for roads and parking lots • Relatively easy to repair/replace	• Susceptible to clogging by sediment

PLANTER AND TREE BOX FILTERS

Planter boxes are bioretention treatment control measures that are completely contained within an impermeable structure with an underdrain (they do not infiltrate). The boxes can be comprised of a variety of materials, such as brick or concrete, (usually chosen to be the same material as the adjacent building or sidewalk) and are filled with gravel on the bottom (to house an underdrain system), planting soil media, and vegetation. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants.

Figure B.8 – Photographs of planter and tree box filters

Table B-24
Pollutant Removal Capacity
Planter and Tree Box Filters

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	70%
Total Phosphorus	30%
Total Nitrogen	55%
TSS	90%
Metals	Good

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-25
Treatment Processes Provided by Planter and Tree Box Filters

Treatment Processes[a]	Process Provided?
Biological Processes	✓
Infiltration	
Filtration	✓
Sedimentation	✓
Vegetated Treatment	✓
Volume Reduction	✓

Notes:
a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-26
Advantages, Disadvantages and Limitations of Planter and Tree Box Filters

Applications	Advantages	Limitations
• Commonly used in densely urbanized areas such as along roads, highways, sidewalks and parking lots	• Reduces volume and rate of runoff • Smaller footprint • required May be used as pretreatment device • Provides decentralized stormwater treatment • Ideal for redevelopment or in ultra-urban settings	• Requires vegetative maintenance • Treats small volumes • Treats small tributary areas

POROUS PAVEMENT

Porous pavement is a permeable alternative to conventional asphalt and concrete and constructed in pedestrian, highly urbanized, or residential settings with low traffic speeds and volumes. A high surface void ratio allows precipitation to pass through the pavement and a stone base, where runoff is retained and sediments and metals are treated to some degree. Porous pavement is designed to achieve peak flow attenuation of small intensity storms and groundwater recharge through infiltration into underlying soils. Porous pavement includes porous asphalt and pervious concrete, which are poured in place, and paving stones and grass pavers, which are typically precast and installed in an interlocking array to create a surface

