# TOWN OF CARLISLE
# HAZARD MITIGATION PLAN 2021 UPDATE

**ADOPTED BY THE TOWN**
**November 23, 2021**

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# ACKNOWLEDGEMENTS & CREDITS

This plan was prepared for the Town of Carlisle by the Metropolitan Area Planning Council (MAPC) under the guidance of the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) and the Massachusetts Emergency Management Agency (MEMA). The plan was funded by Municipal Vulnerability Preparedness (MVP) planning grant from EEA.

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| Navneet Hundal, MD | Conservation Commission board member |
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**Carlisle Participating Officials**

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| Chief Bryan Sorrows | Carlisle Fire Chief |
| Chief John Fisher | Carlisle Police Chief |
| Jon Metivier | Building Commissioner |

# TABLE OF CONTENTS

# TABLES

# FIGURES

# SECTION 1: EXECUTIVE SUMMARY

Hazard Mitigation planning is a proactive effort to identify actions that can be taken to reduce the dangers to life and property from natural hazard events. In the communities of the Boston region of Massachusetts, hazard mitigation planning tends to focus most on flooding, the most likely natural hazard to impact these communities. In Carlisle ice storms and related power outages were also identified by local officials. The Federal Disaster Mitigation Act of 2000 requires all municipalities that wish to be eligible to receive FEMA funding for hazard mitigation grants, to adopt a local multi-hazard mitigation plan and update this plan in five-year intervals.

In 2017, the Massachusetts Executive Office of Energy and Environmental Affairs (EOEEA) inaugurated the Municipal Vulnerability Preparedness (MVP) program to assist municipalities in planning for and implementing strategies to adapt to predicted changes in our warming climate. The predicted changes include both increased flooding from large rain events and a greater likelihood of drought, increased extreme heat days and heat waves, and increased flooding from sea level rise.

The Town of Carlisle received an MVP grant in 2020, which supported the town's participation in a Community Resilience Building (CRB) Workshop held on March 27, 2021. The findings of the workshop are published in a companion volume, *Carlisle Community Resilience Building Report*, and the high priority actions are summarized in Appendix E of this plan. Communities that complete the MVP project become certified as an MVP Community and are eligible for follow-up funding through MVP Action Grants to implement some of the actions identified.

Carlisle's MVP grant also included the preparation of this updated Hazard Mitigation Plan. The updated plan provides a hazard mitigation planning approach, as well as climate resilience provisions for the Town of Carlisle. Taken together, this plan update and the accompanying MVP report provide the Town with a holistic assessment and implementation plan for both hazard mitigation and climate change resiliency.

## HAZARD MITIGATION PLANNING PROCESS

This is an updated Hazard Mitigation Plan to replace the Town of Carlisle's previous plan, which was approved by FEMA on March 16, 2012. This Hazard Mitigation Plan 2021 Update was led by the Carlisle Hazard Mitigation and Municipal Vulnerability Preparedness Core Team (HMP/MVP Core Team; see Table 5). The HMP/MVP Core Team met four times on the following dates: November 18, 2020, January 6, 2021, March 16, 2021, and May 26, 2021. During these meetings, the team reviewed where the impacts of natural hazards most affect the town, updated the town's Critical Facilities and development sites, updated the Town's existing mitigation measures, and new or revised hazard mitigation measures that would benefit the town.

Public participation in this planning process is important for improving awareness of the potential impacts of natural hazards and to build support for the actions the Town takes to mitigate them. The Carlisle HMP/MVP Core Team hosted two public meetings, the first on February 9, 2021,

hosted by the Carlisle Select Board, and the second on June 16, 2021. As part of the MVP project, the town also hosted a Community Resilience Building workshop on March 27, 2021, where 45 participants identified climate resilience vulnerabilities and mitigation strategies. After the workshop, a Public Listening Session was held in conjunction with the Hazard Mitigation Plan public meeting held on June 16, 2021. Key town stakeholders and neighboring communities were notified and invited to review the draft plan update and MVP Report and submit comments. The draft *Carlisle Hazard Mitigation Plan 2021 Update* and the *Carlisle Community Resilience Building Report* were posted on the Town's website for public review at the June 16, 2021, public meeting.

## RISK ASSESSMENT

The Carlisle Hazard Mitigation Plan 2021Update assesses the potential impacts to the town from flooding, high winds, winter storms, wildfires, geologic hazards, extreme temperatures, and drought. For each risk, the assessment identifies the current hazards as well as projected future impacts of a warming climate. These hazards are also shown in the hazards map series in Appendix A. The Carlisle HMP/MVP Core Team identified 81 Critical Facilities. These are also shown on the map series and listed in Table 33, identifying which facilities are located within the mapped hazard areas.

MAPC used Hazards U.S.– Multihazards (HAZUS-MH), a standardized computer methodology developed by FEMA that utilizes Geographic Information Systems (GIS), to estimate physical, economic, and social impacts of disasters. The HAZUS-MH analysis for Carlisle estimates property damages from Hurricanes of 100 year and 500-year magnitude ($6.1 million to $20.1 million), earthquakes of magnitudes 5 and 7 ($103.6 million to $895.8 million), and the 1% and 0.2% chance of flooding ($2.8 million to $3.6 million).

## HAZARD MITIGATION GOALS

The town reviewed the hazard mitigation goals from the 2012 plan. Two additional goals were added, numbers 9 and 10, which focus on incorporating climate change into this plan update.

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

2. Identify and seek funding for measures to mitigate or eliminate each known significant flood hazard area.

3. Integrate hazard mitigation planning as an integral factor in all relevant municipal departments, committees, and boards.

4. Prevent and reduce the damage to public infrastructure resulting from all hazards.

5. Identify areas without water supplies for fire. Identify natural water supplies that are drought resistant.

6. Encourage the business community, major institutions, and non-profits to work with the Town to develop, review, and implement the hazard mitigation plan.

7. Work with surrounding communities, state, regional, and federal agencies to ensure regional cooperation and solutions for hazards affecting multiple communities.

8. Ensure that future development meets federal, state, and local standards for preventing and reducing the impacts of natural hazards.

9. Take maximum advantage of resources from FEMA and MEMA to educate Town staff and the public about hazard mitigation.

10. Educate the public about natural hazards, climate change, and mitigation measures.

11. Consider the potential impacts of climate change and incorporate climate mitigation and resilience in all planning efforts.

## HAZARD MITIGATION STRATEGY

The Carlisle HMP/MVP Core Team identified 19 mitigation measures that would serve to reduce the Town's vulnerability to natural hazard events (see Table 41). Overall, the hazard mitigation strategy recognizes that mitigating hazards for Carlisle will be an ongoing process as our understanding of natural hazards and the steps that can be taken to mitigate their damages changes over time. Global climate change and a variety of other factors will impact the Town's vulnerability in the future, and local officials will need to work together and with state and federal agencies in order to understand and address these changes. The Hazard Mitigation Strategy will be incorporated into the Town's other related plans and policies.

## PLAN REVIEW & UPDATE PROCESS

The process for developing the Carlisle Hazard Mitigation Plan 2021 Update is summarized in Table 1.

**Table 1 Plan Review and Update Process:**

| Section of Plan | Reviews and Updates |
|---|---|
| Section 3: Public Participation | The Carlisle HMP/MVP Core Team placed an emphasis on public participation for the update of the Hazard Mitigation Plan.. During plan development, the plan was discussed at two public meetings hosted by the Carlisle HMP/MVP Core Team on February 9, 2021 and June 16, 2021. The plan was also available on the Town's website for public comment after the second meeting. In addition, as part of the concurrent MVP project, a Community Resilience Building Workshop was held on March 27, 2021, and a Public Listening Session was held on June 16, 2021 in conjunction with the second Hazard Mitigation public meeting |

| Section of Plan | Reviews and Updates |
|---|---|
| Section 4: Risk Assessment | MAPC gathered the most recently available hazard and land use data and met with town staff to identify changes in local hazard areas and development trends. Town staff reviewed critical infrastructure with MAPC staff in order to create an up-to-date list and GIS mapping. The Risk Assessment integrates projected climate impacts. MAPC also used the most recently available version of HAZUS and assessed the potential impacts of flooding, hurricanes, and earthquakes. |
| Section 5: Goals | The Hazard Mitigation Goals were updated to include a focus on climate change in the 2021 plan update. |
| Section 6: Existing Mitigation Measures | The list of existing mitigation measures was updated to reflect the current status mitigation activities in the town. |
| Sections 7 and 8: Hazard Mitigation Strategy | Mitigation measures from the 2012 plan were reviewed and assessed as to whether they were completed, in progress, or deferred. The Carlisle HMP/MVP Team determined whether to carry forward some mitigation measures into the 2021 Plan Update or modify or delete them. The Plan Update's hazard mitigation strategy reflects both new measures and measures carried forward from the 2012 plan. The mitigation measures were prioritized based on current conditions. |
| Section 9: Plan Adoption & Maintenance | This section of the plan was updated with a new ongoing plan implementation review and five-year update process that will assist the Town in incorporating hazard mitigation issues into other Town planning and regulatory review processes and better prepare the Town for the next comprehensive plan update. |

As indicated in Table 39, Carlisle made good progress on some of the mitigation measures from the previous plan. The Town has advanced several projects for implementation, including plans for a $750,000 dam repair/upgrade for the Greenough Pond Dam, installation of a generator in the school, upgrading emergency communications, and updating the floodplain zoning overlay map to be consistent with revisions to the FEMA Flood Insurance Rate Maps for Middlesex County, MA. The Town conducted a Municipal Vulnerability Project (MVP) project to address climate change impacts and identify resiliency opportunities in conjunction with this Hazard Mitigation Plan Update. The priority actions from this project are summarized in Appendix E, and the *Carlisle Community Resilience Building Report* accompanies this plan in a companion document.

Several projects that were not completed will be continued into this plan update. While the town has addressed stormwater challenges in several locations, more improvements are needed at key locations throughout the town. These will be addressed by a town-wide assessment of roads and culverts that are vulnerable to flooding and drainage issues. 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. The Town will document any actions taken within this iteration of the Hazard Mitigation Plan on challenges met and actions successfully adopted as part of the ongoing plan implementation and maintenance to be conducted by the Carlisle HMP/MVP Core Team, as described in Section 9, Plan Adoption and Maintenance.

# SECTION 2 INTRODUCTION

## PLANNING REQUIREMENTS UNDER THE FEDERAL DISASTER MITIGATION ACT

The Federal Disaster Mitigation Act, passed in 2000, requires that after November 1, 2004, all municipalities that wish to continue to be eligible to receive FEMA funding for hazard mitigation grants, must adopt a local multi-hazard mitigation plan and update this plan in five-year intervals. This planning requirement does not affect disaster assistance funding.

Federal hazard mitigation planning and grant programs are administered by the Federal Emergency Management Agency (FEMA) in collaboration with the states. These programs are administered in Massachusetts by the Massachusetts Emergency Management Agency (MEMA) in partnership with the Department of Conservation and Recreation (DCR).

Massachusetts has taken a regional approach and has encouraged regional planning agencies like MAPC to prepare plans for their member communities. The Town of Carlisle contracted with the Metropolitan Area Planning Council (MAPC) to assist the Town in updating its Hazard Mitigation Plan, which was first approved by FEMA in 2012. This Hazard Mitigation Plan 2021 Update is designed to meet the requirements of the Disaster Mitigation Act for the Town of Carlisle while addressing climate change impacts through the Municipal Vulnerability Preparedness (MVP) project conducted in conjunction with this plan update, as described below.

## WHAT IS A HAZARD MITIGATION PLAN?

Natural hazard mitigation planning is the process of determining how to systematically reduce or eliminate the loss of life and property damage resulting from natural hazards such as floods, earthquakes, and hurricanes. Hazard mitigation means to permanently reduce or alleviate the losses of life, injuries, and property resulting from natural hazards through long-term strategies. These long-term strategies include planning, policy changes, programs, projects, and other activities.

The Town of Carlisle received an MVP Planning Grant to concurrently conduct a Municipal Vulnerability Preparedness project and prepare an updated Hazard Mitigation Plan. Many of the required steps of the MVP process also satisfy requirements for updating an HMP. As a result, the Town with assistance from MAPC prepared this Hazard Mitigation Plan 2021 Update in accordance with FEMA guidelines for hazard mitigation planning (Title 44 Code of Regulations (CFR) 201.6) and an MVP Final Report according to the Community Resilience Building (CRB) guidance provided by the Massachusetts Executive Office of Energy & Environmental Affairs' (EEA), This enabled Carlisle to consider the effects of a warming climate 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).

## PREVIOUS FEDERAL/STATE DISASTERS

The Town of Carlisle, a part of Middlesex County, has experienced 22 natural hazards that triggered federal or state disaster declarations since 1991. These are listed in Table 2 below. The majority of these events involved flooding, while five were due to hurricanes or nor'easters, and four were due to severe winter weather.

**Table 2: Previous Federal/State Disaster Declarations**

| Disaster Name (Date of Event) | Type of Assistance | Declared Areas |
|---|---|---|
| Hurricane Bob (August 1991) | FEMA Public Assistance Project Grants | Counties of Barnstable, Bristol, Dukes, Essex, Hampden, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk |
| | Hazard Mitigation Grant Program | Counties of Barnstable, Bristol, Dukes, Essex, Hampden, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk (16 projects) |
| No-Name Storm (October 1991) | FEMA Public Assistance Project Grants | Counties of Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk |
| | FEMA Individual Household Program | Counties of Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk |
| | Hazard Mitigation Grant Program | Counties of Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk (10 projects) |
| December Blizzard (December 1992) | FEMA Public Assistance Project Grants | Counties of Barnstable, Dukes, Essex, Plymouth, Suffolk |
| | Hazard Mitigation Grant Program | Counties of Barnstable, Dukes, Essex, Plymouth, Suffolk (7 projects) |
| March Blizzard (March 1993) | FEMA Public Assistance Project Grants | All 14 Counties |
| January Blizzard (January 1996) | FEMA Public Assistance Project Grants | All 14 Counties |
| May Windstorm (May 1996) | State Public Assistance Project Grants | Counties of Plymouth, Norfolk, Bristol (27 communities) |
| October Flood (October 1996) | FEMA Public Assistance Project Grants | Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk |
| | FEMA Individual Household Program | Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk |
| | Hazard Mitigation Grant Program | Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk (36 projects) |

| Disaster Name (Date of Event) | Type of Assistance | Declared Areas |
|---|---|---|
| 1997 | Community Development Block Grant-HUD | Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk |
| June Flood (June 1998) | FEMA Individual Household Program | Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester |
| | Hazard Mitigation Grant Program | Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester (19 projects) |
| (1998) | Community Development Block Grant-HUD | Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester |
| March Flood (March 2001) | FEMA Individual Household Program | Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester |
| | Hazard Mitigation Grant Program | Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester (16 projects) |
| February Snowstorm (Feb 17-18, 2003) | FEMA Public Assistance Project Grants | All 14 Counties |
| January Blizzard (January 22-23, 2005) | FEMA Public Assistance Project Grants | All 14 Counties |
| Hurricane Katrina (August 29, 2005) | FEMA Public Assistance Project Grants | All 14 Counties |
| May Rainstorm/Flood (May 12-23, 2006) | Hazard Mitigation Grant Program | Statewide |
| April Nor'easter (April 15-27, 2007) | Hard Mitigation Grant Program | Statewide |
| Flooding (March 2010) | FEMA Public Assistance<br>FEMA Individuals and Households Program<br>SBA Loan | Bristol, Essex, Middlesex, Suffolk, Norfolk, Plymouth, Worcester |
| | Hazard Mitigation Grant Program | Statewide |
| Hurricane Earl (September 2010) | FEMA Public Assistance Project Grants | Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, and Worcester |
| Tropical Storm Irene (August 27-28, 2011) | FEMA Public Assistance | Statewide |
| Hurricane Sandy (October 27-30, 2012) | FEMA Public Assistance | Statewide |

| Disaster Name (Date of Event) | Type of Assistance | Declared Areas |
|---|---|---|
| Severe snowstorm and Flooding (February 8-09, 2013) | FEMA Public Assistance; Hazard Mitigation Grant Program | Statewide |
| Blizzard of 2015 (January 26-28, 2015) | FEMA Public Assistance; Hazard Mitigation Grant Program | Statewide |
| Severe Winter Storm (March 2-3, 2018) | FEMA Public Assistance; Hazard Mitigation Grant Program | Salem, Suffolk, Norfolk, Bristol, Plymouth, Barnstable Counties |
| Severe Winter Storm (March 13-14, 2018) | FEMA Public Assistance; Hazard Mitigation Grant Program | Salem, Suffolk, Norfolk, Worcester Counties |

Source: database provided by MEMA

## FEMA FUNDED MITIGATION PROJECTS

The Town of Carlisle has not applied for or received funding from FEMA for hazard mitigation or flood mitigation projects under the Hazard Mitigation Assistance (HMA) program.

**COMMUNITY PROFILE**

Carlisle is located in Middlesex County and is bordered by Concord on the south, Acton and Westford on the west, Chelmsford on the north, and Billerica and Bedford on the east. Carlisle is about 20 miles northwest of Boston and 11 miles south of Lowell. It is home to just one state roadway – Route 225. The Route 225 bridge has a low weight rating. The Fire Department has special permission to drive vehicles over it at 5 MPH straddling the double yellow lines. Public transportation is not provided in Carlisle, though commuter rail stations are located nearby in the neighboring communities of Concord and Acton, as well as bus service from Bedford.

The town is governed by a five-member Select Board and a Town Administrator. The town operates under the open town meeting format. The Town Administrator, appointed by the Select Board, carries out the day-to-day governing functions of the town.

Carlisle was settled in 1650 and incorporated as a town in 1805. The town considers itself a rural community; Map 1 shows that the town has a low population density. There are no public water or sewer systems, these services are provided by private wells and on-site septic systems. Carlisle maintains a rich tradition in the preservation of open space and offers residents and visitors the beauty of Great Brook State Park, numerous hiking trails and open fields. Almost 20% of the town's 15 square miles is dedicated conservation land.

Carlisle is located within the Concord River portion of the Sudbury-Assabet-Concord River watershed. The Concord River forms the Town's eastern border with Bedford. The Concord River is buffered by the Great Meadow National Wildlife Refuge, which extends upstream to Concord.

Carlisle shares regional assets such as the Greater East Brook Woods (owned by Harvard University) and the Cranberry Bog Reservation with its neighbors.

Carlisle is a predominantly residential community. According to the US Census, 5,224 people live in Carlisle (2019 American Community Survey). Other features are summarized in Table 3.

**Table 3: Carlisle Demographic Characteristics**

**Population = 5,224 people**

- 2.9% are under age 5
- 19.4% are over age 65
- 6.8 % have a disability
- 3.8 % are over 65 with a disability
- 16.8% of householders are living alone
- 9.9% of householders are over 65 living alone
- 1.8% speak English less than very well
- 1.3% of households have no vehicle available
- Over 90% of the population is White

**Number of Housing Units = 2,029**

- 1,876 occupied housing units
- 10.3% of housing units were built before 1950
- 94.6% are owner-occupied housing units
- 5.4% are renter-occupied housing units

Source: 2019 American Community Survey

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

- Carlisle is a relatively small community in rural setting with very little commercial development yet is located within commuting distance to Boston.
- One third of the land is protected open space and the town is characterized by *extensive* forests and tree cover.
- There are no public water or sewer systems, and therefore no fire hydrants. All development depends upon *private* wells and septic systems. Cisterns and ponds store water used for firefighting.
- The town is characterized by low density housing on large lots of 2 to 4 acres.
- Common driveways are prevalent, with over 80 in town.
- The town is reliant on one supplier of electric power.
- The Town has a significant elderly population that is expected to increase in coming years.
- There are no hospitals in Carlisle – the closest are Emerson Hospital in Concord or the Lahey Clinic in Burlington.

The Town of Carlisle maintains a website at www.carlislema.gov

# SECTION 3 PLANNING PROCESS & PUBLIC PARTICIPATION

MAPC employs a six-step planning process based on FEMA's hazard mitigation planning guidance focusing on local needs and priorities but maintaining a regional perspective matched to the scale and nature of natural hazard events. Public participation is a central component of this process, providing critical information about the local occurrence of hazards while also serving as a means to build a base of support for hazard mitigation activities. MAPC supports participation by the general public and other plan stakeholders through two public meetings hosted by the Carlisle HMP/MVP Core Team, posting of the plan to the Town's website, and invitations sent to neighboring communities, town boards and commissions, and other local or regional entities to review the plan and provide comment.

## PLANNING PROCESS SUMMARY

The six-step planning process outlined in Figure 1 below is based on the guidance provided by FEMA's Local Multi-Hazard Mitigation Planning Guidance. Public participation is a central element of this process, which attempts to focus on local problem areas and identify needed mitigation measures based on where gaps occur in the existing mitigation efforts of the municipality. In plan updates, the process described below allows MAPC to bring the most recent hazard information into the plan, including new hazard occurrence data, changes to a municipality's existing mitigation measures, and progress made on actions identified in previous plans.

**Figure 1:Six-Step Planning Process**

1. **Map the Hazards** – MAPC relies on data from a number of different federal, state, and local sources in order to map the areas with the potential to experience natural hazards, including FEMA and the Northeast States Emergency Consortium (NESEC). This mapping represents a multi-hazard assessment of the municipality and is used as a set of base maps for the remainder of the planning process. A particularly important source of information is the knowledge drawn from local municipal staff on where natural hazard impacts have occurred. These maps can be found in Appendix A.

2. **Assess the Risks & Potential Damages** – Working with local staff, critical facilities, infrastructure, vulnerable populations, and other features are mapped and contrasted with the hazard data from the first step to identify those that might represent particular vulnerabilities to these hazards. Land use data and development trends are also incorporated into this analysis. In addition, MAPC develops estimates of the potential impacts of certain hazard events on the community. MAPC drew on the following resources to complete the plan:

    - General Bylaws for the Town of Carlisle
    - Zoning By-law for the Town of Carlisle
    - Town of Carlisle Open Space and Recreation Plan
    - Blue Hill Observatory
    - FEMA, Flood Insurance Rate Maps for Middlesex County, MA, 2013
    - FEMA, Hazards U.S. Multi-Hazard
    - FEMA, Local Mitigation Plan Review Guide, October 2011
    - Fourth National Climate Assessment, 2018
    - Massachusetts Flood Hazard Management Program
    - Massachusetts Office of Coastal Zone Management Shoreline Change Data
    - Massachusetts Office of Dam Safety, Inventory of Massachusetts Dams 2018
    - Massachusetts State Hazard Mitigation Plan, 2013
    - Massachusetts State Hazard Mitigation and Climate Adaptation Plan, 2018
    - Metropolitan Area Planning Council, GIS Lab, Regional Plans and Data
    - National Weather Service
    - Nevada Seismological Library
    - New England Seismic Network, Boston College Weston Observatory, http://aki.bc.edu/index.htm
    - NOAA National Centers for Environmental Information, http://www.ncdc.noaa.gov/
    - Northeast Climate Adaptation Science Center
    - Northeast States Emergency Consortium, http://www.nesec.org/
    - Tornado History Project
    - US Census, 2010 and American Community Survey 2019 5-Year Estimates
    - USDA Forest Service, Wildfire Risk to Communities, www.wildfirerisk.org
    - USGS, National Water Information System, http://nwis.waterdata.usgs.gov/usa/nwis

3. **Review Existing Mitigation** – Municipalities in the Boston Metropolitan Region have an active history in hazard mitigation as most have adopted flood plain zoning districts, wetlands protection programs, and other measures as well as enforcing the State building code, which has strong provisions related to hazard resistant building requirements. All current municipal mitigation measures are documented in the plan (Section 7).

4. **Develop Mitigation Strategies** – MAPC works with the local municipal staff to identify new mitigation measures, utilizing information gathered from the hazard identification, vulnerability assessments, and the community's existing mitigation efforts to determine where additional work is necessary to reduce the potential damages from hazard events. Additional information on the development of hazard mitigation strategies can be found in Section 8.

5. **Plan Approval & Adoption** – Once a final draft of the plan is complete it is sent to MEMA for the state level review and, following that, to FEMA for approval. Typically, once FEMA has approved the plan the agency issues a conditional approval (Approval Pending Adoption), with the condition being adoption of the plan by the municipality. More information on plan adoption can be found in Section 9 and documentation of plan adoption can be found in Appendix D.

6. **Implement & Update the Plan** – Implementation is the final and most important part of any planning process. Hazard Mitigation Plans must also be updated on a five-year basis making preparation for the next plan update an important on-going activity. Section 9 includes more detailed information on plan implementation.

## 2012 PLAN IMPLEMENTATION AND MAINTENANCE

The 2012 Town of Carlisle Hazard Mitigation Plan contained a risk assessment of identified hazards for the Town and mitigation measures to address the risk and vulnerability from these hazards. Since approval of the plan by FEMA, progress has been made on incorporation of hazard mitigation into other town plans and policies. In 2014 the town amended its floodplain zoning overlay district to be consistent with revisions to the FEMA Flood Insurance Rate Maps for Middlesex County, MA. The Planning Board adopted regulations that include fire safety provisions, and the Town implemented an enhanced tree management program in coordination with NSTAR. In 2020, the Town conducted a Municipal Vulnerability Preparedness project in close coordination with this Hazard Mitigation Plan update. Both projects were overseen by the Carlisle MVP/HMP Core Team. The Town also advanced several projects for implementation, including plans for a $750,000 dam repair/upgrade for the Greenough Pond Dam, installation of a generator in the school, and upgrading emergency communications.

## THE HAZARD MITIGATION PLANNING AND MVP CORE TEAM

MAPC worked with community representatives to convene a Carlisle HMP/MVP Core Team. Since the Town conducted a Municipal Vulnerability Preparedness project concurrently with this plan update, both projects were coordinated by the Carlisle HMP/MVP Core Team. MAPC briefed the local representatives as to the desired composition of that team as well as the need for public participation in the local planning process.

The Carlisle HMP/MVP Core Team is central to the planning process as it is the primary body tasked with developing a mitigation strategy for the community. The local team was tasked with working with MAPC to set plan goals, provide information on the hazards that impact the town, existing mitigation measures, and helping to develop new mitigation measures for this plan update. The HMP/MVP Core Team membership can be found in Table 4.

**Table 4: Carlisle HMP/MVP Core Team Members**

| Name | Title |
|---|---|
| Madeleine Blake | Co-chair, Carlisle Planning Board; MVP Core Team Coordinator |
| Gary Davis | Carlisle DPW Supervisor |
| Rosemary Duda, MD | Community Volunteer |
| Linda Fantasia | Health Agent |
| John Golis | Community Volunteer |
| Steve Hinton | Municipal Facilities Committee, Open Space Committee |
| Navneet Hundal, MD | Conservation Commission board member |
| Sylvia Willard | Conservation Administrator |

The Carlisle Planning Board and Conservation Commission are the primary entities responsible for regulating development in town. Feedback from the Planning Board and the Conservation Commission was assured through the participation on the MVP/HMP Core Team of a Co-Chair of the Planning Board, who also served as chair of the local team, s well as a member of the Conservation Commission and the Town's Conservation Administrator. In addition, MAPC, the State-designated regional planning authority for Carlisle, works with all agencies that regulate development in the region, including the listed municipal entities and state agencies, such as the MassDOT (which includes MassHighway and MBTA) and the Department of Conservation and Recreation (responsible for open space and dams). This involvement ensured that during the development of the Carlisle Hazard Mitigation Plan, the operational policies and any mitigation strategies or identified hazards from these entities were considered.

The Carlisle HMP/MVP Core Team met on the following four dates: November 18, 2020, January 6, 2021, March 16, 2021, and May 26, 2021. The purpose of the meetings was to introduce the FEMA Hazard Mitigation planning program and the Municipal Vulnerability Preparedness project, gather information on local hazard mitigation issues and sites or areas related to these. The team also coordinated the Community Resilience Building Workshop held on March 27, 2021. Earlier Core Team meetings focused on preparation for that event. Later meetings focused on verifying information gathered by MAPC staff for the Hazard Mitigation Plan, updating existing mitigation practices, reviewing the status of mitigation measures recommended in the Carlisle 2012 Hazard Mitigation Plan, and developing new or revised recommended mitigation measures for this plan update. The agendas for these meetings are included in Appendix B.

## PUBLIC MEETINGS

Public participation in the hazard mitigation planning process is important, both for plan development and for later implementation of the plan. Residents, business owners, and other community members are an excellent source for information on the historic and potential impacts

of natural hazard events and particular vulnerabilities the community may face from these hazards. Their participation in this planning process also builds understanding of the concept of hazard mitigation, potentially creating support for mitigation actions taken in the future to implement the plan.

To gather this information and educate residents on hazard mitigation, the Town held two public meetings, one hosted by the Select Board on February 9, 2021, during the planning process, and one held on June 16, 2021, when the draft plan update was available for review.

In addition to the two public meetings, Carlisle held a Municipal Vulnerability Preparedness workshop attended by 38 people, including town staff, board and committee members, representatives of local businesses, farms, and community organizations, and state legislators. The workshop focused on climate impacts on infrastructure, natural resources, and society. The priority actions identified at the workshop are presented in Appendix E.

The public had an opportunity to provide input to the Carlisle hazard mitigation planning process during a public meeting held remotely via Zoom by the Carlisle Select Board on February 9, 2021. The draft plan update was presented at a remote public meeting via Zoom on June 16, 2021in conjunction with a public listening session on the Community Resilience Building workshop. Both meetings were publicized in accordance with the Massachusetts Public Meeting Law. The meeting announcements, press advisories, meeting agendas, and press coverage for the public meetings can be found in Appendix C.

## LOCAL STAKEHOLDER INVOLVEMENT

The Carlisle HMP/MVP Core Team was encouraged to reach out to local stakeholders that might have an interest in the Hazard Mitigation Plan including neighboring communities, agencies, businesses, nonprofits, and other interested parties. Notice was sent to the following organizations and neighboring municipalities inviting them to attend the public meeting to review the Hazard Mitigation Plan and submit comments to the Town:

- Abode Energy Management
- Carlisle Planning Board Chair
- Carlisle Conservation Administrator
- Carlisle Council on Aging
- Carlisle Dept of Public Works
- Carlisle Land Stewardship Committee
- Carlisle Neighbor Response Team
- Carlisle Fire Chief
- Carlisle Municipal Facilities
- Carlisle Historic Commission, Co-chair
- Carlisle Conservation Commission
- Carlisle School Dept
- Carlisle Heath Agent
- Carlisle Energy Task Force
- Carlisle Conservation Foundation
- Conservation Restriction Advisory Committee
- Carlisle Trails and OS&R Planning Committees
- Clark Farm
- Great Brook Farm
- Great Meadows National Wildlife Refuge
- Holy Family and St. Irene Parishes

- Massachusetts Audubon Society
- MVP Program Coordinator, Northeast Reg.
- Sudbury Valley trustees
- Town of Acton
- Bedford
- Town of Billerica
- Town of Chelmsford
- Town of Concord
- Town of Westford

See Appendix C for public meeting notices. The draft *Carlisle Hazard Mitigation Plan 2021 Update* was posted on the Town's website for the second public meeting on June 16, 2021. Members of the public could access the draft plan and submit comments or questions to the Town.

## PUBLIC COMMENT

In the MVP workshop that took place on March 27, 2021, town stakeholders developed a robust list of priorities to increase resilience to climate-related natural hazards. Participants in the Listening Session/HMP public meeting on June 16, 2021had an opportunity to comment on the draft Hazard Mitigation Plan 2021 Update as well as the Community Resilience Building Workshop recommendations. Both documents were available on the Town website for public review and comment.

## CONTINUING PUBLIC PARTICIPATION

Following the adoption of the 2021 plan update, the Carlisle HMP/MVP Core Team will continue to provide residents, businesses, and other stakeholders the opportunity to learn about the hazard mitigation planning process and to contribute information that will update the town's understanding of local hazards. As updates and a review of the plan are conducted by the HMP/MVP Core Team, these will be placed on the Town's web site, and any meetings of the HMP/MVP Core Team will be publicly noticed in accordance with state open meeting laws.

## PLANNING TIMELINE

| | |
|---|---|
| November 18, 2020 | Meeting#1 of the Carlisle Hazard Mitigation and MVP Core Planning Team |
| January 6, 2021 | Meeting#2 of the Carlisle Hazard Mitigation and MVP Core Planning Team |
| February 9, 2021 | First Public Meeting hosted by the Carlisle Select Board (Virtually) |
| March 27, 2021 | Community Resilience Building Workshop (MVP project) |
| March 16, 2021 | Meeting#3 of the Carlisle Hazard Mitigation and MVP Core Planning Team |
| May 26, 2021 | Meeting#4 of the Carlisle Hazard Mitigation and MVP Core Team (Virtually) |
| June 16, 2021 | MVP Listening Session and Hazard Mitigation Plan Public Meeting (Virtually) |
| June 29, 2021 | Draft *Carlisle Hazard Mitigation Plan 2021 Update* submitted to MEMA |
| November 4, 2021 | Revised *Draft Carlisle Hazard Mitigation Plan 2021 Update* submitted to MEMA |
| November 11, 2021 | Notice of plan Approvable Pending Adoption sent by FEMA [TBD] |
| November 23, 2021 | Final Plan Adopted by the Carlisle Select Board [TBD} |
| TBD | FEMA final approval of the Plan for 5 years, until [TBD] |

## POST-PLAN APPROVAL IMPLEMENTATION TIMELINE

After the plan has been approved by FEMA, the Town will observe the following timeline to implement the plan over the five-year approval period and prepare for the next plan update.

If the Town wishes to apply for a FEMA grant to prepare the next plan update, due in 2026, a grant application should be submitted approximately two years before this plan expires, in order to allow time for the grant to be approved, and the next plan update to be completed before this plan expires. See Section 9 for more details on plan adoption and maintenance.

| | |
|---|---|
| 2023 | Conduct Mid-Term Plan Survey on Progress |
| 2023 | Seek FEMA grant to prepare next plan update |
| 2024 | Begin process to update the plan |
| 2025 | Submit Draft 2025 Plan Update to MEMA and FEMA |
| 2025 | FEMA approval of 2025 Plan Update |

# SECTION 4: RISK ASSESSMENT

The risk assessment analyzes the potential natural hazards that could occur within the Town of Carlisle as well as the relationship between those hazards and current land uses, potential future development, and critical infrastructure. This section also includes a vulnerability assessment that estimates the potential damages that could result from certain large-scale natural hazard events. In order to update Carlisle' risk assessment, MAPC gathered the most recently available hazard and land use data and met with Town staff to identify changes in local hazard areas and development trends. MAPC also used FEMA's damage estimation software, HAZUS.

In this 2021 plan update, the projected impacts of our warming climate on natural hazards are integrated throughout the risk assessment. Key impacts include rising temperatures, which in turn affect precipitation patterns, sea level, and extreme weather.

> *"Global climate is changing rapidly compared to the pace of natural variations in climate that have occurred throughout Earth's history. Global average temperature has increased by about 1.8°F from 1901 to 2016, and observational evidence does not support any credible natural explanations for this amount of warming; instead, the evidence consistently points to human activities, especially emissions of greenhouse or heat-trapping gases, as the dominant cause."*
>
> *Fourth National Climate Assessment, 2018 (Chapter 2-1)*

Climate Change Observations and Projections

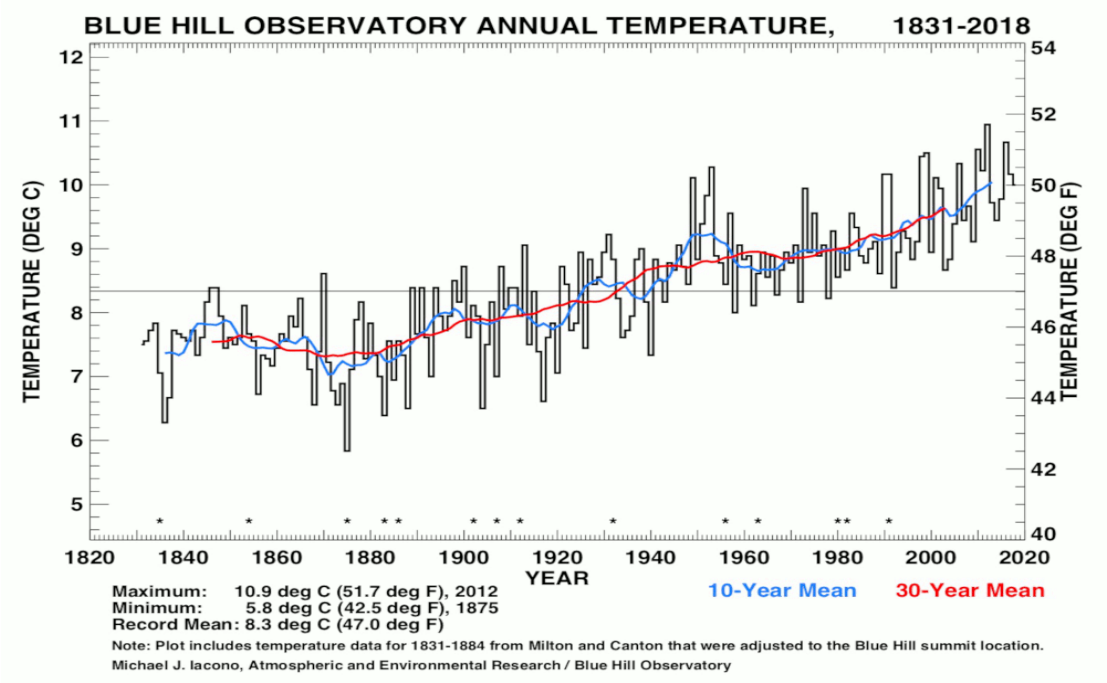
Climate change observations come from a variety of data sources that have measured and recorded changes in recent decades and centuries. Climate change projections, however, predict future climate impacts and by their nature cannot be observed or measured. As a result of the inherent uncertainty in predicting future conditions, climate projections are generally expressed as a range of possible impacts.

Temperature

Our climate has always been regulated by gases, including carbon dioxide, methane, and nitrous oxide, that blanket the earth. These gases trap heat that would otherwise be reflected out to space; without them our planet would be too cold to support life. We refer to these gases as "greenhouse gases" (GHGs) for their heat trapping capacity. The combustion of fossil fuels, our primary energy source in the age of industrialization, releases GHGs into the atmosphere. In the past century, human activity associated with industrialization has contributed to a growing concentration of GHGs in our atmosphere.

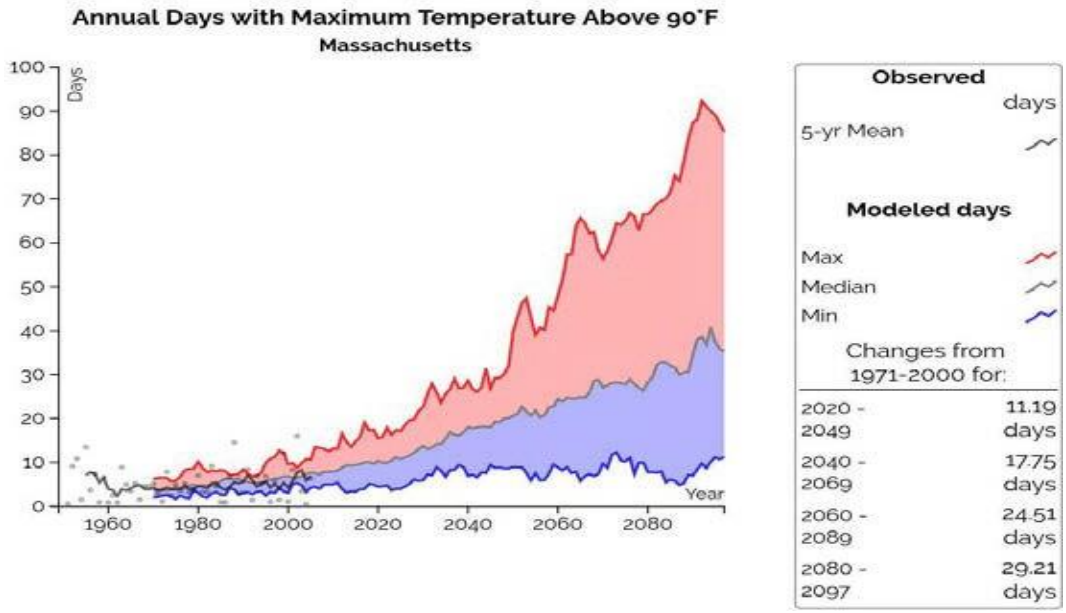
Records from the Blue Hill Observatory in Milton, MA show that average temperatures (30-year mean) have risen approximately 3 degrees (F) in the almost 200 years since record keeping began in 1831(Figure 2).

**Figure 2: Observed Increase in Temperature**




Climate projections include an increase in average temperature and in the number of extreme heat days. Extreme cold days are projected to decrease in number. The Northeast Climate Adaptation Science Center (NECASC) projects average temperatures in Massachusetts will increase by 5 degrees F by mid-century and nearly 7 degrees F by the end of the century. Figure 3 shows the NECASC projections for increases in the number of days over 90 degrees annually.

**Figure 3: Projected Increase in Annual Days Over 90 Degrees F**

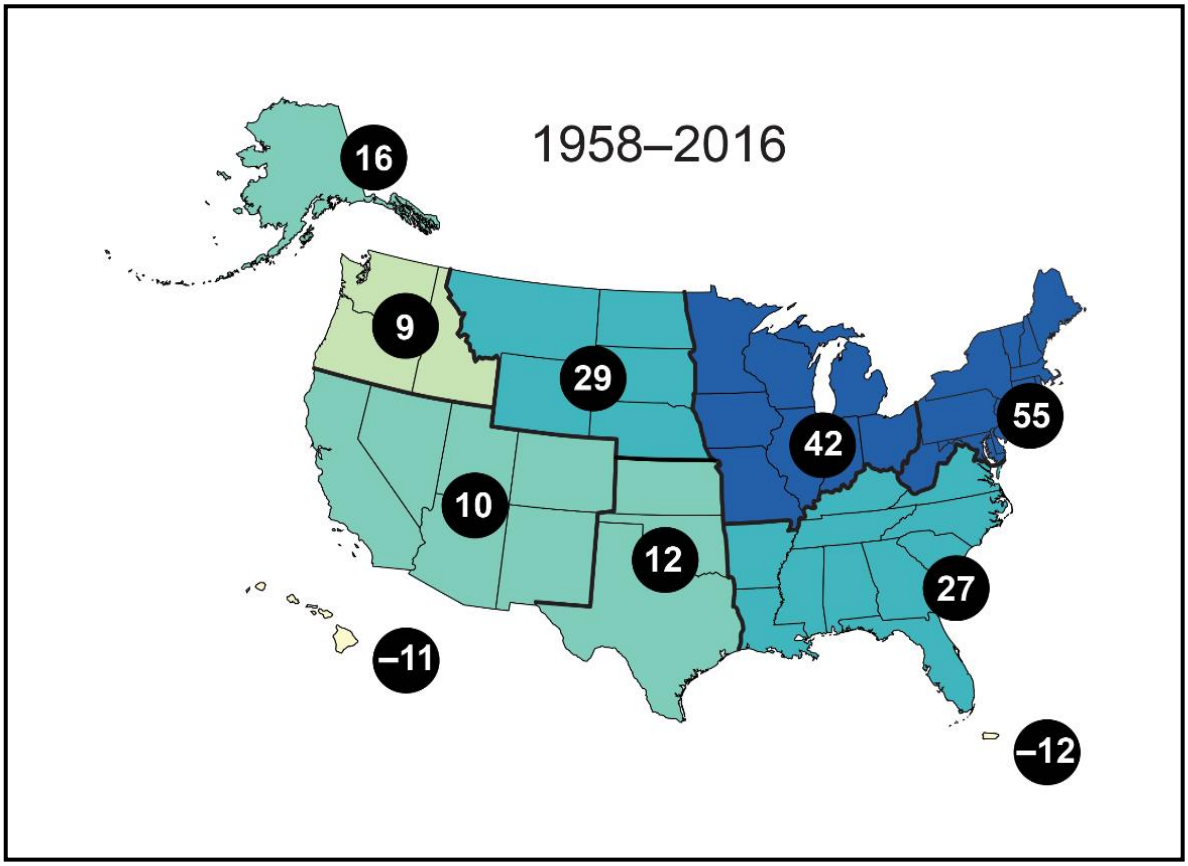



Source: Northeast Climate Adaptation Science Center

Precipitation Patterns

Annual precipitation in Massachusetts has increased by approximately 10% in the fifty-year period from 1960 to 2010 (MA Climate Adaptation Report, 2011). Moreover, there has been a significant increase in the frequency and intensity of large rain events. For the Northeast US, according to the Fourth National Climate Assessment 2018, in the past sixty years there has been a 55% increase in the amount of annual precipitation that falls in the top 1% of storm events (Figure 4). Changes in precipitation are fueled by warming temperatures which increase evaporation and, therefore, the amount of water vapor in the air.