Figure B.9 – Photographs of porous pavement

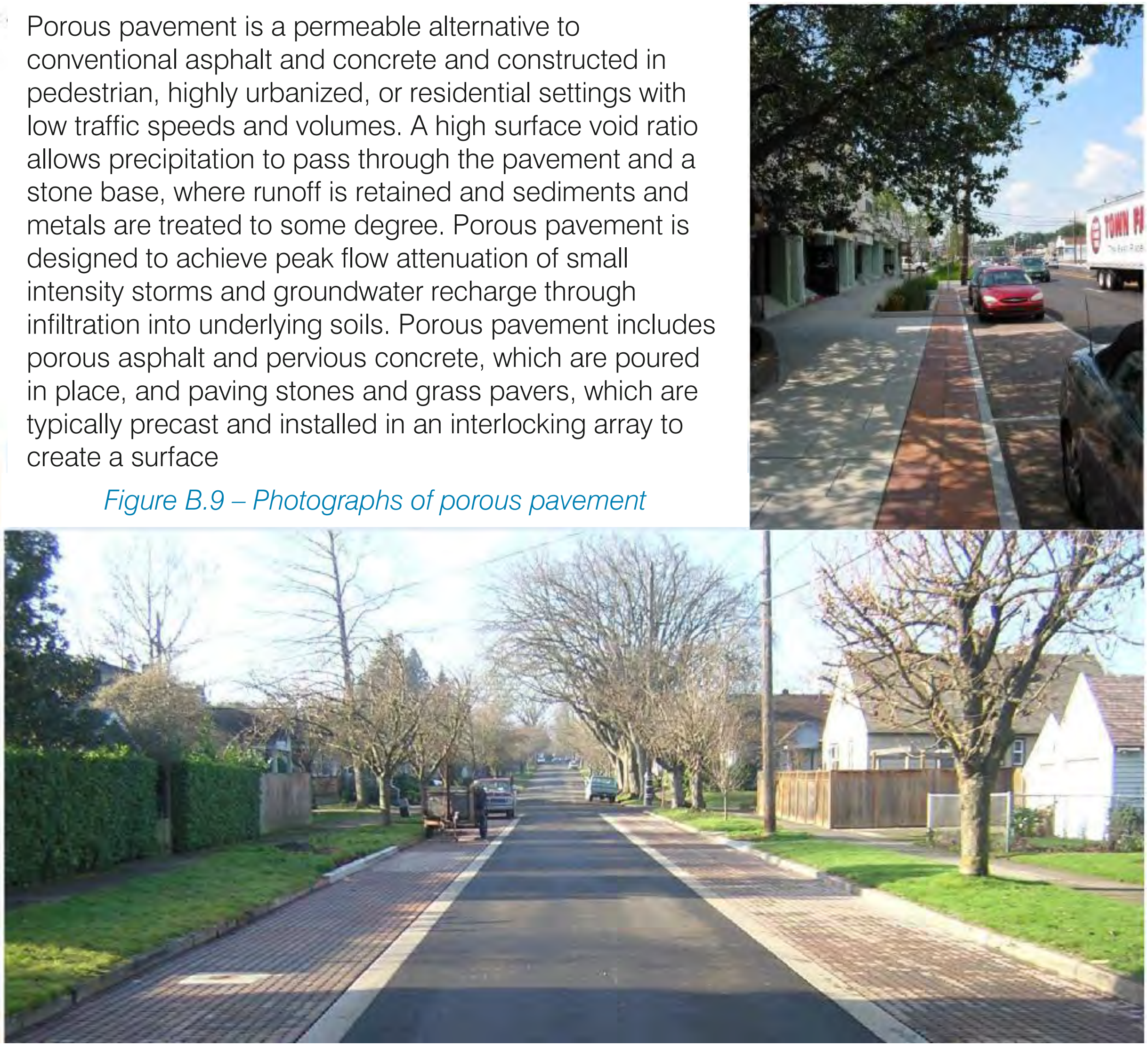


Table B-27
Pollutant Removal Capacity
Porous Pavement

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	95%
Total Phosphorus	40%
Total Nitrogen	40%
TSS	90%
Metals	Good

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-28
Treatment Processes Provided by Porous Pavement

Treatment Processes[a]	Process Provided?
Biological Processes	✓
Infiltration	✓
Filtration	✓
Sedimentation	✓
Vegetated Treatment	
Volume Reduction	✓

Notes:
a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-29
Advantages, Disadvantages and Limitations of Porous Pavement

Applications	Advantages	Limitations
• Good option for commercial and industrial parking lots • Can be used in urban and residential settings • Can be implemented as a retrofit • Preferable for low-volume, low-speed areas or pedestrian • Useful application to sidewalks	• Reduces sediment and particulate-bound pollutants • Reduces amount of impervious area needing water quality treatment	• Frequent clogging if not maintained • No sanding in winter • Compacting of underlying soils is common • Limited removal of dissolved constituents when underdrains are used

PROPRIETARY MEDIA FILTER

Proprietary Media Filters are typically underground structures that first settle out in an upstream structure and then flow through a specific filter media to reduce targeted pollutants.

Removal rates of pollutants vary depending on the filter media. Filtration is the main treatment process that all proprietary media filters provide.