**Figure 4:Observed Change in Total Annual Precipitation Falling in the Heaviest 1% of Events**



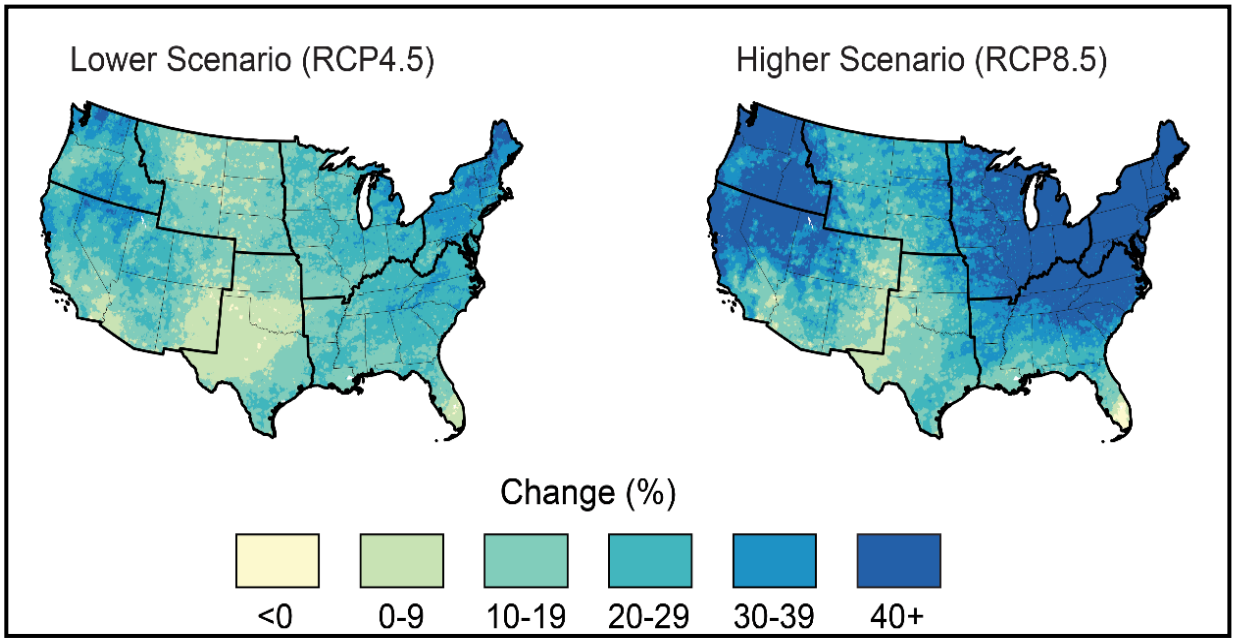

Circled numbers indicate % change.

Source: Fourth National Climate Assessment, 2018

Total annual precipitation in Massachusetts is projected to increase by 1 to 6 inches by mid-century, and by 1.2 to 7.3 inches by the end of this century (SHMCAP p. 2-22). The Fourth National Climate Assessment predicts that the pattern of increasing frequency and intensity of extreme rain events will continue. They project by 2070 to 2099, (relative to 1986 to 2015) a 30-40% increase in total annual precipitation falling in the heaviest 1% of rain events (Figure 5).

Despite overall increasing precipitation, more frequent and significant summer droughts are also a projected consequence of climate change. This is due to projections that precipitation will increase in winter and spring and decrease slightly in the summer and, a result of earlier snow melt, and higher temperatures that will reduce soil moisture.

**Figure 5: Projected Change in Total Annual Precipitation Falling in the Heaviest of 1% of Events for 2070-2099**




Source: Fourth National Climate Assessment, 2018

Sea Level Rise

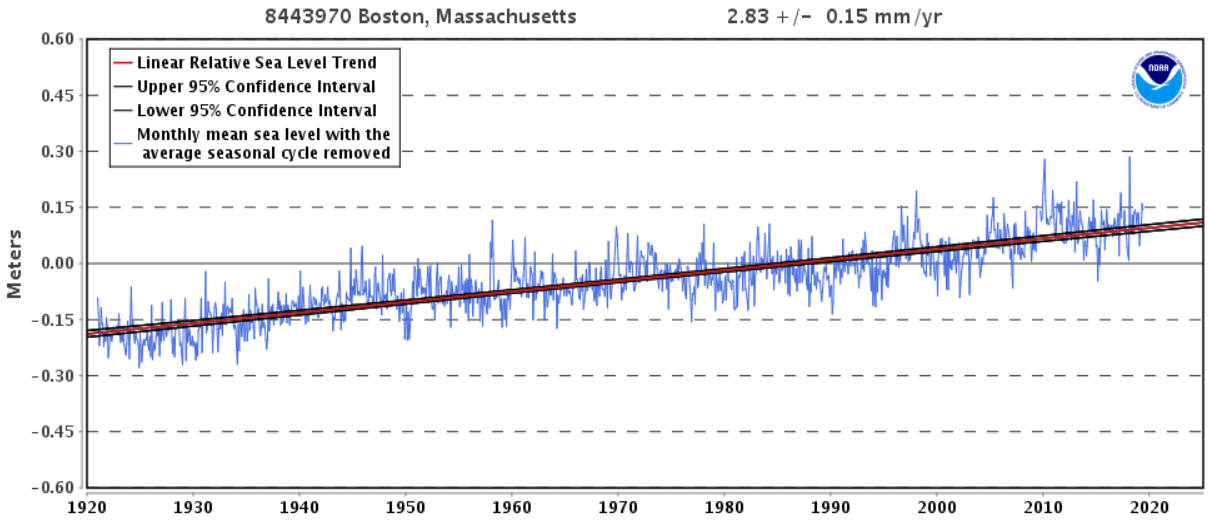
Although Carlisle is not a coastal community, information on sea level rise is included in the plan as some Carlisle residents may have jobs in Boston or other coastal communities, and the greater metropolitan regional economy may be impacted by sea level rise in the future.

Records from the Boston Tide Station show nearly one foot of sea level rise in the past century (Figure 6). Warming temperatures contribute to sea level rise in two ways. First, warm water expands to take up more space. Second, rising temperatures are melting land-based ice which enters the oceans as melt water. A third, quite minor, contributor to sea level rise in New England is not related to climate change. New England is still experiencing a small amount of land subsidence (drop in elevation) in response to the last glacial period.

Projections of sea level rise through 2100 vary significantly depending on future greenhouse gas emissions and melting of land-based glaciers. Currently sea levels are rising at an increasing rate. Figure 7 shows projections for the current rate of sea level rise, as well as for lower and higher greenhouse gas emission scenarios and a higher scenario with greater ice melt. Projections for

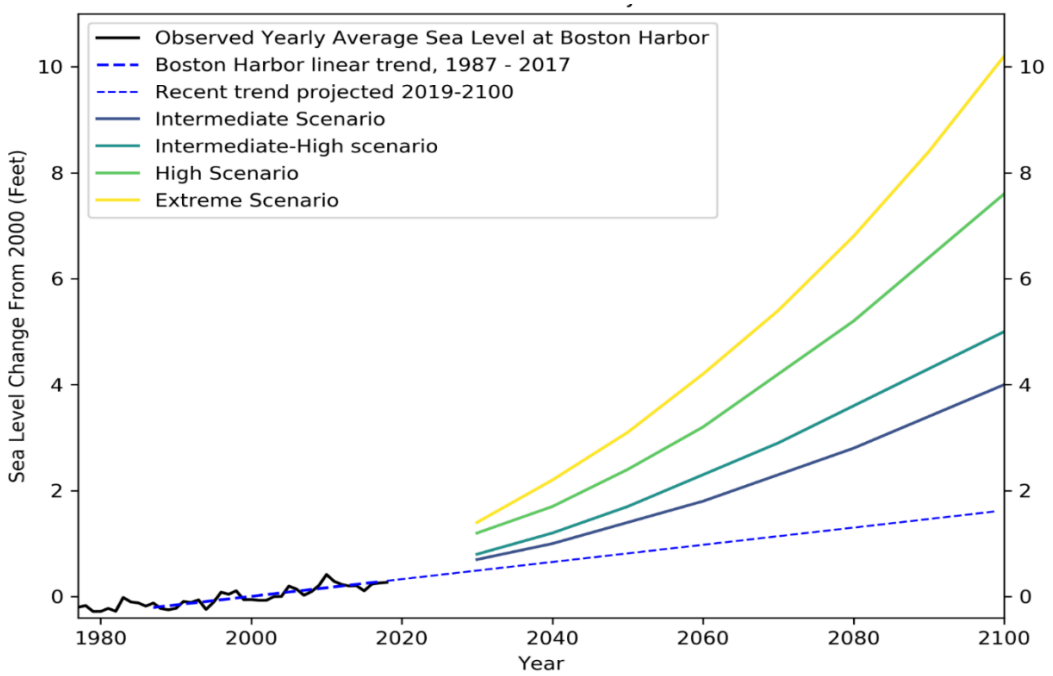
2100 range from 2 feet to 5 feet, to almost 9 feet for the most extreme scenario. However, by 2050 all of the scenarios suggest roughly one foot of sea level rise above the year 2000.

**Figure 6:Observed Increase in Sea Level Rise**




Source: NOAA

**Figure 7: Recent and Projected Increase in Sea Level Rise**

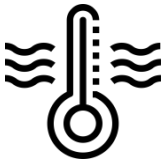



Source: Adapted from the Northeast Climate Adaptation Center data

Following the general outline of the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, this local hazard mitigation plan organizes consideration of natural hazards based on their relationship to projected climate changes. The one exception is that where coastal

and inland flooding are interrelated, they will be considered together. Table 5 below, from the SHMCAP, summarizes the natural hazards reviewed in this plan, climate interactions, and expected impacts.

**Table 5: Climate Change and Natural Hazards**

| Primary Climate Change Interaction | Natural Hazard | Other Climate Change Interactions | Representative Climate Change Impacts |
|---|---|---|---|
|  **Changes in Precipitation** | Inland Flooding | Extreme Weather | Flash flooding, urban flooding, drainage system impacts (natural and human-made), lack of groundwater recharge, impacts to drinking water supply, public health impacts from mold and worsened indoor air quality, vector-borne diseases from stagnant water, episodic drought, changes in snow-rain ratios, changes in extent and duration of snow cover, degradation of stream channels and wetland. Increased wildfire risk due to droughts. |
| | Drought | Rising Temperatures, Extreme Weather | |
| | Landslide | Rising Temperatures, Extreme Weather | |
|  **Sea Level Rise** | Coastal Flooding | Extreme Weather | Increase in tidal and coastal floods, storm surge, coastal erosion, marsh migration, inundation of coastal and marine ecosystems, loss, and subsidence of wetlands |
| | Coastal Erosion | Changes in Precipitation, Extreme Precipitation | |
| | Tsunami | Rising Temperatures | |
|  **Rising Temperatures** | Average/Extreme Temperatures | N/A | Shifting in seasons (longer summer, early spring, earlier timing of spring peak flow), increase in length of growing season, increase of invasive species, ecosystem stress, energy brownouts from higher energy demands, more intense heat waves, public health impacts from high heat exposure and poor outdoor air quality, drying of streams and wetlands, eutrophication of lakes and ponds |
| | Wildfires | Changes in Precipitation | |
| | Invasive Species | Changes in Precipitation, Extreme Weather | |
|  **Extreme Weather** | Hurricanes/Tropical Storms | Rising Temperatures, Changes in Precipitation | Increase in frequency and intensity of extreme weather events, resulting in greater damage to natural resources, property, and infrastructure, as well as increased potential for loss of life |
| | Severe Winter Storm / Nor'easter | Rising Temperatures, Changes in Precipitation | |
| | Tornadoes | Rising Temperatures, Changes in Precipitation | |
| | Other Severe Weather (Including Strong Wind and Extreme Precipitation) | Rising Temperatures, Changes in Precipitation | |
| **Non-Climate-Influenced Hazards** | Earthquake | Not Applicable | There is no established correlation between climate change and this hazard |

## OVERVIEW OF HAZARDS AND IMPACTS

Table 6 summarizes the hazard risks for the state and the Town of Carlisle. This evaluation takes into account the frequency of the hazard, historical records such as the National Climatic Data Center data for Middlesex County, the Carlisle HMP/MVP Core Team, and variations in geography and local climate. The statewide assessment was modified to reflect local conditions in Carlisle using the definitions for hazard frequency and severity listed below.

### Table 6: Hazards Risk Summary

| Hazard | Frequency | | Severity | |
|---|---|---|---|---|
| | Massachusetts | Carlisle | Massachusetts | Carlisle |
| Inland Flooding | High | High | Serious | Serious |
| Drought | Medium | Medium | Minor | Minor |
| Landslides | Low | Very Low | Minor | Minor |
| Coastal Flooding | High | N/A | Serious | N/A |
| Coastal Erosion | Highly variable | N/A | Serious | N/A |
| Tsunami | Very Low | N/A | Extensive | N/A |
| Extreme Temperatures | High | High | Minor | Minor |
| Wildfires | High | High | Minor | Serious |
| Hurricane/Tropical Storm | Medium | Medium | Serious | Serious |
| Severe Winter Storms/Nor'easters | High | High | Extensive | Serious |
| Tornadoes | Medium | Very Low | Serious | Serious |
| Severe Weather Thunderstorms/Winds | High | High | Minor | Minor |
| Earthquake | Very Low | Very Low | Extensive | Extensive |

**Frequency**

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

It should be noted that several of the hazards listed in the 2018 Massachusetts State Hazard Mitigation plan are not applicable to the Town of Carlisle, as follows:

- **Coastal Flooding, Coastal Erosion, and Tsunami** are not applicable to Carlisle since is not a coastal community
  .
- **Ice jams** are not a hazard in Carlisle. The US Army Corps Ice Jam Database shows no record of ice jams in Carlisle, and the Town did not identify this as an issue of concern.

## FLOOD-RELATED HAZARDS

Flooding was one of the most prevalent natural hazards identified by local officials in Carlisle. The town is subject to two kinds of flooding, riverine flooding, generally within FEMA designated flood hazard areas, and localized flooding caused by stormwater drainage problems, which is not necessarily located within FEMA flood hazard areas.

Both kinds of flooding are generally caused by severe rainstorms, thunderstorms, Nor'easters, and hurricanes. Spring snowmelt may exacerbate flooding during storm events. Nor'easters are most common in winter. Hurricanes are most common in the summer and early fall, as are thunderstorms.

In addition to the Concord River in the east, the town's three major waterways are Spencer Brook, Page's Brook, and the River Meadow (Great) Brook. Floodplains in the town generally border these major waterbodies, as well as tributary streams, low-lying areas, and ponds formed naturally and from man-made dams. Carlisle is in an area of extensive wetland areas, resulting in a moderate risk of flooding. However, Carlisle also has extensive conservation land, large lot zoning, and strict land use controls that minimize development and impervious area that might otherwise exacerbate any flooding.

Flooding in Carlisle is occasional, with most flooding caused by proximity to waterways or floodplain, and due to beaver activity. The terrain may cause occasional street flooding as well as undersized or outdated drainage infrastructure. Damage is generally property-related and consists of flooded lawns, basements, farms, and roads.

Carlisle has no town water and no municipal sewerage, so all residences rely on wells and septic. In some cases, flooding of septic systems may be a concern.

### Regionally Significant Storms

There have been a number of major rainstorms that have resulted in significant flooding in northeastern Massachusetts over the last fifty years. Significant storms include:

- March 1968
- January 1979
- April 1987
- October 1991
- October 1996
- June 1998
- March 2001
- April 2004
- May 2006
- April 2007
- March 2010
- March 2013
- January 2018
- March 2018

The best available local data on previous flooding events are for Middlesex County through the National Centers for Environmental Information. Middlesex County experienced 48 flood events from 2010 to 2020 (see Table 7). There were no deaths or injuries reported and the total reported property damage in the county was over $42 million dollars. The March 2010 storms account for $35.2 million of those total damages from 2010 to 2020.

The impacts of flooding on the Town of Carlisle are not quite as severe as many neighboring communities, but still may be locally significant. Potential damages from flooding in the town were estimated using FEMA's HAZUS-MH program. The results, shown in Table 36, indicate potential damages from a 1% Annual Chance Flood (100-year) at $2.8 million and from a 0.2% Annual Chance Flood (500-year) at $3.6 million. Localized areas of flood vulnerability are listed below.

**Table 7: Middlesex County Flood Events, 2010- 2020**

| Date | Deaths | Injuries | Property Damage ($) |
|---|---|---|---|
| 3/14/2010 | 0 | 0 | 26,430,000 |
| 3/29/2010 | 0 | 0 | 8,810,000 |
| 4/1/2010 | 0 | 0 | 0 |
| 8/28/2011 | 0 | 0 | 5,000 |
| 10/14/2011 | 0 | 0 | 0 |
| 6/8/2012 | 0 | 0 | 0 |
| 6/23/2012 | 0 | 0 | 15,000 |
| 7/18/2012 | 0 | 0 | 5,000 |
| 10/29/2012 | 0 | 0 | 0 |
| 6/7/2013 | 0 | 0 | 0 |
| 7/1/2013 | 0 | 0 | 0 |
| 7/23/2013 | 0 | 0 | 0 |
| 9/1/2013 | 0 | 0 | 10,000 |
| 3/30/2014 | 0 | 0 | 35,000 |
| 7/27/2014 | 0 | 0 | 0 |
| 8/31/2014 | 0 | 0 | 0 |
| 10/22/2014 | 0 | 0 | 20,000 |
| 10/23/2014 | 0 | 0 | 0 |
| 12/9/2014 | 0 | 0 | 5,000 |
| 12/9/2014 | 0 | 0 | 30,000 |
| 5/31/2015 | 0 | 0 | 0 |
| 8/4/2015 | 0 | 0 | 0 |
| 8/15/2015 | 0 | 0 | 125,000 |
| 9/30/2015 | 0 | 0 | 0 |
| 4/6/2017 | 0 | 0 | 0 |
| 6/27/2017 | 0 | 0 | 1,000 |

| Date | Deaths | Injuries | Property Damage ($) |
|---|---|---|---|
| 7/12/2017 | 0 | 0 | 1,000,000 |
| 7/18/17 | 0 | 0 | 0 |
| 8/2/2017 | 0 | 0 | 5,000 |
| 10/25/17 | 0 | 0 | 0 |
| 10/30/2017 | 0 | 0 | 0 |
| 1/12/2018 | 0 | 0 | 0 |
| 1/13/2018 | 0 | 0 | 0 |
| 4/16/2018 | 0 | 0 | 0 |
| 6/25/2018 | 0 | 0 | 15,000 |
| 8/8/2018 | 0 | 0 | 35,000 |
| 8/12/2018 | 0 | 0 | 30,000 |
| 8/17/2018 | 0 | 0 | 0 |
| 10/29/2018 | 0 | 0 | 0 |
| 11/3/2018 | 0 | 0 | 0 |
| 11/10/2018 | 0 | 0 | 0 |
| 7/6/2019 | 0 | 0 | 0 |
| 8/07/19 | 0 | 0 | 0 |
| 9/2/2019 | 0 | 0 | 300 |
| 6/21/20 | 0 | 0 | 0 |
| 6/28/20 | 0 | 0 | 5,000 |
| 7/23/20 | 0 | 0 | 0 |
| 9/10/20 | 0 | 0 | 3,000 |
| **TOTAL** | **0** | **0** | **$42,049,300** |

Source: NOAA, National Environmental Information Center

Based on the record of previous occurrences flooding events in Carlisle are a high frequency event as defined by the Massachusetts State Hazard Mitigation Plan. This hazard may occur more frequently than once in five years, or a greater than 20% chance per year.

## LOCALLY IDENTIFIED AREAS OF FLOODING

Information on potential flood hazard areas was taken from two sources. The first was the National Flood Insurance Rate Maps. The FIRM flood zones are shown on Map 3 in Appendix A. The "Locally Identified Areas of Flooding" listed below were identified and mapped by the Carlisle HMP/MVP Core Team as areas where local flooding is known to occur. These areas do not necessarily coincide with the flood zones from the FIRM maps. Flood sources may include inadequate drainage systems, undersized culverts, beaver activity, high groundwater, or other local conditions. These sites are shown in Table 8. The site numbers correspond to the numbers on Map 8, "Local Hazard Areas."

Carlisle's Public Works Director provided more detail on localized drainage and flooding issues. He noted that none of the culverts are in worse shape than others. There are beaver problems around Maple and Brook streets. They are now using a device called a Beaver Deceiver, which works well. A few years ago, they replaced one of the culverts on Brook Street, and the pipe is now set a little lower. This may have been done to take wildlife crossings into consideration. At least two residents on Brook Street have issues in heavy rain, where their yards flood.

### Table 8: Carlisle Locally Identified Areas of Flooding

| | |
|---|---|
| 1 | Acton Street |
| 2 | Baldwin Road |
| 3 | Bedford Road |
| 4 | Brook Street |
| 5 | Carlton Road |
| 6 | Church Street |
| 7 | East Street |
| 8 | Fiske Street |
| 9 | Lowell Street |
| 10 | Meadowbrook Road |

| | |
|---|---|
| 11 | Milne Cove Road |
| 12 | North Road |
| 13 | River Road |
| 15 | South Street |
| 16 | Sunset Road |
| 17 | Tophet Road |
| 18 | Route 225 (Westford Road) |
| 19 | Center Circle |

| | |
|---|---|
| 22 | Culvert backup where small brook runs under road |
| 23 | Culvert backup where small brook runs under road |
| 24 | Double culvert ""blowout"" in past events |
| 26 | Brook has washed out dirt road |

The DPW Director emphasized that culverts in a particular area are all connected. One of them could not be enlarged without enlarging all the ones along that stream. To enlarge only one would cause problems downstream. In Carlisle there are many small culverts, but no big ones.

The most local flooding occurs from East Street through the Tophet Swamp, then to Brook Street, then to the Concord River. The worst flooding is on East Street, although this usually lasts only a few days. This is all one watershed/drainage basin. If all of these culverts were enlarged, more water would be discharged into the Concord River.

There is a new system now on Russell Street. There used to be beavers at this location, but they don't seem to be there anymore. This new system seems to be working well.

With heavy rains, there are washouts on some roads. One problem is that the catch basins get clogged due to storms, wind, and rain. When they are clogged, they don't drain well.

**Repetitive Loss Structures**

As defined by FEMA, a repetitive loss property is a NFIP-insured structure that has had two or more paid flood losses of $1,000 or more in any given 10-year period since 1978.

According to FEMA records, there are no repetitive loss structures in Carlisle. For more information on repetitive losses see https://www.fema.gov/txt/rebuild/repetitive_loss_faqs.txt and https://www.fema.gov/repetitive-flood-claims-grant-program-fact-sheet.

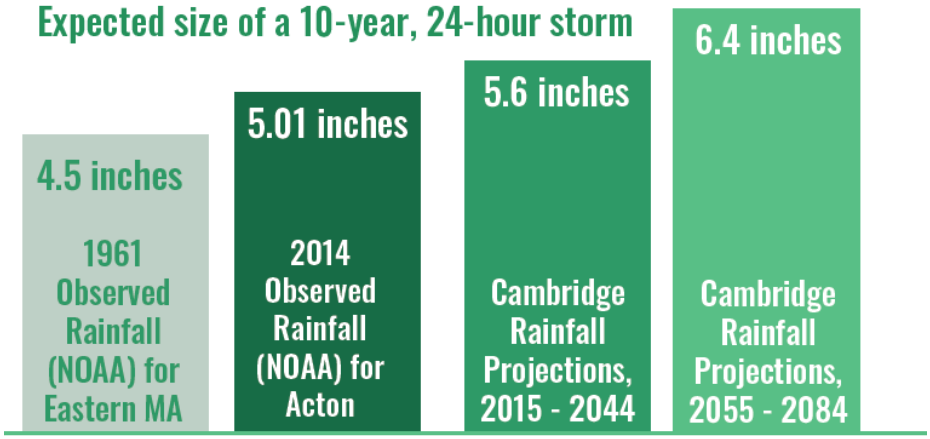
## FLOODING AND CLIMATE CHANGE

Due to climate change, scientists project an increase in severity and frequency of precipitation events. Because of its location in the Concord River watershed, extreme precipitation events and changing precipitation patterns could increase the frequency and severity of flooding in Carlisle. Annual precipitation in Massachusetts has already increased by approximately 10% in the fifty-year period from 1960 to 2010 (MA Climate Change Adaptation Report 2011). Moreover, for

the Northeast US, according to the U.S. National Climate Assessment, 2014, there was a 71% increase in the amount of rain that falls in the top 1% of storm events for the period 1958-2012.

Precipitation frequency estimates, which are used to derive stormwater design standards, were published in 196l by the U.S. Commerce Department in a document known as TP-40 (Technical Paper 40). The 10-year, 24-hour storm for eastern Massachusetts was calculated as a 4.5-inch event. Recently the National Oceanic and Atmospheric Administration published updated estimates (NOAA Atlas 14), which increased this design storm by 0.5 inch to 5.01 inches. In the future, based on projections developed for the City of Cambridge, the region will likely experience more frequent and intense precipitation events, including an increase in the standard "design storm" from historic levels of 4.5 inches to 6.4 inches by the late 21st century (Figure 8). According to data on ResilientMA.org, by mid- to late century, the region can anticipate 9-108 days with precipitation events with greater than one inch of rain, and an increase in total annual precipitation from 46 to 50 inches.

**Figure 8: Design Storm Trends and Projections for the 10-year, 24-hour Storm**



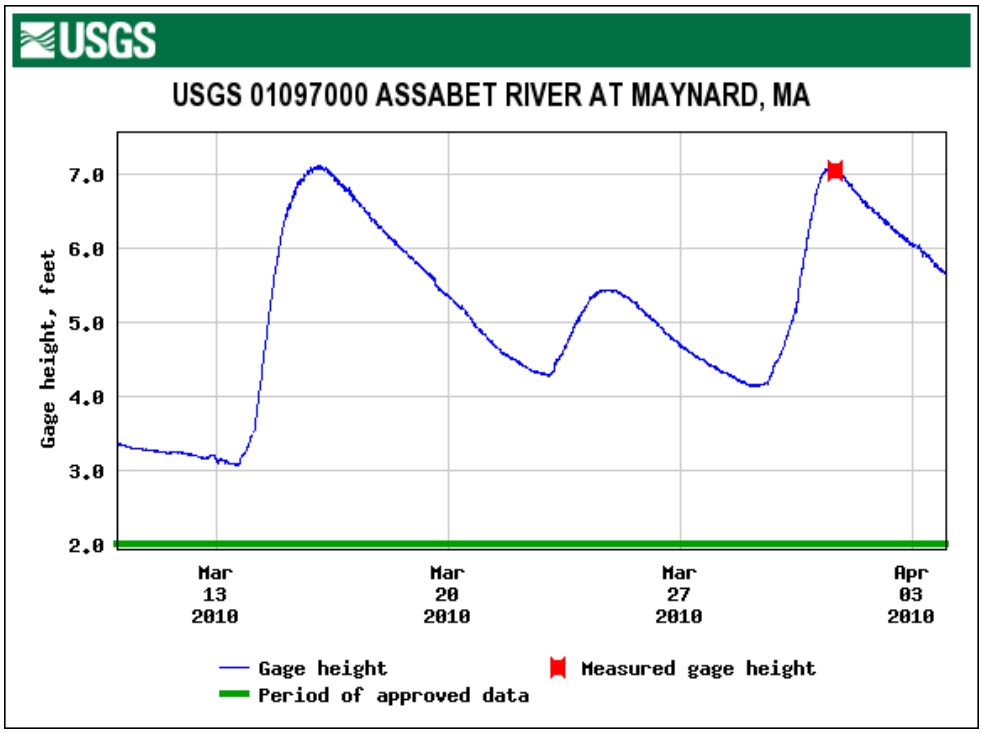

Sources: NOAA; Cambridge Climate Vulnerability Assessment. Part 1. April 2017

The March 2010 rainstorms in Massachusetts fit the profile of a type of event expected to increase in frequency as the climate warms. That is, significant precipitation, falling in late winter, on frozen ground, as rain rather than snow. The Blue Hill Observatory in Milton recorded 17.7 inches of rain from three storms in the 19 days from March 13 to 31. As shown in the USGS Assabet River gage, the closest gage to Carlisle, river levels surged with each storm (Figure 9). The river's level peaked at 7.0 feet after the first storm on March 13, and again at 7.0 feet after the March 29 storm. By comparison, the normal river level at this time of year is 3 to 4 feet.

The March 2010 storms were a federally declared disaster making federal assistance available to property owners who did not carry flood insurance. Based on the flood damage claims, Carlisle experienced only moderate flood damage from these March 2010 storms. There were no

regular flood insurance claims, and there were 15 disaster claims, all of which were located outside of FEMA Special Flood Hazard Areas. The claims were not concentrated in one part of Carlisle, but rather were distributed across most areas of the town (see Map 3 in Appendix A).

**Figure 9: March 2010 USGS Assabet River Gage**




Source: USGS National Water Information System

***DAM FAILURE***

Dam failure can arise from two types of situations. Dams can fail because of structural problems or age, independent of any storm event. Dam failure can follow an earthquake by causing structural damage. Dams can fail structurally because of flooding arising from a storm or they can overspill due to flooding.

In the event of a dam failure, the energy of the water stored behind a dam can cause loss of life and property damage if there are people or buildings downstream. The number of fatalities from a dam failure depends on the amount of warning provided to the population and the number of people in the area in the path of the dam's floodwaters.

An issue for dams in Massachusetts is that many were built in the 19th century without the benefits of modern engineering or construction oversight. In addition, some dams have not been properly maintained. The increasing intensity of precipitation is the primary climate concern for dams, as they were most likely designed based on historic weather patterns.

Dam failure is a highly infrequent occurrence, but a severe incident could result in loss of lives and significant property damage. According to the Association of State Dam Safety Officials, three dams have failed in Massachusetts since 1984, one of which resulted in a death.
The Department of Conservation and Recreation (DCR) Office of Dam Safety lists seven dams in Carlisle (Table 9). DCR classifies dam hazards as shown below. Only one of the dams, a cranberry bog dam at Curve Street, is rated as significant. One other dam is rated Low Hazard, Cranberry Bog Dam # 1. The remaining five dams are not significant enough to have a hazard rating from DCR.

**DCR Dam Hazard Classification**

The Massachusetts DCR has three hazard classifications for dams:

- **High**: Dams located where failure or mis-operation will likely cause loss of life and serious damage to homes(s), industrial or commercial facilities, important public utilities, main highways(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)
- **Low:** Dams located where failure or mis-operation may cause minimal property damage to others. Loss of life is not expected.

**Table 9: Inventory of Dams in Carlisle**

| Dam Name | River | Impoundment Name | Owner | Owner Type | Hazard Potential Classification |
|---|---|---|---|---|---|
| Cranberry Bog Dam # 1 | Tributary of River Meadow Brook | Cranberry Bog #1 | Town of Carlisle | Municipality | Low |
| Cranberry Bog Dam | Tophet Swamp-Offstream | Cranberry Bog | Town of Carlisle, Board of Selectmen | Municipality | N/A |
| Greenough Pond Dam | Pages Brook | Greenough Pond | Town of Carlisle, Conservation Commission | Municipality | N/A |
| Spencer Brook Dam | | | Not Available for Unregulated small dams | Private | N/A |
| Cabin Pond Dam | Cabin Pond | Great Brook | DCR - Dept. of Conservation & Recreation | State-DCR MassParks | N/A |
| Curve St. Dam | Great Brook | Cranberry bog | Town of Carlisle | Municipality | Significant |
| Lowell Rd. Dam | Great Brook | None | DCR - Dept. of Conservation & Recreation | State-DCR MassParks | N/A |

Source: DCR, Office of Dam Safety

A brief description of dams in Carlisle follows. These dams have been mapped and the numbers following the dam names correspond to the Critical Facilities ID provided on the maps in Appendix A.

Cranberry Bog No. 1 Dam (71)
This cranberry bog dam is privately-owned and is located on a tributary to Meadow Brook in the northern part of town. This dam is listed as in fair condition.

Cranberry Bog Dam (70)
This cranberry bog dam is privately-owned and is located offstream of Tophet Swamp in the northern part of town. This dam is listed as in fair condition.

Greenough Pond Dam (24)
Greenough Pond Dam, located on Pages Brook and Greenough Pond in the eastern portion of town, is town-owned. The dam has an earthen spillway. While it is a low hazard dam, it is in disrepair with a failed spillway and the dam has breached in the past. Downstream of the dam is mainly conservation land, roughly a 20-acre wetland that is home to two rare species. The Town is in the process of conducting a restoration project at this dam. Permits for the work have been obtained and an engineering consultant has been retained. The Town is in the process of seeking funding for the project, estimated at $750,000.

Spencer Brook Dam (76)
This dam on Spencer Brook in the southern part of town near Butchard's Pond, is an older dam and privately-owned. Downstream is mostly open land, but there are questions if homes on Hartwell Avenue could be impacted in the event of a breach.

Cabin Pond Dam (75)
The Cabin Pond dam is located at Great Brook and Cabin Pond in the northern portion of town. It is an earthen and masonry dam owned by DCR and is listed as in fair condition.

Curve Street Dam (72)
The Curve Street dam is located on Great Brook in the northwest portion of town. It is owned by DCR and is listed as in poor condition.

Lowell Road Dam (74)
The Lowell Road dam is located on Great Brook in the northern portion of town. It is a concrete dam owned by DCR and is listed as in fair condition.

DCR requires that dams that are rated as low hazard be inspected every ten years while dams that are rated as significant hazards must be inspected every five years.

There have been no recorded dam failures in Carlisle. Based on the record of previous occurrences dam failure in Carlisle is considered to be a Very Low frequency event. This hazard may occur less frequently than once in 100 years (less than 1% chance per year).

### Dams and Climate Change

Climate change could further increase the risk of dam failure in several ways. More intense or frequent precipitation events could alter the river discharge rates, creating greater structural stress to the dam, increasing scouring and erosion, and causing loss of flood storage capacity in nearby spillways or floodplain wetlands.

## DROUGHT

Drought is a temporary irregularity in precipitation and differs from aridity since the latter is restricted to low rainfall regions and is a permanent feature of climate. Drought is a period characterized by long durations of below normal 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. Drought can affect agriculture, water supply, aquatic ecology, wildlife, and plant life.

Average annual precipitation in Massachusetts is 44 inches per year, with approximately three to four-inch average amounts for each month of the year. In Massachusetts, droughts are caused by the prevalence of dry northern continental air and a decrease in coastal- and tropical-cyclone activity. During the 1960s, a cool drought occurred because dry air from the north caused lower temperatures in the springs and summers of 1962 through 1965. The northerly winds drove frontal systems to sea along the southeast coast and prevented the northeastern states from receiving the normal amount of moisture (U.S. Geological Survey). In the driest year (1965), the statewide precipitation total of 30 inches was only 68% of the average total.

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. The 2019 Massachusetts Drought Management Plan divides the state into seven regions: Western, Central, Connecticut River Valley, Northeast, Southeast, and Cape Cod, and Islands. Carlisle is located in the Northeast region. Drought is a potential town-wide hazard in Carlisle.

The MA Drought Management Plan was revised in 2019 to change the state's classification of droughts by establishing four levels to characterize drought severity: Mild Drought, Significant Drought, Critical Drought, and Emergency. These levels are based on conditions of natural resources and provide information on the current status of water resources. The levels provide a framework from which to take actions to assess, communicate, and respond to drought conditions. The Massachusetts drought levels are shown in comparison to the U.S. Drought Monitor levels in

Table 10. The two sets of drought indices are similar, but Massachusetts combines the USDM's level D2 and D3 into one category, Critical Drought.

**Table 10: MA Statewide Drought Levels Compared to US Drought Monitor**

| USDM Names | Recurrence | Percentile Ranges | MA DMP Levels | MA Percentile Ranges | MA DMP Names |
|---|---|---|---|---|---|
| D0: Abnormally Dry | once per 3 to 5 years | 21 to 30 | 1 | >20 and ≤30% | Mild Drought |
| D1: Moderate | once per 5 to 10 years | 11 to 20 | 2 | >10 and ≤20% | Significant Drought |
| D2: Severe Drought | once per 10 to 20 years | 6 to 10 | 3 | >2 and ≤10% | Critical Drought |
| D3: Extreme Drought | once per 20 to 50 years | 3 to 5 | | | |
| D4: Exceptional Drought | once per 50 to 100 years | 0 to 2 | 4 | ≤2% | Emergency |

Source: Massachusetts Drought Management Plan, 2019

As dry conditions can have a range of different impacts, a number of drought indices are available to assess these various impacts. Massachusetts uses a multi-index system that takes advantage of several of these indices to determine the severity of a given drought or extended period of dry conditions. Drought level is determined monthly based on the number of indices which have reached a given drought level. Drought levels are declared on a regional basis for each of the seven regions in Massachusetts. County by county or watershed-specific determinations may also be made. A determination of drought level is based on six indices:

1. Standardized Precipitation Index (SPI) reflects soil moisture and precipitation.
2. The Stream flow Index is based on the number of consecutive months that stream flow levels are below normal.
3. The Lakes and Impoundments Index is based on the water levels of small, medium, and large index reservoirs across the state, relative to normal conditions for each month.
4. The Groundwater Level Index is based on the number of consecutive month's groundwater levels below normal.
5. Keetch Byram Drought Index (KBDI) is designed for fire-potential assessment.
6. Crop Moisture Index (CMI) reflects soil moisture conditions for agriculture.

Table 11 shows the range of values for each of the indices associated with the drought levels.

Because drought tends to be a regional natural hazard, this plan references state data as the best available data for previous drought occurrences.

**Table 11: Indices Values Corresponding to Drought Index Severity Levels**

| Index Severity Level | Standardized Precipitation Index | Streamflow | Lakes and Impoundments | Groundwater | Keetch-Byram Drought Index | Crop Moisture Index |
|---|---|---|---|---|---|---|
| 0 | >30th percentile | | | | < 200 | > -1.0 |
| 1 | ≤30 and >20 | | | | 200-400 | ≤-1.0 and > -2.0 |
| 2 | ≤20 and >10 | | | | 400-600 | ≤-2.0 and < -3.0 |
| 3 | ≤10 and >2 | | | | 600-700 | ≤ -3.0 and > -4.0 |
| 4 | ≤2 | | | | 700-800 | ≤-4.0 |

Source: MA Drought Management Plan, 2019

**Drought Emergencies** have been declared infrequently, with five events occurring in the period between 1850 and 2020: 1883, 1911, 1941, 1957, and 1965 to 1966. The drought period between 1965 and 1966 is viewed as the most severe drought to have occurred in modern times in Massachusetts because of its long duration. On a monthly basis over the 162-year period of record, there is a 1% chance of being in a drought emergency.

**Drought Warning** levels not associated with drought emergencies have occurred six times, in 1894, 1915, 1930, 1985, and 2016, and 2020. On a monthly basis over the 162-year period of record, there is a 2% chance of being in a Drought Warning.

**Drought Watches** not associated with higher levels of drought generally have occurred in three to four years per decade between 1850 and 1950. In the 1980s, there was a lengthy drought watch between 1980 and 1981, followed by a drought warning in 1985. The overall frequency of being in a Drought Watch level is 8% on a monthly basis over the 162-year period of record.

Based on the record since 1850, the SHMCAP calculates that statewide there is a 1% chance of being in a drought emergency in any given month. For drought warning and watch levels, the chance is 2% and 8% respectively in any given month (Table 12u).

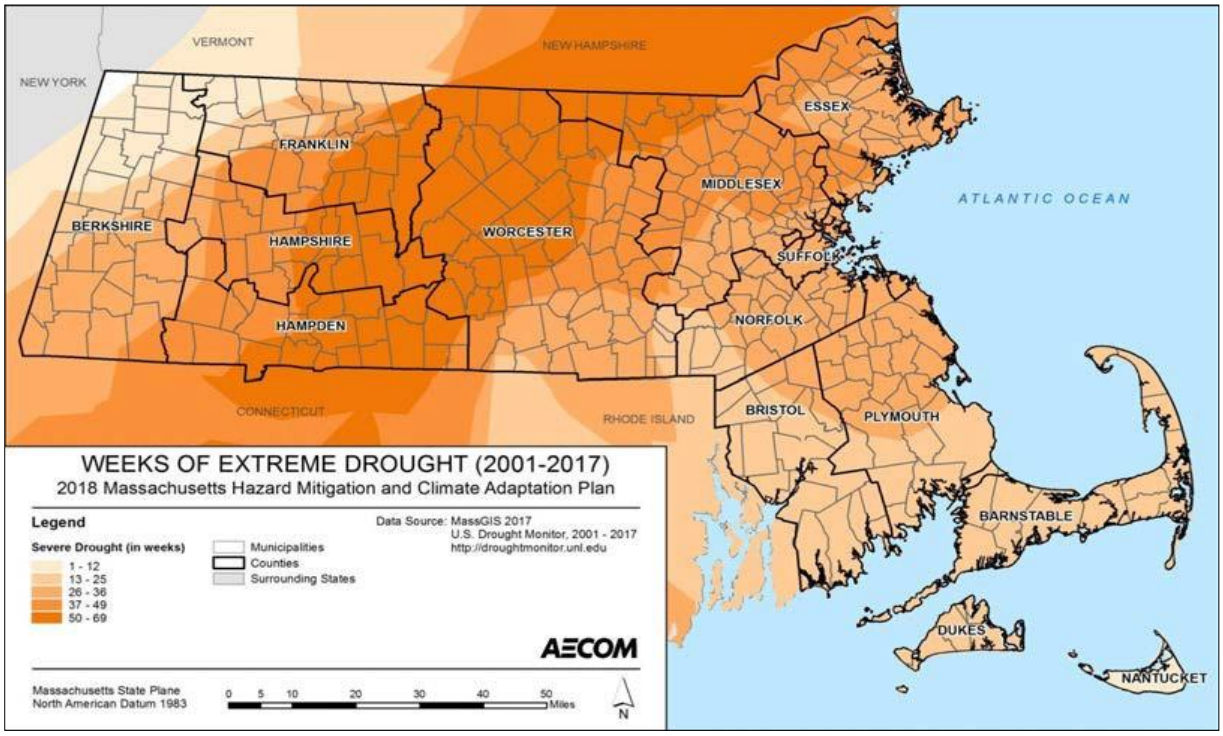
**Table 12: Frequency of Massachusetts Drought Levels**

| Drought Level | Frequency Since 1850 | Probability of Occurrence in a Given Month |
|---|---|---|
| Drought Emergency | 5 occurrences | 1% chance |
| Drought Warning | 5 occurrences | 2% chance |
| Drought Watch | 46 occurrences | 8% chance |

Source: SHMCAP

The U.S. Drought Monitor characterizes droughts as abnormally dry, moderate, severe, extreme, or exceptional. As shown in Figure 10, Carlisle experienced between 37 and 49 weeks of severe drought between 2001 and 2017.

**Figure 10: Weeks of Severe Drought (2001-2017)**



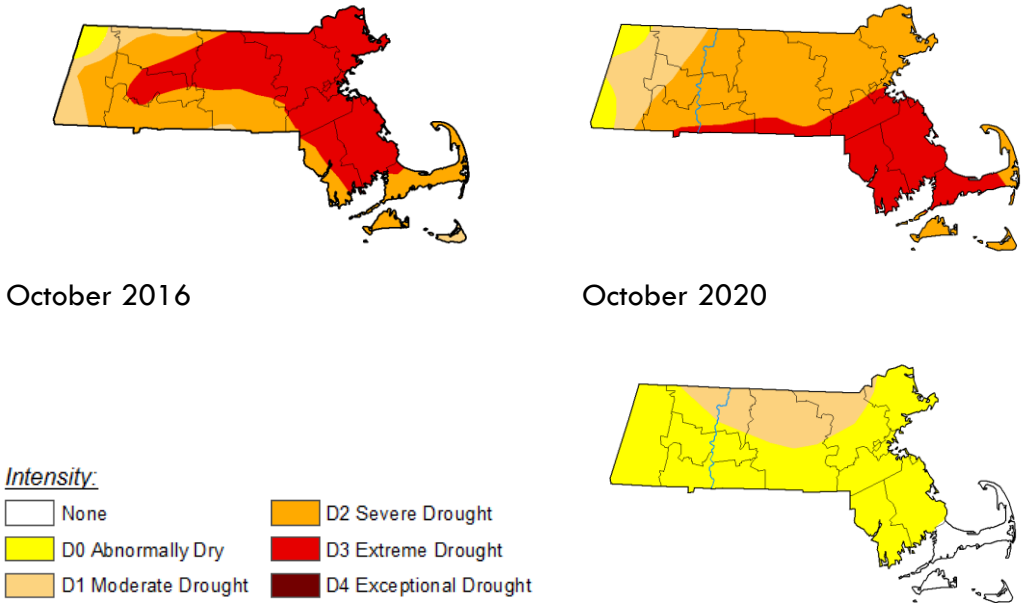

Source: MA SHMCAP

Since the 2012 Carlisle Hazard Mitigation Plan there have been three droughts in Massachusetts. The drought of 2016 was the worst one since 1985, with more than half of the state reaching the Extreme Drought stage for several months (Figure 11). This was followed by another drought just four years later in 2020, which was most severe in Southeastern Massachusetts and somewhat less so in Carlisle. Finally, in the early spring of 2021 a third, milder drought was declared.

Determinations regarding the end of a drought or reduction of the drought level focus on two key drought indicators: precipitation and groundwater levels. These two factors have the greatest long-term impact on stream flow, water supply, reservoir levels, soil moisture, and potential for forest fires.

Drought impacts can include reduced groundwater and surface water levels, affecting water quality and quantity, streamflow, and wetlands levels, and negatively impacting aquatic organisms that rely on riverine and wetland habitats. Drought also increases stress on plant communities, weakening trees, and increasing the likelihood of forest and brush fires.

**Figure 11: Recent Drought Events (2016-2021)**




Source: US Drought Monitor

Potential damages of a severe drought include increased risk of wildfires, which is particularly important in Carlisle since the town has extensive forested land (over 70%), and limited water sources for firefighting in some areas. A lowering water table can affect private wells. Drought affects natural water supplies for firefighting. Drought causes swamps to dry out and if they catch fire the peat/swamp areas are difficult to extinguish. Extended drought could also cause losses of landscaped areas if outdoor watering is restricted and potential loss of business revenues if water supplies were severely restricted for a prolonged period. Economic sectors impacted could include commercial water users, recreation facilities, agriculture, landscaping, and forestry.