Table B-30
Advantages, Disadvantages and Limitations of
Proprietary Media Filter

Applications	Advantages	Limitations
• Sites with space constraints • Ultra-urban areas	• Suitable for specialized applications, such as industrial sites, for specific target pollutants • Preferred for redevelopments or in the ultra-urban setting when LID or larger conventional practices are not practical	• Must be purchased from private sector firm • May require more maintenance • "Wet" systems that are designed to retain water can cause mosquito and vector problems unless access points are sealed

SAND FILTERS

Sand filters are engineered sand filled depressions that treat stormwater runoff from small tributary areas. Sand filters allow for the percolation of runoff through the void space within the sand before it is eventually released through an underdrain at the bottom of the filter. Stormwater runoff enters the filter from a pretreatment system (sediment forebay or vegetated filter strip) and spreads evenly over the surface. As flows increase, water backs up on the surface of the filter where it is held until it can percolate through the sand. As stormwater passes through the sand, pollutants are trapped in the small pore spaces between sand grains or are adsorbed to the sand surface. The effectiveness and efficiency of a sand filter depends heavily on the pretreatment BMPs performance to settle out sand, clay, and silt particles, which prevent clogging of the sand filter.

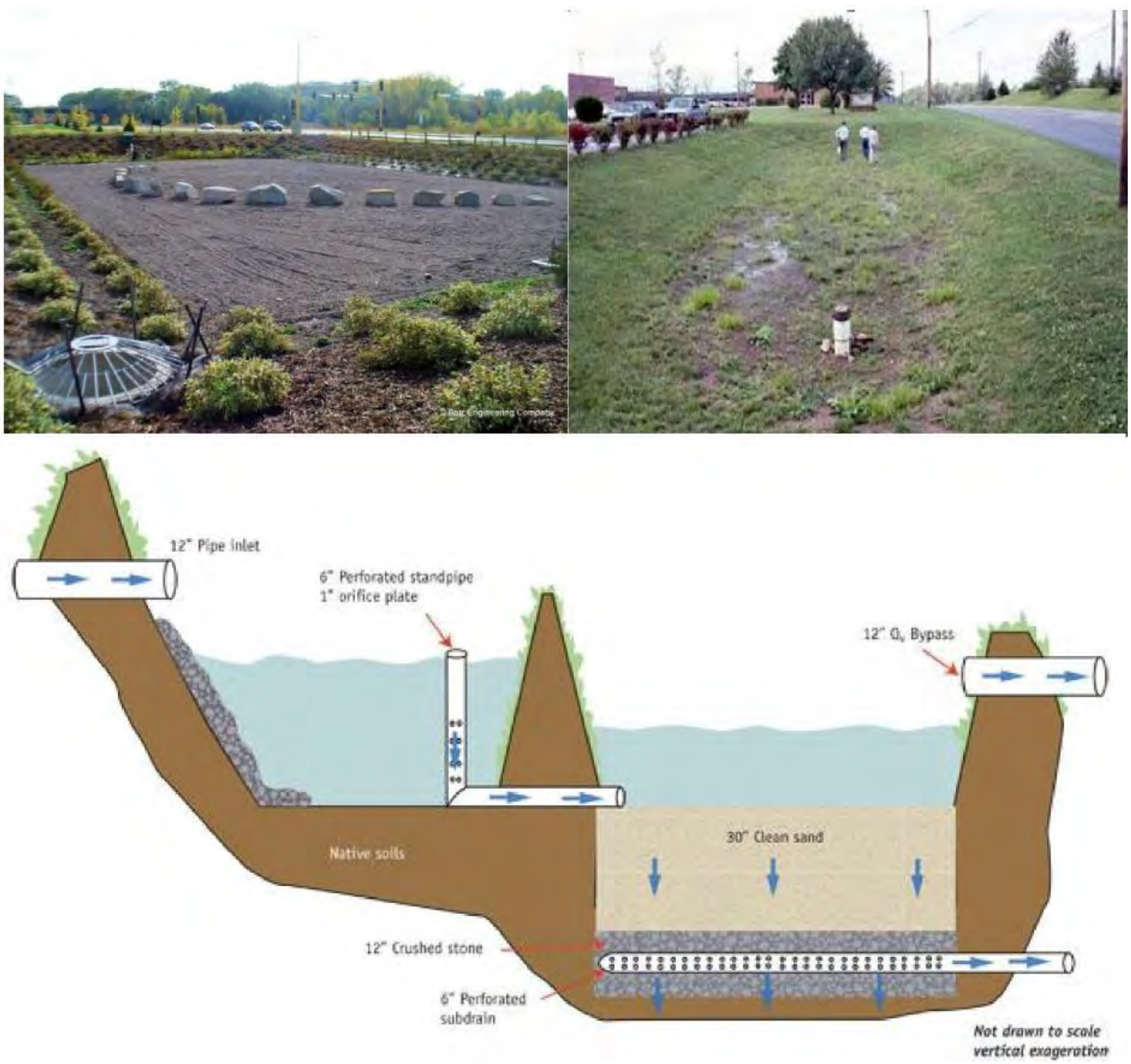


Figure B.10 – Photographs and schematic of sand filters

Table B-31
Pollutant Removal Capacity
Sand Filter

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	70%
Total Phosphorus	59%
Total Nitrogen	32%
TSS	86%
Metals	Good

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-32
Treatment Processes Provided by
Sand Filter

Treatment Processes[a]	Process Provided?
Biological Processes	✓
Infiltration	
Filtration	✓
Sedimentation	✓
Vegetated Treatment	
Volume Reduction	

Notes:

a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-33
Advantages, Disadvantages and Limitations of
Sand Filter

Applications	Advantages	Limitations
• Can be used in ultra-urban sites with small drainage areas • Drainage area can be 100% impervious like parking lots • May be useful as redevelopment / retrofit projects	• Long design life if properly maintained • Good for densely urban areas or parking lots • Relatively small footprint area	• Pretreatment required to prevent clogging • Frequent maintenance required • Costly to build and install • Limited removal of dissolved constituents • May not be effective in winter • Can be unattractive and create odors