As a severe, prolonged drought has not occurred in the region since the mid-1960s, there are no data or estimates of potential financial damages, but under a severe long-term drought scenario it would be reasonable to expect a range of potential damages of several million dollars. If a drought triggered severe and widespread wildfires that affected many residences, damages for the town could be in the range of tens of millions of dollars.

Given Carlisle's forest cover, the entire town is vulnerable to the impacts of drought. Emergency drought conditions over the 162 period of record in Massachusetts are a low frequency event that can occur from once in 50 years to once in 100 years (1% to 2% chance per year).

**Drought and Climate Change**

Changing precipitation patterns and the number of extreme weather events per year is difficult to project into the future. The Northeast Climate Science Center does report an anticipated increase

in rainfall for Massachusetts in the spring and winter months and slightly decreased summer rainfall. Consequently, warming temperatures can cause greater evaporation in the summer and fall, as well as earlier snow melt. This, combined with projected higher summer temperatures, could increase the frequency of episodic droughts in the future.

## EXTREME TEMPERATURES

### *AVERAGE AND EXTREME TEMPERATURES*

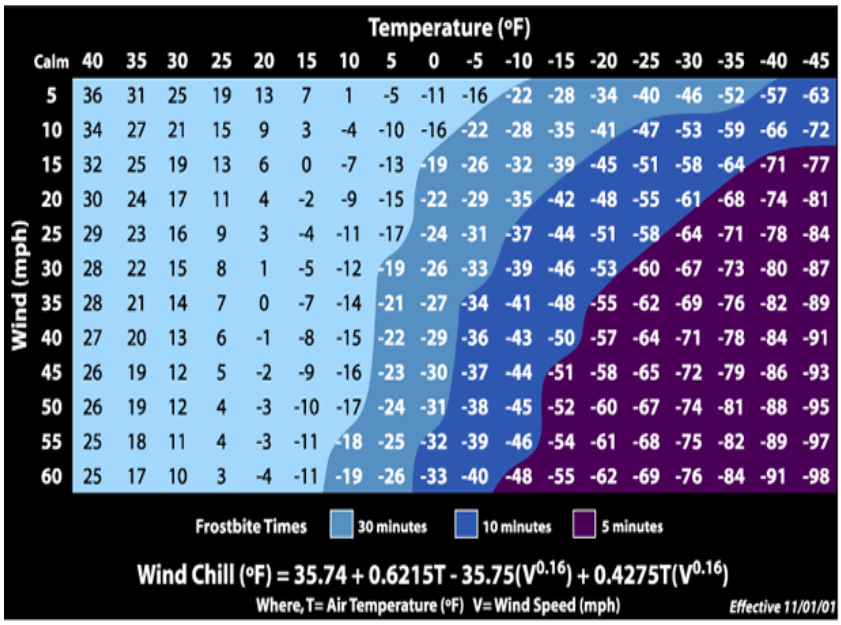
Carlisle has four well-defined seasons, characterized mainly by seasonal temperatures. Extreme temperatures can be defined as those that are far outside of the normal seasonal ranges for Massachusetts. The average temperature for Winter (December to February) in Massachusetts is 31.8 degrees Fahrenheit. The average temperature for Summer (June to August) is 71 degrees F.

Extreme temperatures can occur for brief periods of time and be acute, or they can occur over longer periods of time when there is a long stretch of excessively hot or cold weather.

### *EXTREME COLD*

For extreme cold, temperature is typically measured using the Wind Chill Temperature Index (Figure 12), which is provided by the National Weather Service (NWS). Wind chill is the apparent temperature felt on exposed skin due to the combination of air temperature and wind speed and is meant to show how cold conditions feel on unexposed skin and can lead to frostbite.

**Figure 12: Wind Chill Temperature Index and Frostbite Risk**




Source: National Weather Service

The best available local data on past occurrences of extreme cold in Carlisle are for Middlesex County, through the National Centers for Environmental Information (NCEI). There have been three extreme cold events in the past ten years, which caused no deaths, no injuries, or property damage (see Table 13).

**Table 13: Middlesex County Extreme Cold and Wind Chill Occurrences**

| Date | Deaths | Injuries | Damage |
|---|---|---|---|
| 2/15/2015 | 0 | 0 | 0 |
| 2/16/2015 | 0 | 0 | 0 |
| 2/14/2016 | 0 | 0 | 0 |
| **TOTAL** | **0** | **0** | **0** |

Source: NOAA, National Centers for Environmental Information

Extreme cold is a dangerous situation that can result in health emergencies for susceptible people, such as those without shelter, those who are stranded, or those who live in homes that are poorly insulated or without heat. In Carlisle 12.8 percent of the population is over age 65.

***EXTREME HEAT***

While a heat wave for Massachusetts is defined as three or more consecutive days above 90°F, another measure used for identifying extreme heat events is through a Heat Advisory from the National Weather Service (NWS). These advisories are issued when the heat index (Figure 13) is forecast to exceed 100°F for two or more hours; an excessive heat advisory is issued if the forecast predicts the temperature to rise above 105°F.

**Figure 13: Heat Index Chart**

| 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. |

Source: National Weather Service

The best available local data on past occurrences of extreme heat in Carlisle are for Middlesex County, through the National Centers for Environmental Information. From 1995 - 2020, there have been a total of two excessive heat events recorded, with one reported death, no injuries, and no property damage resulting from excessive heat (see Table 14).

**Table 14: Middlesex County Extreme Heat Occurrences 1995 to 2020**

| Date | Deaths | Injuries | Damage |
|---|---|---|---|
| 7/6/2010 | 0 | 0 | 0 |
| 7/5/2013 | 1 | 0 | 0 |
| **Total** | **1** | **0** | **0** |

Source: NOAA, National Centers for Environmental Information

Prolonged exposure to high temperatures can cause heat-related illnesses, such as heat cramps, heat exhaustion, heat stroke, and death. Heat exhaustion is the most common heat-related illness and if untreated, it may progress to heat stroke. People who perform manual labor, particularly those who work outdoors, are at increased risk for heat-related illnesses. Prolonged heat exposure and the poor air quality and high humidity that often accompany heat waves can also exacerbate pre-existing conditions, including respiratory illnesses, cardiovascular disease, and mental illnesses.

Older adults are often at elevated risk due to a high prevalence of pre-existing and chronic conditions. In Carlisle, 20.6 percent of the population is over the age of 65. People who live in older housing stock and in housing without air conditioning have increased vulnerability to heat-related illnesses. Power failures are more likely to occur during heat waves, affecting the ability of residents to remain cool during extreme heat. Individuals with pre-existing conditions and those who require electric medical equipment may be at increased risk during a power outage.

**The Heat Island Effect and Hot Spots**

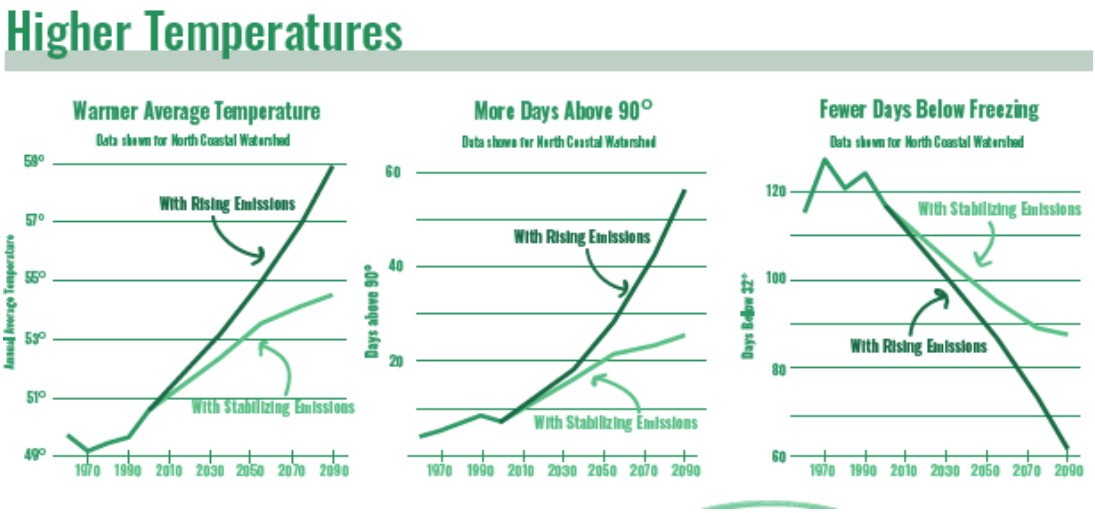
Due to what is termed the "heat island effect", areas with less shade and more dark surfaces (pavement and roofs) will experience even hotter temperatures; these surfaces absorb heat during the day and release it in the evening, keeping nighttime temperatures warmer as well. Map 9 in Appendix A displays areas in Carlisle that are among the hottest 5% of land in the MAPC region based on land surface temperature derived from satellite imagery on July 13, 2016, when the high temperature at Logan Airport was 92°F. Due to the extensive tree cover and lack of large, paved areas, there are no significant "hot spots" in Carlisle

**Extreme Temperatures and Climate Change**

Extreme cold events are predicted to decrease in the future, while extreme heat, as well as average temperatures, are projected to increase. Global temperatures have increased by nearly 2 degrees in the last century and even small changes in temperature have widespread and

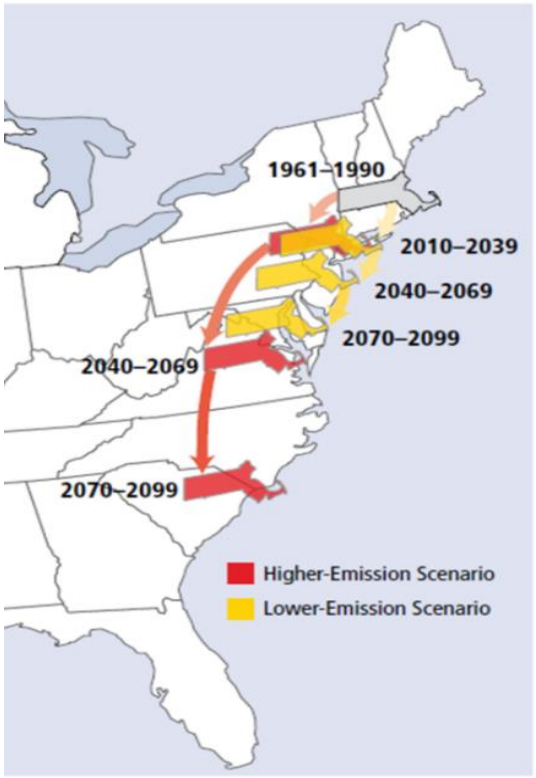
significant changes to our climatic system. For example, the northeast has experienced a 10-day increase in the growing season in since 1980.

**Figure 14: Projected Temperatures for Climate Scenarios to 2100**




Source: ResilientMA.org

**Figure 15 Temperature Scenarios Map**




Source: Union of Concerned Scientists

Future temperature projections are shown in Figure 14. The projections are based on two future climate scenarios, with stabilizing and rising greenhouse gas emissions to the end of the century. The projections show an increase in average temperatures in the range of 4 to 8 degrees from the current 51 degrees to a range of 55 to 59 degrees. The number of days over 90 degrees is projected to increase from the current 10 days to a range of 25 to 55 days per year. This change represents the present-day climate from Virginia to South Carolina (Figure 15). The projected increase in extreme heat and heat waves is one of the key health concerns related to climate change.

## WILDFIRE HAZARDS

A wildfire is a non-structure fire occurring in a forested, shrub or grassland area. In the Boston Metro region generally, these fires rarely grow to the size of a wildfire as seen more typically in the western U.S. However, with over 70% forested land, Carlisle has a much greater potential for wildfires than most other communities in the Boston metropolitan region.

There are three different classes of wildfires:

- **Surface fires** are the most common type and burn along the floor of a forest, moving slowly and killing or damaging trees
- **Ground fires** are usually started by lightning and burn on or below the forest floor
- **Crown fires** spread rapidly by wind, jumping along the tops of trees

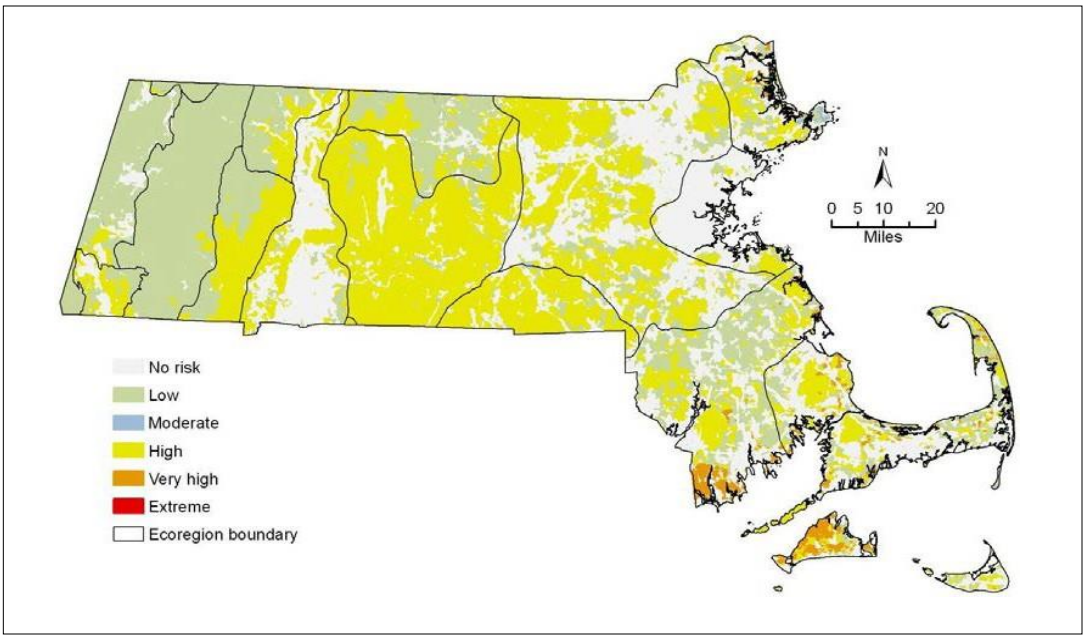
A wildfire differs greatly from other fires by its extensive size, the speed at which it can spread out from its original source, its potential to unexpectedly change direction, and its ability to jump gaps such as roads, rivers, and fire breaks. Wildfire season can begin in March and usually ends in late November. The majority of wildfires typically occur in April and May, when most vegetation is void of any appreciable moisture, making them highly flammable. Once "green-up" takes place in late May to early June, the fire danger usually is reduced somewhat. As the climate warms, drought and warmer temperatures may increase the risk of wildfire as vegetation dries out and becomes more flammable.

These fires can present a hazard where there is the potential for them to spread into developed or inhabited areas, particularly residential areas where sufficient fuel materials might exist to allow the fire the spread into homes. Protecting structures from fire poses special problems and can stretch firefighting resources to the limit. This is particularly true in Carlisle since most homes are located in forested areas, and some areas are without adequate water for fighting fires.

If heavy rains follow a fire, other impacts can occur, including landslides and mudflows. If a wildfire destroys the ground cover, then erosion becomes one of several potential problems.

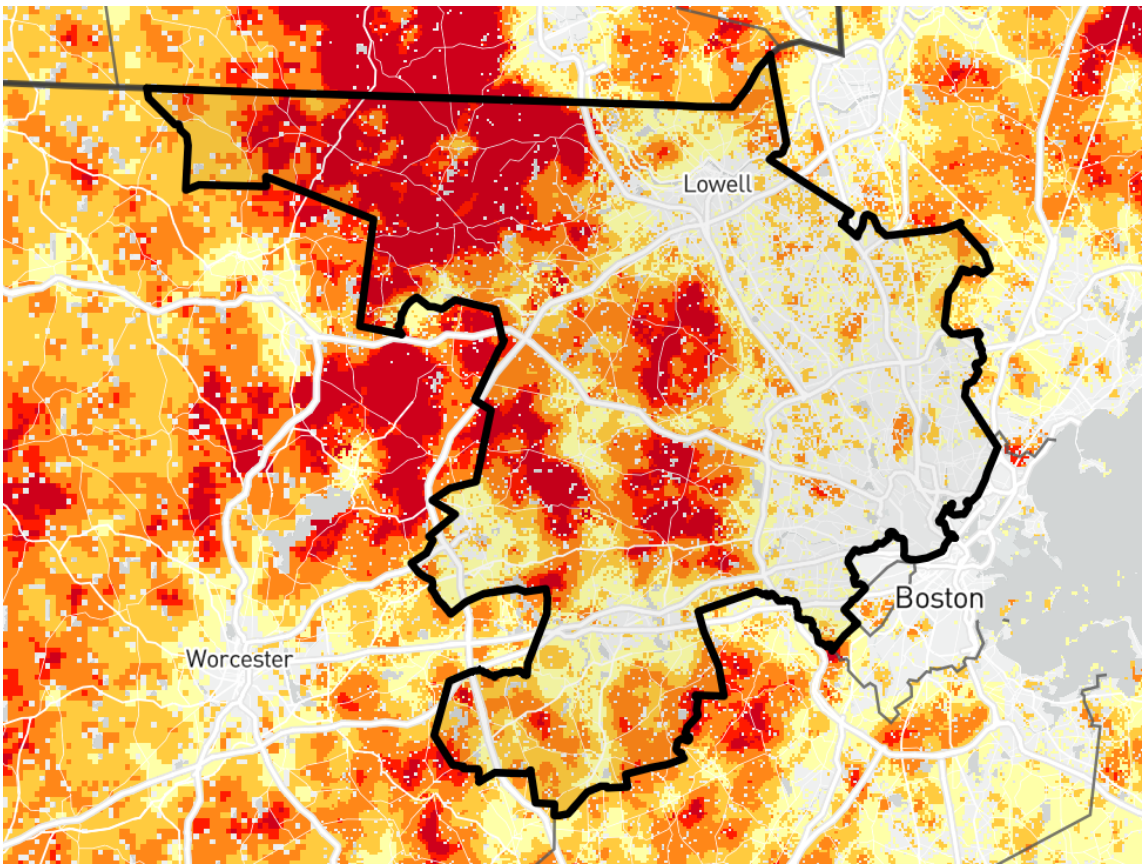
The MA State Hazard Mitigation and Climate Adaptation Plan depicts statewide fire risk incorporating three risk components: fuel, wildland-urban interface, and topography (Figure 16). The wildland-urban interface reflects communities where housing and vegetation intermingle, and fire can spread from structures to vegetated areas. The most susceptible fuels are pitch pine, scrub oak and oak forests. Topography can affect the behavior of fires, as fire spreads more easily uphill. Since Carlisle has oak forests and some hilly terrain, wildfires are considered a serious hazard in the Town. Carlisle is shown in the “High” wildfire risk area in Figure 16. Carlisle’s Fire Chief provided a more detailed county-level map of “wildfire risk to homes” produced by the USDA Forest Service. The map for Middlesex County is shown in Figures 17, and Figure 18 has a close-up of the Town of Carlisle along with a reference map showing town boundaries. This map clearly shows that Carlisle is in the “bull’s eye” for wildfire risk in this part of the region.

## Figure 16: Massachusetts Wildfire Risk Areas



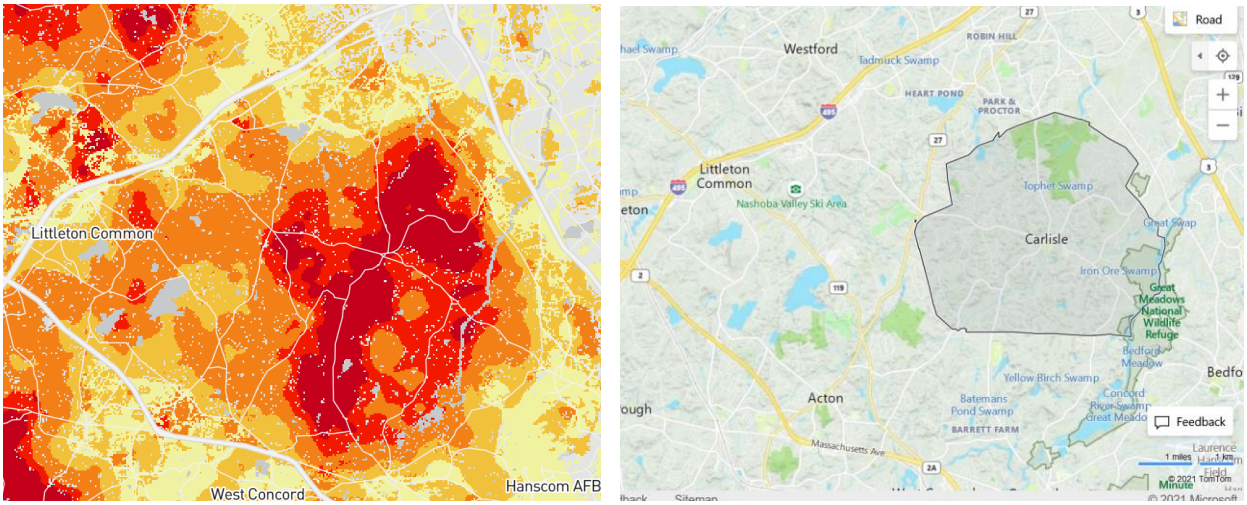

Source: Mass SHMCAP

## Figure 17: USDA Wildfire Risk to Homes, Middlesex County




Source: USDA Forest Service

**Figure 18: USDA Wildfire Risk to Homes, Carlisle Close-up, and Reference Map**




Sources: USDA Forest Service and Google Maps

Carlisle Fire Department records show 19 incidents from 2017 to 2021. These are listed in Table 15 below:

**Table 15: Carlisle Fire Incident Records**

| Date | Location | Incident Type |
|---|---|---|
| 4/15/17 | 130 Indian Hill Road | Brush/Woods/Grass fire |
| 4/21/18 | 800 Maple Street | Small outside fire |
| 5/5/18 | 272 Virginia Farme Road | Investigation-smoke/fire outside |
| 7/11/18 | 18 Westford Street | Investigation-smoke/fire outside |
| 1/6/19 | 493 Westford Street | Brush fire |
| 10/17/19 | 425 Brook Street | Wire fire |
| 1/16/20 | 126 Martin Street | Investigation-smoke/fire outside |
| 3/7/20 | 142 Bedford Road | Brush/Woods/Grass fire |
| 3/10/20 | 395 Rutland Road | Wire down – small fire |
| 3/22/20 | 91 Westford Street | Brush/Woods/Grass fire |
| 4/26/20 | 195 Virginia Farme Road | Brush/Woods/Grass fire |
| 5/19/20 | 43 Partridge Lane | Brush/Woods/Grass fire |
| 8/18/20 | 1420 Curve Street | Brush/Woods/Grass fire |
| 12/30/20 | 566 Acton Street | Investigation-smoke/fire outside |
| 1/16/21 | 646 South Street | Investigation-smoke/fire outside |
| 3/6/21 | 453 River Road | Brush/Woods/Grass fire |
| 3/21/21 | 123 West Street | Brush/Woods/Grass fire |
| 4/26/21 | 426 Bellows Hill Road | Brush/Woods/Grass fire |
| 5/24/21 | 43 Fifty Acre Way | Shed fire |

Source: Carlisle Fire Department Incident Records

In addition to these recent incidences the Carlisle Fire Chief reports that about 15 ago there were a few years with dry conditions resulting in multiple brush fires in town. The main concern is having several years of plentiful rain followed by a year or two of dry summers, which could lead to almost western US fire conditions. Increased drought and extreme heat due to climate change will likely increase this threat. Under such a scenario the Fire Chief estimates that wildfires could threaten up to one-third of the town. With climate change there is a need for the Town to plan for worst-case scenarios that would be more severe than past incidents would indicate.