SUBSURFACE INFILTRATION

Subsurface infiltration structures are underground systems that capture and infiltrate runoff into the groundwater through highly permeable rock and gravel. It is usually not practical to infiltrate runoff at the same rate that is generated; therefore, these facilities generally include both a storage component and a drainage component. Typical subsurface infiltration systems that can be installed to enhance groundwater recharge include pre-cast concrete or plastic pits, chambers (manufactured pipes), and perforated pipes.

Figure B.11—Rendering of subsurface infiltration structure.

Table B-34
Pollutant Removal Capacity
Subsurface Infiltration

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	90%
Total Phosphorus	55%
Total Nitrogen	40%
TSS	90%
Metals	Good

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-35
Treatment Processes Provided by
Subsurface Infiltration

Treatment Processes[a]	Process Provided?
Biological Processes	
Infiltration	✓
Filtration	✓
Sedimentation	✓
Vegetated Treatment	
Volume Reduction	✓

Notes:

a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-36
Advantages, Disadvantages and Limitations of Subsurface Infiltration

Applications	Advantages	Limitations
• Applicable for private and public projects, commercial and residential • Can be implemented as a retrofit • May be useful in urban areas adjacent to	• Low cost per unit of treatment • Especially suitable retrofit roads and parking lots	• Susceptible to clogging by sediment • Minimum soil rate of 0.5 inches per hour • Separation from seasonal high groundwater, minimum of 2 feet

VEGETATED DRAINAGE WAYS

Structural drainage systems and storm sewers are designed to be hydraulically efficient for removing stormwater from a site. However, in doing so, these systems tend to increase peak runoff discharges, flow velocities and the delivery of pollutants to downstream waters. An alternative is the use of natural drainage ways such as grass natural drainage systems.

The use of natural open channels allows for more storage of stormwater flows on-site, lower stormwater peak flows, a reduction in erosive runoff velocities, infiltration of a portion of the runoff volume, and the capture and treatment of stormwater pollutants

Figure B.12—Photograph of vegetated drainage ways.