Carlisle often has brush fires in the spring, however, the greatest risk occurs in mid-summer, when there may be 3 to 4 fires occurring on at once. If conditions are dry, other nearby towns may also have fires at the same time and may not be able to assist Carlisle. This is a major risk and probably the greatest risk the town faces from climate change natural conditions.

One of the most significant challenges facing Carlisle regarding wildfires is that there is no municipal water supply or hydrants in the town. All residences and development are served by well water. Water for firefighting is serviced by fire ponds and over 30 cisterns spread throughout the town. The Fire Department's specification is for cisterns is 30,000 gallons. However, there are a number of areas in town that do not have adequate water sources for fighting fires. The Fire Department provided the following initial list of locations of concern, but the Fire Chief identified the need for a more thorough and systematic assessment that also evaluates the quality of the water sources. There is also a need to analyze ponds and streams to see if they are reliably available during a drought. Areas with insufficient water should be identified and plotted on GIS map.

1. East St from Blaisdell to Woodbine and Cutter's Ridge
2. East Riding Drive and Tophet and Carlton Roads
3. Meadow Brook and Hillside.
4. Autumn Lane-all of it.
5. Concord Rd- Church St to Russell St
6. Lowell Rd- Sunset Road to Wolf Rock.
7. South St-Concord Rd to Wildwood.
8. Log Hill and Woodland Road
9. Bedford Rd- Kimball Farm to Stoney Gate (new Woodward Cistern will help this area)
10. Curve St to Forest Park Rd and Evergreen Road Area.

The Fire Chief notes that strategically, there are different ways the town could address this risk. Additional cisterns could be installed in areas without adequate water sources. Or, the Town could have two functioning tanker trucks, along with sufficient firefighters to staff them.

Staffing is another factor that affects capability to respond to wildfires, particularly larger or multiple fires. The Carlisle Fire Department operates under a dynamic staffing model as an on-call fire department, where individuals have other jobs but are available to fight fires. This helps the Town be prepared to fight a large fire, as they could muster 30 people if needed, whereas if

the Town had a "career" department with full-time employees, they would not be able to have so much coverage and the ability to respond to large or multiple fires.

Based on the previous record of occurrences, significant brushfires are a high frequency event in Carlisle, occurring more frequently than once in 5 years (greater than 20% chance per year).

**Wildfires and Climate Change**

Warmer temperatures, more extended heat waves, and increasing drought due to climate change could increase the risk of wildfires in the future. With higher rates of evaporation and potential heat stress impacting vegetation, forests and brush lands could become more flammable, potentially leading to more frequent and/or more severe wildfires. While California and much of the western US have been an extreme example of this in recent years, shifting climate pattens could augment this risk in the northeastern US as well.

## EXTREME WEATHER HAZARDS

### *HURRICANES AND TROPICAL STORMS*

A hurricane is a violent wind and rainstorm with wind speeds of 74 to 200 miles per hour. A hurricane is strongest as it travels over the ocean and is particularly destructive to coastal property as the storm hits land. A tropical storm has similar characteristics, but wind speeds are below 74 miles per hour. Climate models suggest that hurricanes and tropical storms will become more intense as warmer ocean waters provide more fuel for the storms. In addition, rainfall amounts associated with hurricanes are predicted to increase because warmer air can hold more water vapor. Hurricanes in Massachusetts since 1938 are shown in Table 16.

**Table 16: Hurricane Records for Massachusetts, 1938 to 2018**

| 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 |

*Category 3 Source: National Oceanic and Atmospheric Administration

Hurricane intensity is measured according to the Saffir/Simpson scale, which categorizes hurricane intensity linearly based upon maximum sustained winds, barometric pressure, and storm surge potential. These are combined to estimate potential damage. Table 17 gives an overview of the wind speeds, surges, and range of damage caused by different hurricane categories.

**Table 17: Saffir/Simpson Scale**

| Scale No. (Category) | Winds (mph) | Surge (ft) | Potential Damage |
|---|---|---|---|
| 1 | 74 – 95 | 4 - 5 | Minimal |
| 2 | 96 – 110 | 6 - 8 | Moderate |
| 3 | 111 – 130 | 9 - 12 | Extensive |
| 4 | 131 – 155 | 13 - 18 | Extreme |
| 5 | > 155 | >18 | Catastrophic |

Source: NOAA

The Town of Carlisle's entire area is vulnerable to hurricanes, which occur between June and November. A hurricane or storm track is the line that delineates the path of the eye of a hurricane or tropical storm. No hurricanes have tracked directly through the Town of Carlisle, and one tropical storm tracked through town in 1897. However, the town also experiences the impacts of the wind and rain from hurricanes and tropical storms in Massachusetts regardless of whether the storm track passes through the town. The hazard mapping indicates that the 100-year wind speed in Carlisle is 110 miles per hour.

Potential hurricane damages to Carlisle have been estimated using HAZUS-MH. Total damages are estimated at $6.1 million for a 100-year hurricane and $20.1 million for a 500-year hurricane. Other potential impacts such as debris disposal and sheltering needs are detailed in Table 34.

Carlisle has been impacted by high winds due to hurricanes and one tropical storm passed through Carlisle in 1897 (see Map 5). Winds impacted Carlisle during the 1938 hurricane as well as the 1944 Great Atlantic Hurricane and Hurricanes Gloria and Bob. Impacts included road blockages due to downed trees. In fact, all major roadways in Carlisle were blocked in the aftermath of Gloria.

Tree damage during high winds has the potential to be a significant hazard in Carlisle because it is a rural community. Trees can knock out power lines and block major roadways, which hinders emergency response. Trees down in the area of Route 225 is a concern as this is a principal route out of town. It is common for tree limbs to come down resulting in road closures for short periods to several hours. Downed trees have also caused power outages since most of the electrical wires in town are overhead. Power outages can also lead to loss of water supply since the Town relies on private well that require electricity to operate. The Town has also had numerous trees come down on homes causing significant damage. This has become more common in recent years.

Based on records of previous occurrences, hurricanes in Carlisle are a medium frequency event. This hazard occurs from once in 5 years to once in 50 years, or a 2% to 20% chance per year.

### *NOR'EASTERS*

A northeast storm, known as a nor'easter, is typically a large counterclockwise wind circulation around a low-pressure center. Featuring strong northeasterly winds blowing in from the ocean over coastal areas, nor'easters are relatively common in the winter months in New England occurring one to two times a year. The storm radius of a nor'easter can be as much as 1,000 miles and these storms feature sustained winds of 10 to 40 mph with gusts of up to 70 mph. These storms are accompanied by heavy rain or snow, depending on temperatures.

Previous occurrences of nor'easters include the storm events shown on Table 18. Many of the historic flood events identified in the previous section were precipitated by nor'easters, including the "Perfect Storm" event in 1991. More recently, blizzards in February 2013, January 2015, and in March 2018 were large nor'easters that caused significant impacts on Massachusetts with heavy snowfall, high winds, and coastal flooding.

**Table 18: Nor'easter Events for Massachusetts, 1978 to 2020**

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

Carlisle is vulnerable to both the wind and precipitation that accompany nor'easters. High winds can cause damage to structures, fallen trees, and downed power lines leading to power outages. Intense rainfall can overwhelm drainage systems causing localized flooding of rivers and streams as well as stormwater ponding and localized flooding. Fallen tree limbs as well as heavy snow accumulation and intense rainfall can impede local transportation corridors, and block access for emergency vehicles. In Carlisle, the entire town is potentially at risk from the wind, rain, or snow impacts of a nor'easter.

Based on previous occurrences, nor'easters in Carlisle are high frequency events. This hazard may occur more frequently than once in five years (greater than 20% chance per year).

**Nor'easters and Climate Change**

As with hurricanes, warmer ocean water and air will provide more fuel for storms. According to the SHMCAP it appears that Atlantic coast nor'easters are increasing in frequency and intensity.

***HEAVY SNOW AND BLIZZARDS***

Winter storms, including heavy snow, blizzards, and ice storms, are the most common and most familiar of the region's hazards that affect large geographic areas.

Winter storms are a combination hazard because they often involve wind, ice, and heavy snow fall. The National Weather Service defines "heavy snow fall" as an event generating at least four inches of snowfall within a 12-hour period. Blizzards and winter storms are often associated with a Nor'easter event, a large counterclockwise wind circulation around a low-pressure center often resulting in heavy snow, high winds, and rain (see Nor'easters above).

A blizzard is a winter snowstorm with sustained or frequent wind gusts to 35 mph or more, accompanied by falling or blowing snow which reduces visibility to or below ¼ mile. These conditions must be the predominant condition over a three-hour period. Extremely cold temperatures are often associated with blizzard conditions but are not a formal part of the definition. The hazard related to the combination of snow, wind, and low visibility significantly increases when temperatures drop below 20 degrees.

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: Extreme, Crippling, Major, Significant, and Notable. The NESIS categories are summarized in Table 19. 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.

**Table 19: 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 Plan, 2013

The best available data on previous occurrences and impacts of heavy snow events in Carlisle are for Middlesex County, which includes Carlisle. According to National Centers for Environmental Information (NCEI) records, from 2010 to 2020, Middlesex County experienced 37 days with heavy snowfall events, resulting in no injuries, deaths, and property damage of $142,500. See Table 20 for and heavy snow events and impacts in Middlesex County.

**Table 20: Heavy Snow events and Impacts in Middlesex County 2010 – 2020**

| Date | Deaths | Injuries | Damage-$ |
|---|---|---|---|
| 1/18/2010 | 0 | 0 | 0 |
| 2/16/2010 | 0 | 0 | 15,000 |
| 2/23/2010 | 0 | 0 | 8,000 |
| 1/12/2011 | 0 | 0 | 0 |
| 1/26/2011 | 0 | 0 | 0 |
| 10/29/2011 | 0 | 0 | 30,000 |
| 12/29/2012 | 0 | 0 | 0 |
| 2/8/2013 | 0 | 0 | 0 |
| 2/8/2013 | 0 | 0 | 0 |
| 2/23/2013 | 0 | 0 | 0 |
| 3/7/2013 | 0 | 0 | 0 |
| 3/18/2013 | 0 | 0 | 0 |
| 12/14/2013 | 0 | 0 | 0 |
| 12/17/2013 | 0 | 0 | 0 |
| 1/2/2014 | 0 | 0 | 0 |
| 1/18/2014 | 0 | 0 | 0 |
| 2/5/2014 | 0 | 0 | 0 |
| 2/13/2014 | 0 | 0 | 0 |
| 2/18/2014 | 0 | 0 | 0 |
| 11/26/2014 | 0 | 0 | 10,000 |
| 1/24/2015 | 0 | 0 | 0 |
| 1/26/2015 | 0 | 0 | 0 |
| 2/2/2015 | 0 | 0 | 0 |
| 2/8/2015 | 0 | 0 | 0 |
| 2/14/2015 | 0 | 0 | 0 |
| 2/5/2016 | 0 | 0 | 75,000 |
| 3/21/2016 | 0 | 0 | 0 |
| 4/4/2016 | 0 | 0 | 0 |
| 12/29/2016 | 0 | 0 | 0 |
| 3/14/2017 | 0 | 0 | 0 |
| 11/15/2018 | 0 | 0 | 0 |
| 12/1/2019 | 0 | 0 | 4,000 |
| 1/18/20 | 0 | 0 | 0 |
| 3/23/20 | 0 | 0 | 0 |
| 10/30/20 | 0 | 0 | 500 |
| 12/05/20 | 0 | 0 | 0 |
| 12/16/20 | 0 | 0 | 0 |
| **TOTAL** | **0** | **0** | **$142,500** |

Source: NOAA, National Centers for Environmental Information

The most significant severe winter storm in recent history was the "Blizzard of 1978," which resulted in over three feet of snowfall and multiple day closures of roadways, businesses, and schools. In Carlisle, blizzards and severe winter storms that were declared disasters have occurred in the following years (Table 21):

**Table 21: Severe Weather Major Disaster Declarations in Eastern MA**

| Storm Event | Date |
|---|---|
| Severe Winter Storm and Snowstorm | March 2018 |
| Severe Winter Storm, Snowstorm, and Flooding | January 2015 |
| Severe Winter Storm, Snowstorm, and Flooding | February 2013 |
| Hurricane Sandy | October/November 2012 |
| Severe Storm and Snowstorm | October 2011 |
| Tropical Storm Irene | August 2011 |
| Severe Winter Storm and Snowstorm | January 2011 |
| Severe Winter Storm and Flooding | December 2008 |
| Severe Storms and Inland and Coastal Flooding | April 2007 |
| Severe Storm and Flooding | October 2005 |
| Severe Storms & Flooding | March 2001 |
| Blizzard | December 1992 |
| Winter Coastal Storm | October 1991 |
| Severe Coastal Storm | August 1991 |
| Hurricane Bob | September 1985 |
| Hurricane Gloria | February 1978 |
| Coastal Storm, Flood, Ice, Snow | January 1966 |
| Hurricane, floods | August 1955 |
| Hurricanes | September 1954 |

Winter storms are a potential town-wide hazard in Carlisle. Map 6 in Appendix A indicates that the average annual snowfall for the Town of Carlisle is 48-72 inches per year.

The town provides standard snow plowing operations and clearing snow has not posed any significant challenges. However, the town does experience roadway icing on some of the hilly parts of town. It can be a challenge, particularly on narrow roads or on the main roads during rush hour. The following two areas were identified by Town staff as roads that have experienced more snow issues or icing:

- Route 225 into Westford is a particular challenge because of its steepness and because it is a commuter road. The hill can be a problem for emergency vehicles, and cars have difficulty handling the hill in the snow. One stopped car can block the entire road. This area is more difficult during rush hour.

- Center Circle, in the center of town, can also be difficult in the snow, especially for larger trucks.

Most blizzards and ice storms in the region cause more inconvenience than they do serious property damage, injuries, or deaths. However, periodically, a storm will occur which is a true disaster, and necessitates intense large-scale emergency response. A number of public safety issues can arise during severe winter storms. Impassible streets are a challenge for emergency vehicles and affect residents and employers. Snow-covered sidewalks force people to walk in streets, which are already less safe due to snow, slush, puddles, and ice. Large piles of snow can also block sight lines for drivers, particularly at intersections. Refreezing of melting snow can cause dangerous roadway conditions. In addition, transit operations may be impacted, as they were in the 2015 blizzards which caused the closure of the MBTA system for one day and limited services on the commuter rail for several weeks.

Heavy snow and blizzards are considered to be high frequency events in Carlisle based on past occurrences. This hazard occurs more than once in five years, with a greater than 20 percent chance of occurring each year.

***Severe Winter Storms and Climate Change***

As with nor'easters, warmer ocean water and air will provide more fuel for severe winter storms. According to the SHMCAP changing atmospheric patterns favor the development of winter storms.

### *ICE STORMS AND HAIL EVENTS*

The ice storm category covers a range of different weather phenomena that collectively involve rain or snow being converted to ice in the lower atmosphere leading to potentially hazardous conditions on the ground. Ice storm conditions are defined by liquid rain falling and freezing on contact with cold objects, creating ice buildups of **one-fourth of an inch** or more. An ice storm warning, which is now included in the criteria for a winter storm warning, is issued when a **half inch or more** of accretion of freezing rain is expected.

Sleet and hail are other forms of frozen precipitation. Sleet occurs when raindrops fall into subfreezing air thick enough that the raindrops refreeze into ice before hitting the ground. The difference between sleet and hail is that sleet is a wintertime phenomenon whereas hail falls from convective clouds (usually thunderstorms), often during the warm spring and summer months.

Hail size refers to the diameter of the hailstones. Warnings may report hail size through comparisons with real-world objects that correspond to certain diameters shown in Table 22.

**Table 22: Hail Size Comparisons**

| Description | Diameter (inches) |
|---|---|
| Pea | 0.25 |
| Marble or mothball | 0.50 |
| Penny or dime | 0.75 |
| Nickel | 0.88 |
| Quarter | 1.00 |
| Half dollar | 1.25 |
| Walnut or ping pong ball | 1.50 |

| | |
|---|---|
| Golf ball | 1.75 |
| Hen's egg | 2.00 |
| Tennis ball | 2.50 |
| Baseball | 2.75 |
| Teacup | 3.00 |
| Grapefruit | 4.00 |
| Softball | 4.50 |

The greatest ice-related hazard is created by freezing rain conditions, which is rain that freezes on contact with hard surfaces leading to a layer of ice on roads, walkways, trees, and other surfaces. The conditions created by freezing rain can make driving particularly dangerous and emergency response more difficult. The weight of ice on tree branches can also lead to falling branches causing power outages and blocking roadways. The impacts of winter storms may also include roof collapses and property damage and injuries related to the weight of snow and ice.

The best available local data on previous ice storm and hail occurrences in Carlisle are for Middlesex County through the National Environmental Information Center (NEIC). Middlesex County, which includes Carlisle, had three ice storm events recorded from 1998 to 2020 (see Table 23). No deaths or injuries were reported and the total reported property damage in the county was $6.15 million dollars.

**Table 23: Middlesex County Ice Storm Events, 1998- 2020**

| Date | Deaths | Injuries | Property Damage |
|---|---|---|---|
| 1/9/1998 | 0 | 0 | 5,000 |
| 11/16/2002 | 0 | 0 | 150,000 |
| 12/11/2008 | 0 | 0 | 6,000,000 |
| **TOTAL** | **0** | **0** | **6,155,000** |

Source: NOAA, National Centers for Environmental Information

Ice storms are considered to be medium frequency events based on past occurrences. This hazard occurs once in five years to once in 50 years, with a 2% to 20% chance of occurring each year. However, according to the Massachusetts State Hazard Mitigation Plan, ice storms occur more frequently in the higher elevations of Western and Central Massachusetts.

Compared to ice storms, hail events are much more frequent in Middlesex County, but less damaging than ice storms. NEIC records show that Middlesex County experienced 25 hail events from 2010 to 2020, with no recorded property damage, injuries, or deaths (Table 24).

Hail events are considered to be medium frequency events in Carlisle based on past occurrences. This hazard occurs once in five years to once in 50 years, with a 2% to 20% chance of occurring each year.

## Table 24: Middlesex County Hail Events, 2010 through 2020

| DATE | MAGNITUDE | DEATHS | INJURIES | PROPERTY DAMAGE |
|---|---|---|---|---|
| 5/4/2010 | 0.75 | 0 | 0 | 0 |
| 5/7/2011 | 0.75 | 0 | 0 | 0 |
| 6/1/2011 | 0.75 | 0 | 0 | 0 |
| 8/2/2011 | 0.75 | 0 | 0 | 0 |
| 8/19/2011 | 0.75 | 0 | 0 | 0 |
| 3/13/2012 | 1.25 | 0 | 0 | 0 |
| 3/14/2012 | 1 | 0 | 0 | 0 |
| 6/23/2012 | 0.75 | 0 | 0 | 0 |
| 7/18/2012 | 1 | 0 | 0 | 0 |
| 10/30/2012 | 1 | 0 | 0 | 0 |
| 6/17/2013 | 0.75 | 0 | 0 | 0 |
| 5/25/2014 | 0.75 | 0 | 0 | 0 |
| 7/3/2014 | 1 | 0 | 0 | 0 |
| 8/7/2014 | 0.75 | 0 | 0 | 0 |
| 9/6/2014 | 0.88 | 0 | 0 | 0 |
| 8/4/2015 | 1 | 0 | 0 | 0 |
| 8/15/2015 | 0.75 | 0 | 0 | 0 |
| 7/23/2016 | .75 | 0 | 0 | 0 |
| 6/27/2017 | 1.00 | 0 | 0 | 0 |
| 8/2/2017 | .75 | 0 | 0 | 0 |
| 6/29/19 | .75 | 0 | 0 | 0 |
| 6/06/20 | 1.00 | 0 | 0 | 0 |
| 6/28/20 | 1.00 | 0 | 0 | 0 |
| 7/30/20 | .75 | 0 | 0 | 0 |
| 8/23/20 | 1.00 | 0 | 0 | 0 |
| **TOTAL** | | **0** | **0** | **0** |

*Magnitude refers to diameter of hail stones in inches
Source: NOAA, National Environmental Information Center

### *SEVERE THUNDERSTORMS*

While less severe than the other types of storms discussed, thunderstorms can lead to localized damage and represent a hazard risk for communities. Generally defined as a storm that includes thunder, which always accompanies lightning, a thunderstorm is a storm event featuring lightning, strong winds, and rain and/or hail. Thunderstorms sometime give rise to tornados. On average, these storms are only around 15 miles in diameter and last for about 30 minutes. A severe thunderstorm can include winds of close to 60 mph and rain sufficient to produce flooding. The town's entire area is potentially subject to severe thunderstorms.

The best available data on previous occurrences of thunderstorms in Carlisle are for Middlesex County through the National Centers for Environmental Information (NCEI). Between the years 2010 and 2020, NCEI records show 71 thunderstorm events in Middlesex County (Table 25). These storms resulted in a total of $3.336 million in property damages. There were seven injuries and no deaths reported.