Table B-37
Pollutant Removal Capacity
Vegetated Drainage Ways

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	No Treatment
Total Phosphorus	No Data
Total Nitrogen	No Data
TSS	No Data
Metals	No Data

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-38
Treatment Processes Provided by
Vegetated Drainage Ways

Treatment Processes	Process Provided?
Biological Processes	
Infiltration	
Filtration	
Sedimentation	✓
Vegetated Treatment	✓
Volume Reduction	

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-39
Advantages, Disadvantages and Limitations of Vegetated Drainage Ways

Applications	Advantages	Limitations

• Use vegetated open channels in the street of-way to convey and treat stormwater runoff from roadways, particularly for low-density development and residential subdivisions where density, topography, soils, slope, and safety issues
• permit.
Use vegetated open channels in place of curb and gutter to convey and
• Design drainage systems and open
  ◦ Increase surface roughness to retard velocity.
  ◦ Include wide and flat channels to reduce velocity of flow and encourage sheet
  ◦ Increase channel flow path to increase time of concentration and
	• Reduces or eliminates the cost of constructing storm sewers or other conveyances, and reduce the need for land disturbance and grading.
	• Increases travel times and lower peak discharges.
	• Can be combined with buffer systems to enhance stormwater filtration and infiltration.
		• Maximum longitudinal slope of 4%, without checkdams
		• Can erode during large storms
		• Treats small tributary areas

WATER QUALITY SWALE

Water quality swales are shallow, open conveyance channels with low-lying vegetation designed to settle out suspended pollutants due to shallow flow depths and slow velocities. Additional pollutant removal mechanisms include volume reduction through infiltration and evapotranspiration and biochemical processes that provide treatment of dissolved constituents. It is generally accepted that water quality swales have higher pollutant removal efficiencies than grass channels. An effective vegetated swale achieves uniform sheet flow through a vegetated area for at least 10 minutes.

Figure B.13 – Photograph of water quality swale

Vegetated open channels designed to treat and attenuate the water quality volume and convey excess stormwater runoff. Dry swales are primarily designed to receive drainage from small impervious areas and rural roads.

Wet swales are primarily used for highway runoff, small parking lots, rooftops, and pervious areas. Vegetated open channels designed to treat and attenuate the water quality volume and convey excess stormwater runoff. Dry swales are primarily designed to receive drainage from small impervious areas and rural roads. Wet swales are primarily used for highway runoff, small parking lots, rooftops, and pervious areas.

Table B-40
Pollutant Removal Capacity
Water Quality Swale

Target Constituents	Removal Rates Based on the *Rhode Island Stormwater Design and Installation Standards Manual*[a]
Bacteria	70%
Total Phosphorus	30%
Total Nitrogen	55%
TSS	90%
Metals	Good

Notes:

a. Removal rates taken from Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs of the *Rhode Island Stormwater Design and Installation Standards Manual*

Table B-41
Treatment Processes Provided by Water Quality Swale

Treatment Processes[a]	Process Provided?
Biological Processes	✓
Infiltration	✓
Filtration	✓
Sedimentation	✓
Vegetated Treatment	✓
Volume Reduction	✓

Notes:

a. Treatment processes identified from Boston Water and Sewer Commission (BWSC) *Stormwater Best Management Practices: Guidance Document*, January 2013.

Table B-42
Advantages, Disadvantages and Limitations of Water Quality Swale

Applications	Advantages	Limitations
• Residential settings along roadways.	• Low capital cost • Low maintenance requirements	• Can erode during large storms • Treats small tributary areas • Not for areas with very flat grades, steep topography, or poorly drained soils • Higher degree of maintenance than curb and gutter systems

REFERENCES

Boston Water and Sewer Commission. (2013). *Stormwater Best Management Practices: Guidance Document.*

RIDEM. (2010). *Rhode Island Stormwater Design and Installation Standards Manual*.