**Table 25: Middlesex County Thunderstorm Wind Events, 2010-2020**

| Date | Magnitude-(knots) | Deaths | Injuries | Damage-$ |
|---|---|---|---|---|
| 5/4/2010 | 50 | 0 | 0 | 30000 |
| 6/1/2010 | 50 | 0 | 0 | 5000 |
| 6/3/2010 | 50 | 0 | 0 | 20000 |
| 6/5/2010 | 50 | 0 | 0 | 40000 |
| 6/6/2010 | 50 | 0 | 1 | 100000 |
| 6/24/2010 | 50 | 0 | 0 | 30000 |
| 7/12/2010 | 50 | 0 | 0 | 50000 |
| 7/19/2010 | 50 | 0 | 0 | 25000 |
| 6/1/2011 | 50 | 0 | 0 | 5000 |
| 6/9/2011 | 50 | 0 | 0 | 15000 |
| 8/2/2011 | 50 | 0 | 0 | 1000 |
| 8/19/2011 | 50 | 0 | 0 | 15000 |
| 6/8/2012 | 50 | 0 | 0 | 25000 |
| 6/23/2012 | 45 | 0 | 0 | 5000 |
| 7/4/2012 | 50 | 0 | 0 | 10000 |
| 7/18/2012 | 70 | 0 | 0 | 350000 |
| 9/7/2012 | 50 | 0 | 0 | 10000 |
| 9/8/2012 | 40 | 0 | 0 | 3000 |
| 6/17/2013 | 50 | 0 | 0 | 25000 |
| 6/18/2013 | 45 | 0 | 0 | 10000 |
| 6/24/2013 | 45 | 0 | 0 | 3000 |
| 7/23/2013 | 50 | 0 | 0 | 20000 |
| 7/29/2013 | 50 | 0 | 0 | 5000 |
| 7/3/2014 | 50 | 0 | 0 | 75000 |
| 7/7/2014 | 87 | 0 | 0 | 100000 |
| 7/15/2014 | 50 | 0 | 0 | 25000 |
| 7/28/2014 | 50 | 0 | 0 | 50000 |
| 9/6/2014 | 50 | 0 | 1 | 15000 |
| 5/28/2015 | 45 | 0 | 0 | 5000 |
| 8/4/2015 | 50 | 0 | 0 | 40000 |
| 8/15/2015 | 50 | 0 | 0 | 25000 |
| 2/25/2016 | 50 | 0 | 0 | 30000 |
| 3/17/2016 | 45 | 0 | 0 | 5000 |

| Date | Magnitude-(knots) | Deaths | Injuries | Damage-$ |
|---|---|---|---|---|
| 7/22/2016 | 50 | 0 | 0 | 14,000 |
| 7/23/2016 | 50 | 0 | 0 | 0 |
| 8/22/2016 | 50 | 0 | 0 | 0 |
| 9/11/2016 | 50 | 0 | 0 | 10,000 |
| 5/18/2017 | 50 | 0 | 0 | 0 |
| 6/13/2017 | 52 | 0 | 0 | 0 |
| 6/23/2017 | 52 | 0 | 0 | 1000 |
| 6/27/2017 | 50 | 0 | 0 | 0 |
| 7/12/2017 | 50 | 0 | 0 | 0 |
| 8/2/2017 | 50 | 0 | 0 | 0 |
| 9/6/2017 | 50 | 0 | 0 | 0 |
| 5/15/2018 | 40 | 0 | 0 | 0 |
| 6/18/2018 | 50 | 0 | 0 | 0 |
| 6/25/2018 | 43 | 0 | 0 | 0 |
| 7/17/2018 | 50 | 0 | 0 | 3000 |
| 7/26/2018 | 50 | 0 | 0 | 5000 |
| 8/7/2018 | 50 | 0 | 0 | 3000 |
| 8/17/2018 | 50 | 0 | 0 | 4000 |
| 9/6/2018 | 50 | 0 | 0 | 2000 |
| 10/23/2018 | 46 | 0 | 0 | 10,000 |
| 6/30/2019 | 50 | 0 | 0 | 800 |
| 7/17/2019 | 50 | 0 | 0 | 7250 |
| 7/31/2019 | 50 | 0 | 0 | 2500 |
| 8/7/2019 | 50 | 0 | 0 | 800 |
| 9/4/2019 | 55 | 0 | 0 | 26700 |
| 5/15/20 | 50 | 0 | 0 | 285,000 |
| 6/06/20 | 50 | 0 | 0 | 7000 |
| 6/21/20 | 50 | 0 | 0 | 38,200 |
| 6/28/20 | 55 | 0 | 0 | 6000 |
| 7/02/20 | 50 | 0 | 0 | 15300 |
| 7/05/20 | 50 | 0 | 0 | 12300 |
| 7/23/20 | 60 | 0 | 0 | 40600 |
| 7/30/20 | 50 | 0 | 0 | 3100 |
| 8/22/20 | 50 | 0 | 0 | 6000 |
| 8/23/20 | 50 | 0 | 0 | 25600 |
| 8/27/20 | 50 | 0 | 0 | 1600 |
| 10/07/20 | 61 | 0 | 5 | 6500 |
| 11/15/20 | 56 | 0 | 0 | |
| **TOTAL** | | **0** | ***7*** | **$3,336,000** |

Source: NOAA, National Centers for Environmental Information
Magnitude refers to maximum wind speed in knots.

Severe thunderstorms are a town-wide hazard for Carlisle. The town's vulnerability to severe thunderstorms is similar to that of nor'easters. High winds can cause falling trees and power outages, as well as obstruction of key routes and emergency access. Heavy precipitation may also cause localized flooding, both riverine and urban drainage related.

Based on the record of previous occurrences, severe thunderstorms in Carlisle are high frequency events. This hazard may occur more frequently than once in 5 years (greater than 20% per year).

***Thunderstorms and Climate Change***

As noted previously, the intensity of rainfall events has increased significantly, and those trends are expected to continue. The SHMCAP does not specifically address whether climate will affect the intensity or frequency of thunderstorms.

***TORNADOS***

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud. These events are spawned by thunderstorms and occasionally by hurricanes and may occur singularly or in multiples. They develop when cool air overrides a layer of warm air, causing the warm air to rise rapidly. Most vortices remain suspended in the atmosphere. Should they touch down, they become a force of destruction. Some ingredients for tornado formation include:

- Very strong winds in the mid and upper levels of the atmosphere
- Clockwise turning of the wind with height (from southeast at the surface to west aloft)
- Increasing wind speed with altitude 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

Tornado damage severity is measured by the Fujita Tornado Scale, in which wind speed is not measured directly but rather estimated from the amount of damage. As of February 1, 2007, the National Weather Service began rating tornados using the Enhanced Fujita-scale (EF-scale), which allows surveyors to create more precise assessments of tornado severity. The EF-scale is summarized in Table 26 below.

The frequency of tornadoes in eastern Massachusetts is low; on average, there are six tornadoes that touchdown somewhere in the Northeast region every year. The strongest tornado in Massachusetts history was the Worcester Tornado in 1953 (NESEC). Recent tornado events in Massachusetts were in Springfield in 2011 and in Revere in 2014. The Springfield tornado caused significant damage and resulted in four deaths in June of 2011. The Revere tornado

touched down in Chelsea just south of Route 16, moved north into Revere's business district along Broadway, and ended near the intersection of Routes 1 and 60. The path was approximately two miles long and 3/8 mile wide, with wind speeds up to 120 miles per hour. Approximately 65 homes had substantial damages and 13 homes and businesses were rendered uninhabitable.

**Table 26: 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

On August 22, 2016, an F1 tornado passed through part of neighboring Concord. It impacted an area 0.85 miles long by 400 yards wide. According to the report from the National Centers for Environmental Information:

> "This tornado touched down near the Cambridge Turnpike and headed northeast. Most of the damage was concentrated in an area beginning near the intersection of Lexington Road and Alcott Road and continuing up to the neighborhood of Alcott and Independence Roads. Numerous trees were uprooted or had the tops sheared off. These subsequently blocked roads, damaged homes, and downed power lines, cutting off power to the neighborhood. In addition, utility poles were downed either from the wind or from the downed power lines. Thirty-nine houses in this area were damaged to some degree. Only one house suffered significant structural damage. The tornado continued for a short distance beyond this neighborhood before lifting. The historical home of Louisa May Alcott and her family was right next to the tornado path but was not damaged.

Since 1955, there have been 18 tornadoes in Middlesex County recorded by the NCEI. Two tornados were F3, four were F2, 10 were F1 and two were F 0. These 11 tornadoes resulted in one fatality and four injuries and $4.88 million in damages, as summarized in Table 27.

**Table 27: Tornado Records for Middlesex County**

| Date | Fujita Scale | Deaths | Injuries | Property Damage $ | Length | Width |
|---|---|---|---|---|---|---|
| 10/24/1955 | 1 | 0 | 0 | 2.50K | 10 | 0.1 |
| 6/19/1957 | 1 | 0 | 0 | 25.00K | 17 | 1 |
| 6/19/1957 | 1 | 0 | 0 | 0.25K | 100 | 0.5 |
| 7/11/1958 | 2 | 0 | 0 | 250.00K | 17 | 1.5 |

| Date | Fujita Scale | Deaths | Injuries | Property Damage $ | Length | Width |
|---|---|---|---|---|---|---|
| 8/25/1958 | 2 | 0 | 0 | 2.50K | 50 | 1 |
| 7/3/1961 | 0 | 0 | 0 | 25.00K | 10 | 0.5 |
| 7/18/1963 | 1 | 0 | 0 | 25.00K | 50 | 1 |
| 8/28/1965 | 2 | 0 | 0 | 250.00K | 10 | 2 |
| 7/11/1970 | 1 | 0 | 0 | 25.00K | 50 | 0.1 |
| 10/3/1970 | 3 | 1 | 0 | 250.00K | 60 | 35.4 |
| 7/1/1971 | 1 | 0 | 1 | 25.00K | 10 | 25.2 |
| 11/7/1971 | 1 | 0 | 0 | 0.25K | 10 | 0.1 |
| 7/21/1972 | 2 | 0 | 4 | 2.500M | 37 | 7.6 |
| 9/29/1974 | 3 | 0 | 1 | 250.00K | 33 | 0.1 |
| 7/18/1983 | 0 | 0 | 0 | 0.25K | 20 | 0.4 |
| 9/27/1985 | 1 | 0 | 0 | 0.25K | 40 | 0.1 |
| 8/7/1986 | 1 | 0 | 0 | 250.00K | 73 | 4 |
| 8/22/2016 | 1 | 0 | 0 | 1.000M | 400 | .85 |
| **TOTAL** | | **1** | **6** | **$4.88 M** | | |

Source: The Tornado History Project

Buildings constructed prior to current building codes may be more vulnerable to damages caused by tornadoes. Evacuation of impacted areas may be required on short notice. Sheltering and mass feeding efforts may be required along with debris clearance, search and rescue, and emergency fire and medical services. Key routes may be blocked by downed trees and other debris, and widespread power outages are also typically associated with tornadoes.

Although tornadoes are a potential town-wide hazard in Carlisle, tornado impacts are relatively localized compared to severe storms and hurricanes. Damages from any tornado in Carlisle would greatly depend on the track of the tornado. The greatest damages would be cause if a tornado passed through the town center area, which has the greatest density of buildings and population in town.

Based on the record of previous occurrences since 1956, Tornado events in Carlisle are a very low frequency event as there is no record of tornado activity in Carlisle. This hazard occurs less frequently than once in 100 years (less than 1% per year).

**Tornadoes and Climate Change**

According to the SHMCAP, it is possible that severe thunderstorms which can include tornadoes may increase in frequency and intensity. However, scientists have less confidence in the models that seek to project future changes in tornado activity.

## NON-CLIMATE INFLUENCED HAZARDS

Geologic hazards include earthquakes, landslides, sinkholes, subsidence, and unstable soils such as fill, peat, and clay. The HMP/MVP Core Team did not identify any problems with areas of geologic instability, such as sinkholes or subsidence. Although new construction under recent building codes generally will be built to seismic standards, there are still many structures in town which pre-date building code updates. Information on geologic hazards in Carlisle can be found on Map 4 in Appendix A.

### *EARTHQUAKES*

Damage in an earthquake stems from ground motion, surface faulting, and ground failure in which weak or unstable soils, such as those composed primarily of saturated sand or silts, liquefy. The effects of an earthquake are mitigated by distance and ground materials between the epicenter and a given location. An earthquake in New England affects a much wider area than a similar earthquake in California due to New England's solid bedrock geology` (NESEC).

Seismologists use a magnitude scale known as the Richter scale to express the seismic energy released by each earthquake. The typical effects of earthquakes in various ranges are summarized in Table 28.

**Table 28: Richter Scale and Effects**

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

Source: Nevada Seismological Library (NSL), 2005

According to the State Hazard Mitigation Plan, New England experiences an average of five earthquakes per year. From 1668 to 2007, 355 earthquakes were recorded in Massachusetts (NESEC). Most have originated from the La Malbaie fault in Quebec or from the Cape Ann fault located off the coast of Rockport. The region has experienced larger earthquakes in the distant past, including a magnitude 5.0 earthquake in 1727 and a 6.0 earthquake that struck in 1755 off the coast of Cape Ann. More recently, a pair of damaging earthquakes occurred near Ossipee, NH in 1940. A 4.0 earthquake centered in Hollis, Maine in October 2012 was felt in the

Boston area. Historic records of some of the more significant earthquakes in the region are shown in Table 29.

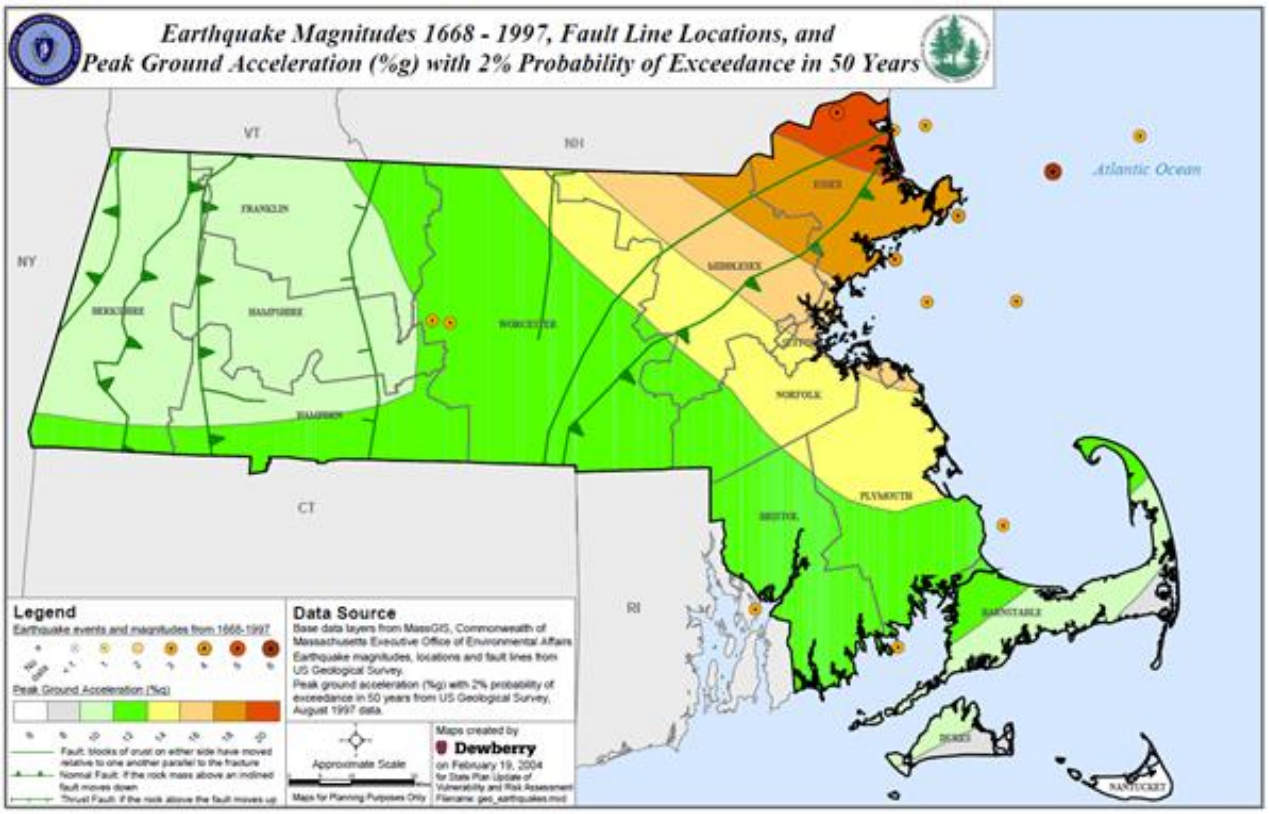
**Table 29: Historical Earthquakes in Massachusetts or Surrounding Area**

| Location | Date | Magnitude |
|---|---|---|
| MA - Cape Ann | 11/10/1727 | 5 |
| MA - Cape Ann | 12/29/1727 | NA |
| MA - Cape Ann | 2/10/1728 | NA |
| MA - Cape Ann | 3/30/1729 | NA |
| MA - Cape Ann | 12/9/1729 | NA |
| MA - Cape Ann | 2/20/1730 | NA |
| MA - Cape Ann | 3/9/1730 | NA |
| MA - Boston | 6/24/1741 | NA |
| MA - Cape Ann | 6/14/1744 | 4.7 |
| MA – Salem | 7/1/1744 | NA |
| MA - Off Cape Ann | 11/18/1755 | 6 |
| MA - Off Cape Cod | 11/23/1755 | NA |
| MA - Boston | 3/12/1761 | 4.6 |
| MA - Off Cape Cod | 2/2/1766 | NA |
| MA - Offshore | 1/2/1785 | 5.4 |
| MA - Wareham/Taunton | 12/25/1800 | NA |
| MA - Woburn | 10/5/1817 | 4.3 |
| MA - Marblehead | 8/25/1846 | 4.3 |
| MA - Brewster | 8/8/1847 | 4.2 |
| MA - Boxford | 5/12/1880 | NA |
| MA - Newbury | 11/7/1907 | NA |
| MA - Wareham | 4/25/1924 | NA |
| MA - Cape Ann | 1/7/1925 | 4 |
| MA - Nantucket | 10/25/1965 | NA |
| MA - Boston | 12/27/74 | 2.3 |
| MA - Nantucket | 4/12/12 | 4.5 |
| ME – Hollis | 10/17/12 | 4.0 |

Source: Boston HIRA

One measure of earthquake risk is ground motion, which is measured as maximum peak horizontal acceleration, expressed as a percentage of gravity (%g). The range of peak ground acceleration in Massachusetts is from 10 %g to 20 %g, with a 2% probability of exceedance in 50 years. Carlisle is in the middle to upper part of the range for Massachusetts, at 16 %g to 18 %g, (Figure 19), making it a relatively moderate area of earthquake risk within the state, although the state as a whole is considered to have a low risk of earthquakes compared to the rest of the country. There have been no recorded earthquake epicenters within Carlisle.

**Figure 19: State of Massachusetts Earthquake Probability Map**




Source: Massachusetts Hazard Mitigation Plan

Although New England has not experienced a damaging earthquake since 1755, seismologists state that a serious earthquake occurrence is possible. There are five seismological faults in Massachusetts, but there is no discernible pattern of previous earthquakes along these fault lines. Earthquakes occur without warning and may be followed by aftershocks. The majority of older buildings and infrastructure were constructed without specific earthquake resistant design features.

Earthquakes are a hazard with multiple impacts beyond the obvious building collapse. Buildings may suffer structural damage which may or may not be readily apparent. Earthquakes can cause major damage to roadways, making emergency response difficult. Water lines and gas lines can break, causing flooding and fires. Another potential vulnerability is equipment within structures. For example, a hospital may be structurally engineered to withstand an earthquake, but if the equipment inside the building is not properly secured, the operations at the hospital could be severely impacted during an earthquake. Earthquakes can also trigger landslides.

According to the Boston College Weston Observatory, in most parts of New England, there is a one in ten chance that a potentially damaging earthquake will occur in a 50-year time period. The Massachusetts State Hazard Mitigation Plan classifies earthquakes as "very low" frequency events that occur less frequently than once in 100 years, or a less than 1% chance per year.

Earthquakes are a potential town-wide hazard for Carlisle. 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 most recent building code. Potential earthquake damages to Carlisle have been estimated using HAZUS-MH. Total building damages are estimated at $103.6 million for a 5.0 magnitude earthquake and $895.8 million for a 7.0 magnitude earthquake. Other potential impacts of earthquakes such as sheltering and debris generation, are detailed in Table 35.

***LANDSLIDES***

According to the U.S. Geological Survey, "The term landslide includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity acting on an over steepened slope is the primary reason for a landslide, there are other contributing factors." Among the contributing factors are 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.

In Massachusetts, according to the SHMCAP, the most common cause of landslides are geologic conditions combined with steep slopes and/or heavy rains. Landslides associated with heavy rains typically occur on steep slopes with permeable soils underlain by till or bedrock.

Landslides can result from human activities that destabilize an area or can occur as a secondary impact from another natural hazard, such as flooding. In addition to structural damage to buildings and the blockage of transportation corridors, landslides can lead to sedimentation of water bodies. Typically, a landslide occurs when the condition of a slope changes from stable to unstable. Natural precipitation such as heavy snow accumulation, torrential rain, and run-off may saturate soil, creating instability enough to contribute to a landslide.

Changes in precipitation may increase the chance of landslides, as extreme rain events could result in more frequent saturated soils which are conducive to landslides. Drought may also increase the likelihood of landslides if loss of vegetation decreases soil stability.

There is no universally accepted measure of landslide extent, but it has been represented as a measure of the destructiveness. Table 30 summarizes the estimated intensity for a range of landslides. Fast moving rock falls have the highest intensity while slow moving landslides have the lowest intensity.

The majority of Carlisle is classified as having a low incidence of landslides, while a small area to the east along the Concord River is classified a low incidence and moderate susceptibility to landslides (see Map 4, Appendix A). Much of this area is in the floodplain with open space and little development.

**Table 30: Landslide Volume and Velocity**

| Estimated 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: *A Geomorphological Approach to the Estimation of Landslide Hazards and Risks in Umbria, Central Italy*, M. Cardinali et al, 2002

There is no history of damaging landslides in Carlisle and the HMP/MVP Core Team did not identify any significant issues related to landslides. Should a landslide occur in the future, the type and degree of impacts would be highly localized. Although unlikely, the Town's vulnerabilities could include damage to structures, transportation and other infrastructure, and localized road closures. Injuries and casualties, while possible, would be unlikely given the low extent and impact of landslides in Carlisle.

The SHMCAP, utilizing data from the MA Department of Transportation from 1986 to 2006 estimates that, on average, roughly one to three known landslides have occurred each year. A slope stability map published by the MA Geological Survey and UMass-Amherst indicates that the most significant risk of landslide is in western Massachusetts.

Based on past occurrences, landslides are considered to be a very low frequency events in Carlisle, events that occur less frequently than once in 100 years (less than 1% per year)

## LAND USE AND DEVELOPMENT TRENDS

### *EXISTING LAND USE*

The most recent land use statistics available from the state are from aerial photography done in 2005. Some change has certainly occurred in Carlisle since then, but this data still provides the most detailed town wide description of land use available. Table 31 shows the acreage and percentage of land in 21 categories.

The table indicates that Carlisle is predominantly forested – 73% of the community is characterized as forest or forested wetland, one of the highest in the MAPC region. The second largest land use in Carlisle is low-density housing, comprising 28.1% of the town's land area. Cropland and pasture make up 5.1% of the total. Being a predominantly residential community, commercial uses make up only 0.2% of the

town and only 0.1% is industrial land use. Approximately one-third of the Town's land is permanently protected open space.

**Table 31: Town of Carlisle, MA 2005 Land Use**

| Land Type | Acres | Percent |
|---|---|---|
| Brushland/Successional | 0.6 | 0.0 |
| Cemetery | 10.2 | 0.1 |
| Commercial | 22.7 | 0.2 |
| Cranberry Bog | 48.6 | 0.5 |
| Cropland | 308.2 | 3.1 |
| Forest | 5758.6 | 58.0 |
| Forested Wetland | 1524.8 | 15.3 |
| Industrial | 9.0 | 0.1 |
| Low Density Residential | 864.6 | 8.7 |
| Medium Density Residential | 0.2 | 0.0 |
| Multi-Family Residential | 23.3 | 0.2 |
| Non-Forested Wetland | 464.7 | 4.7 |
| Nursery | 0.8 | 0.0 |
| Open Land | 69.5 | 0.7 |
| Participation Recreation | 22.2 | 0.2 |
| Pasture | 196.6 | 2.0 |
| Powerline/Utility | 19.7 | 0.2 |
| Transitional | 8.4 | 0.1 |
| Urban Public/Institutional | 26.2 | 0.3 |
| Very Low Density Residential | 460.4 | 4.6 |
| Waste Disposal | 1.7 | 0.0 |
| Water | 94.2 | 0.9 |
| **Total Acres** | **9935.4** | 100 |

For more information on how the land use statistics were developed and the definitions of the categories, please go to http://www.mass.gov/mgis/lus.htm

## DEVELOPMENT TRENDS

Development trends throughout the metropolitan region are tracked by MassBuilds, MAPC's Development Database, which provides an inventory of new development over the last 15 years. The database includes fourteen projects in the Town of Carlisle since 2007 (Table 32). The database also includes other attributes of the recent developments, including housing units. The fourteen developments include a total of 195 housing units.

**Table 32: Summary of Carlisle Developments, 2007-2020**

| Name | Project Type | Housing Units | Year | |
|---|---|---|---|---|
| Hobblebush Lane | Residential | 4 | | 2009 |
| Benfield Farms | Residential | 26 | 26 affordable, age-restricted units by nonprofit developer (NOAH) | 2016 |
| Garrison Place | Residential | 16 | "Senior Residential Open Space Community (SROSC) Sixteen condominiums on 12 acres with 22 acres preserved as open space | 2018 |
| Lifetime Green Homes | Residential | 20 | 20-unit 40B residential development | 2020 |
| Hart Farm Estates | Residential | 12 | | 2007 |
| Pine Meadow Carlisle | Residential | 15 | | 2007 |
| Rocky Point | Residential | 8 | 4 duplexes with 2 affordable units | 2007 |
| Carriage Way | Residential | 10 | | 2007 |
| Greystone Crossing | Residential | 23 | 15 cluster lots & 8 ANR lots | 2020 |
| Great Brook Estates | Residential | 10 | | 2007 |
| Hanover Hill | Residential | 35 | | 2020 |
| Chestnut Estates | Residential | 7 | LID techniques employed | 2011 |
| Apple Grove Lane | Residential | 4 | | 2009 |
| Maplewood | Residential | 5 | | 2012 |

The development database includes a GIS analysis of the location of development sites with respect to hazard areas such a flooding, landslide risk, annual snowfall, and maximum wind speed. Only a portion of one site, the Maplewood, is partially within the X: 0.2% Annual Chance of Flooding zone. None of the new development sites are located within a locally identified flood area of concern or area of potential wildfire concern. Other categories of hazards are geographically uniform across the town, so all sites are within the same hazard categories. This includes landslide risk, which is "Low Incidence" for all sites, average annual snowfall, which is 48 to 72 inches for all sites, and maximum wind speed, which is 110 miles per hour for all sites. The recent development does not significantly increase the Town's vulnerability to natural hazards.

## POTENTIAL FUTURE DEVELOPMENT

MAPC consulted with the Carlisle HMP/MVP Core Team to determine areas that may be developed in the future, based on the Planning Board records of pending development applications. A total of ten sites were identified and mapped. These areas are listed below in Table 33 and shown on Map 8 in Appendix A, using the Map ID letters in the first column.

**Table 33 Potential future development projects:**

| Map ID | Name | Description | |
|---|---|---|---|
| A | Long Term Development | Potential Development | 7.7% in AE: 1% Annual Chance of Flooding, with BFE |
| G | Chestnut Estates Cluster Development (6 units) | Potential Development | 15.43% in X: 0.2% Annual Chance of Flooding |
| H | Elliott Farms Way | Conservation Cluster (7 lots) | 17.22% in AE: 1% Annual Chance of Flooding, with BFE |
| I | Judy Farm Road #61 (1) | 6-lot CD | 51.45% in X: 0.2% Annual Chance of Flooding |
| J | 81 Russell Street | 16 Unit SROSC | 10.64% in AE: 1% Annual Chance of Flooding, with BFE |
| K | 570 West Street | 4-lot subdivision | |
| L | 48 Bingham Road | 2-lot CD | 47.61% in X: 0.2% Annual Chance of Flooding |
| M | 267 R | 3-lot CD | 66.31% in X: 0.2% Annual Chance of Flooding |
| N | 491, 495 Cross Street | CD amendment (2-lot, paving) | 6.93% in AE: 1% Annual Chance of Flooding, with BFE |
| O | South Street | Wetlands Protection Act filing before Carlisle Cons. Comm. | 8.44% in X: 0.2% Annual Chance of Flooding |

As with the recent new development, a GIS analysis was conducted on the potential future development sites with respect to hazard areas such a flooding, landslide risk, annual snowfall, and maximum wind speed. Most of the sites are partially within a designated flood zone, typically a part of site outside of the building envelope, given Carlisle's Floodplain Overlay Zoning restrictions. As described above all other hazards are uniform across the entire town, so all of the sites are within the area classified as "Low Incidence" for landslide, within the area of 48 to 72 inches of average annual snowfall, and all are within the zone of maximum wind speed of 110 miles per hour. The new development does not significantly increase the Town's vulnerability to natural hazards.

## CRITICAL INFRASTRUCTURE IN HAZARD AREAS

Critical infrastructure includes facilities that are important for disaster response and evacuation (such as emergency operations centers, fire stations, water pump stations, etc.) and facilities where additional assistance might be needed during an emergency (such as nursing homes, elderly housing, day care centers, etc.). There are 94 facilities identified in Carlisle. These are listed in Table 33 and are shown on the maps in Appendix A.

The purpose of mapping the natural hazards overlaying the critical facilities is to present an overview of hazards in the community and how they relate to critical facilities.

Much of the Critical infrastructure in Carlisle is clustered near the center of town, with several critical sites scattering the outer edges of the town. The table shows two facilities located in the X: 0.2% Annual Chance (500-year) FEMA flood zone, one located in the AE 1% Annual Chance (100-year) flood zone, and eight facilities are located within the AE Regulatory Floodway. However, these are all dams, which by definition are located in the floodway. Aside from the dams, the only facilities in a flood hazard zone are a cistern and the Public Works Dept, which is in an X, 0.2% chance of flooding zone.

Three sites were identified by the Fire Chief for brush fire potential, Town Hall, Malcom Meadows and the Children's Place.

Landslide risks are considered "low incidence" in most of the town, with one area to the southeast that is classified as "Low Incidence and Moderate Susceptibility." The table below indicates that all but four Critical Facility sites are located in the "Low Incidence" area.

The entire town has snow accumulation averages of 48-72 inches and therefore all critical facilities fall within this category. This also holds true for average wind speeds, which are uniform at 110 mph throughout the town.

The breakdown of the critical sites and how they relate to selected hazards follows in Table 34.

**Explanation of Columns in Table 34**

- ***Column 1: ID #:*** The first column in Table 34 is an ID number which appears on the maps that are part of this plan. See Appendix A.
- ***Column 2: Name****:* The second column is the name of the site.
- ***Column 3: Type*:** The third column indicates what type of site it is.
- ***Column 4: FEMA Flood Zone*:** The fourth column addresses the risk of flooding. A "No" entry in this column means that the site is not within any of the mapped risk zones on the Flood Insurance Rate Maps (FIRM maps). If there is an entry in this column, it indicates the type of flood zone. as follows: **Zone AE** (1% annual chance) **-** Zones AE is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the FIS by detailed methods. Mandatory flood insurance purchase requirements apply.

  **Zone VE** (1% annual chance) **-** 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.

  **Zone X** (.2% annual chance) - Zones X is the flood insurance rate zone that corresponds to the 500-year floodplains.
- ***Column 5: Brush Fire Area:*** The sixth column indicates the risk of brush fire in local hazard areas. A "No" entry in this column means that the site is not within any of the mapped brush fire hazard zones. If there is an entry in this column, it indicates the local hazard area.
- ***Column 6:*** **Hot spots** indicates areas that are within the 5% of hottest areas in the MAPC region based on satellite data from 2016.
- ***Colum 7:*** **Landslides**: Infrastructure in areas of Low Incidence (Low) or Low Incidence/Moderate Susceptibility (Mod/Low)
- ***Column 8: Average Annual Snowfall***

**Table 34: Critical Facilities and Relationship to Hazard Areas**

| MAP # | FACILITY NAME | FACILITY TYPE | FEMA FLOOD ZONE | BRUSH FIRE | HOT SPOT | LANDSLIDE | AVG. ANNUAL SNOWFALL |
|---|---|---|---|---|---|---|---|
| 1 | Department of Public Works | Municipal | X: 0.2% Annual Chance | No | No | Low | 48.1 - 72.0 |
| 2 | Department of Public Works | Municipal | No | No | No | Low | 48.1 - 72.0 |
| 3 | Fire Department | Fire Station | No | No | No | Low | 48.1 - 72.0 |
| 4 | Police Department | Police Station | No | No | No | Low | 48.1 - 72.0 |
| 5 | Carlisle Public School Complex | School | No | No | No | Low | 48.1 - 72.0 |
| 6 | Town Hall | Municipal | No | Yes | No | Low | 48.1 - 72.0 |
| 7 | Carlisle Elder Housing | Elder Housing | No | No | No | Low | 48.1 - 72.0 |
| 8 | Malcolm Meadows | Elder Housing | No | Yes | No | Low | 48.1 - 72.0 |
| 9 | Pump Station @ School | Wastewater Treatment | No | No | No | Low | 48.1 - 72.0 |
| 10 | Wastewater Treatment | Wastewater Treatment | No | No | Yes | Low | 48.1 - 72.0 |
| 11 | The Red Balloon Nursery School | Child Care | No | No | No | Low | 48.1 - 72.0 |
| 12 | The Children's Place | Child Care | No | Yes | No | Low | 48.1 - 72.0 |
| 13 | Noah's Ark Nursery School | Child Care | No | No | No | Low | 48.1 - 72.0 |
| 14 | Concord Montessori School #1 | Child Care | No | No | No | Low | 48.1 - 72.0 |
| 15 | Carlisle Extended Day Program | Child Care | No | No | No | Low | 48.1 - 72.0 |
| 16 | Carlisle Early Literacy Preschool | Child Care | No | No | Yes | Low | 48.1 - 72.0 |
| 17 | Carlisle Congregational Church | Church | No | No | No | Low | 48.1 - 72.0 |
| 18 | Fire Station | Hazardous Material Site | No | No | No | Low | 48.1 - 72.0 |
| 19 | Fire Station PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 20 | Town Hall PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 21 | Library PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 22 | School PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |

| MAP # | FACILITY NAME | FACILITY TYPE | FEMA FLOOD ZONE | BRUSH FIRE | HOT SPOT | LANDSLIDE | AVG. ANNUAL SNOWFALL |
|---|---|---|---|---|---|---|---|
| 23 | State Park | Dam | No | No | Yes | Low | 48.1 - 72.0 |
| 24 | Greenough Pond | Dam | AE: Regulatory Floodway | No | No | Low | 48.1 - 72.0 |
| 25 | Milne Cove | Dam | AE: Regulatory Floodway | No | No | Low/Mod | 48.1 - 72.0 |
| 26 | Hobblebush Lane | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 27 | Buttrick Lane | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 28 | Aaron Way | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 29 | Cranberry Hill | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 30 | Elizabeth Ridge Rd. #1 | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 31 | Elizabeth Ridge Rd. #2 | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 32 | Hart Farm Rd. #2 | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 33 | Hart Farm Rd. #1 | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 34 | Daniel's Lane | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 35 | Hutchins Road | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 36 | Swanson Lane | Cistern Water Source | X: 0.2% Annual Chance | No | No | Low | 48.1 - 72.0 |
| 37 | Kimball Road | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 38 | Nathan Lane | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 39 | Sunset Road | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 40 | Rocky Point (Lowell Road) | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 41 | Carriage Way | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 42 | Davis Road | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 43 | Ice Pond Road | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 44 | Nickles Lane | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |

| MAP # | FACILITY NAME | FACILITY TYPE | FEMA FLOOD ZONE | BRUSH FIRE | HOT SPOT | LANDSLIDE | AVG. ANNUAL SNOWFALL |
|---|---|---|---|---|---|---|---|
| 45 | Patch Meadow Lane | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 46 | Great Brook Path | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 47 | Tanglewood Drive | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 48 | Woodbine Rd. Ext. | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 49 | High Woods | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 50 | Koning Farm Rd. | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 51 | Suffolk Lane | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 52 | Rodgers Road | Cistern Water Source | No | No | Yes | Low | 48.1 - 72.0 |
| 53 | Malcom Meadows | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 54 | Applegrove Lane | Cistern Water Source | No | No | No | Low | 48.1 - 72.0 |
| 55 | Wee Forest Folk PWS | Public Water Supply | No | No | No | Low/Mod | 48.1 - 72.0 |
| 56 | Cell Tower | Communication Tower | No | No | No | Low | 48.1 - 72.0 |
| 57 | Cell Tower | Communication Tower | No | No | No | Low/Mod | 48.1 - 72.0 |
| 58 | Great Brook Farm State Park PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 59 | Great Brook State Park PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 60 | Carlisle Town Hall PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 61 | Saint Irene's Church PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 62 | Carlisle Extended Day Program PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 63 | First Religious Society PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 64 | Carlisle Congregational Church | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 65 | Kimball Farms Ice Cream PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 66 | The Children's Place PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 67 | Assurance Technology Corp. PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |

| MAP # | FACILITY NAME | FACILITY TYPE | FEMA FLOOD ZONE | BRUSH FIRE | HOT SPOT | LANDSLIDE | AVG. ANNUAL SNOWFALL |
|---|---|---|---|---|---|---|---|
| 68 | Assurance Technology Corp. PWS | Public Water Supply | No | No | No | Low | 48.1 - 72.0 |
| 69 | Carlisle Animal Hospital | Animal Hospital | No | No | No | Low/Mod | 48.1 - 72.0 |
| 70 | Cranberry Bog | Dam | AE: 1% Annual Chance of Flooding; with BFE | No | No | Low | 48.1 - 72.0 |
| 71 | Cranberry Bog No 1 | Dam | No | No | Yes | Low | 48.1 - 72.0 |
| 72 | Curve St. | Dam | AE: Regulatory Floodway | No | No | Low | 48.1 - 72.0 |
| 73 | Meadow Brook | Dam | AE: Regulatory Floodway | No | No | Low | 48.1 - 72.0 |
| 74 | Lowell Rd. | Dam | AE: Regulatory Floodway | No | No | Low | 48.1 - 72.0 |
| 75 | Cabin Pond | Dam | No | No | Yes | Low | 48.1 - 72.0 |
| 76 | Spencer Brook | Dam | AE: Regulatory Floodway | No | No | Low | 48.1 - 72.0 |
| 79 | Lions Gate Cistern | Fire Protection | No | No | No | Low | 48.1 - 72.0 |
| 77 | Benfield Farms | Elder housing | No | No | No | Low | 48.1 - 72.0 |
| 78 | Garrison Place | Elder housing | No | No | No | Low | 48.1 - 72.0 |
| 81 | Hemlock Hill Cistern | Fire Protection | No | No | No | Low | 48.1 - 72.0 |
| 80 | Birch Lane Cistern | Fire Protection | No | No | No | Low | 48.1 - 72.0 |

# VULNERABILITY ASSESSMENT

The purpose of the 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 hurricanes, earthquakes, and flooding through the HAZUS-MH software.

Introduction to HAZUS-MH

HAZUS- MH (multiple-hazards) is a computer program developed by FEMA to estimate losses due to a variety of natural hazards. The following overview of HAZUS-MH is taken from the FEMA website. For more information on the HAZUS-MH software, go to http://www.fema.gov/plan/prevent/hazus/index.shtm

> "HAZUS-MH is a nationally applicable standardized methodology and software program that contains models for estimating potential losses from earthquakes, floods, and hurricane winds. HAZUS-MH was developed by the Federal Emergency Management Agency (FEMA) under contract with the National Institute of Building Sciences (NIBS). Loss estimates produced by HAZUS-MH are based on current scientific and engineering knowledge of the effects of hurricane winds, floods, and earthquakes. Estimating losses is essential to decision-making at all levels of government, providing a basis for developing and evaluating mitigation plans and policies as well as emergency preparedness, response, and recovery planning.
>
> HAZUS-MH uses state-of-the-art geographic information system (GIS) software to map and display hazard data and the results of damage and economic loss estimates for buildings and infrastructure. It also allows users to estimate the impacts of hurricane winds, floods and earthquakes on populations."

There are three modules included with the HAZUS-MH software: hurricane wind, flooding, and earthquakes. There are also three levels at which HAZUS-MH can be run. Level 1 uses national baseline data and is the quickest way to begin the risk assessment process. The analysis that follows was completed using Level 1 data. Level 1 relies upon default data on building types, utilities, transportation, etc. from national databases as well as census data. While the databases include a wealth of information on the Town of Carlisle, it does not capture all relevant information. In fact, the HAZUS training manual notes that the default data is "subject to a great deal of uncertainty."

However, for the purposes of this plan, the analysis is useful. This plan is attempting to generally indicate the possible extent of damages due to certain types of natural disasters and to allow for a comparison between different types of disasters. Therefore, this analysis should be considered to be a starting point for understanding potential damages from the hazards.

## Estimated Damages from Hurricanes

The HAZUS software was used to model potential damages to the community from a 100-year and 500-year hurricane event; storms that are 1% and 0.2% likely to happen in a given year, and roughly equivalent to a Category 2 and Category 4 hurricane. The damages caused by these hypothetical storms were modeled as if the storm track passed directly through the town, bringing the strongest winds and greatest damage potential.

Though there are no recorded instances of a hurricane equivalent to a 500-year storm passing through Massachusetts, this model was included in order to present a reasonable "worst case scenario" that would help planners and emergency personnel evaluate the impacts of storms that might be more likely in the future, as we enter into a period of more intense and frequent storms.

**Table 35: Estimated Damages from Hurricanes**

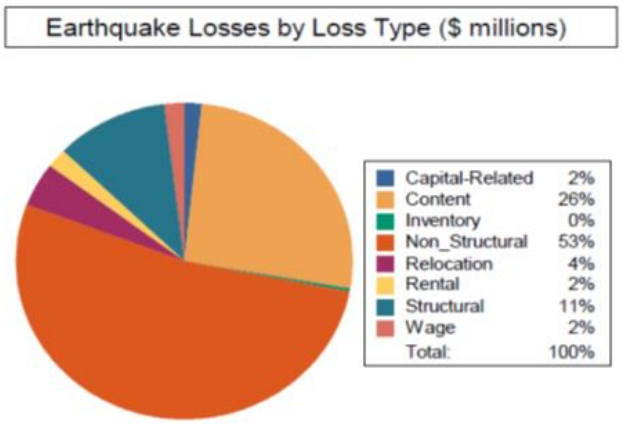
| | 100 Year | 500 Year |
|---|---|---|
| **Building Characteristics** | | |
| Estimated total number of buildings | 1,889 | |
| Estimated total building replacement value (2014 $) | $962,000,000 | |
| | | |
| **Building Damages** | | |
| # of buildings sustaining minor damage | 24 | 201 |
| # of buildings sustaining moderate damage | 1 | 18 |
| # of buildings sustaining severe damage | | 1 |
| # of buildings destroyed | | |
| | | |
| **Population Needs** | | |
| # of households displaced | 0 | 0 |
| # of people seeking public shelter | 0 | 0 |
| | | |
| **Debris** | | |
| Building debris generated (tons) | 72 | 457 |
| Tree debris generated (tons) | 3878 | 11,213 |
| **Total** | **3950** | **11,670** |
| # of truckloads to clear building debris | | |
| | | |
| **Value of Damages** | | |
| Total property damage (buildings and content) (Thousands of dollars) | $6,111.92 | $19,675.88 |
| Total losses due to business interruption (Thousands of dollars) | $4.96 | $401.47 |
| **Total** | **$6,116.88** | **$20.077.35** |

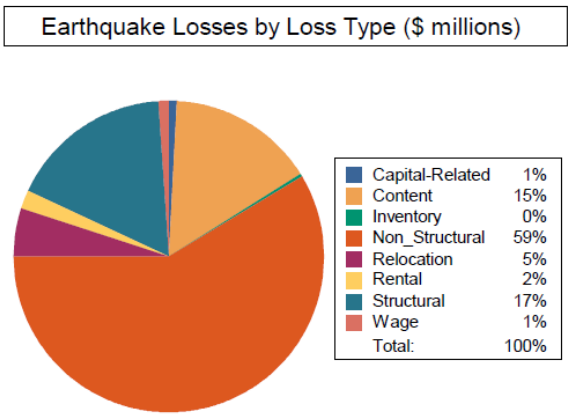
## Estimated Damages from Earthquakes

The HAZUS earthquake module allows users to define an earthquake magnitude and model the potential damages caused by that earthquake as if its epicenter had been at the geographic center of the study area. For the purposes of this plan, two earthquakes were selected: magnitude 5.0 and a magnitude 7.0. Historically, major earthquakes are rare in New England, though a magnitude 5 event occurred in 1963.

**Table 36: Estimated Damages from Earthquakes**

| | Magnitude 5.0 | Magnitude 7.0 |
|---|---|---|
| **Building Characteristics** | | |
| Estimated total number of buildings | 1,889 | |
| Estimated total building replacement value (2014 $) (Millions of dollars | $962,000,000 | |
| | | |
| **Building Damages** | | |
| # of buildings sustaining slight damage | 565 | 37 |
| # of buildings sustaining moderate damage | 287 | 322 |
| # of buildings sustaining extensive damage | 70 | 536 |
| # of buildings completely damaged | 17 | 992 |
| | | |
| **Population Needs** | | |
| # of households displaced | 13 | 847 |
| # of people seeking public shelter | 7 | 450 |
| | | |
| **Debris** | | |
| Building debris generated (tons) | 10,000 | 113,000 |
| # of truckloads to clear debris (@ 25 tons/truck) | 400 | 4,250 |
| | | |
| **Value of Damages (Millions of dollars)** | | |
| Total property damage | $92.96 | $815.33 |
| Total losses due to business interruption | $10.65 | $80.50 |
| Total Losses | **$103.61** | **$895.83** |



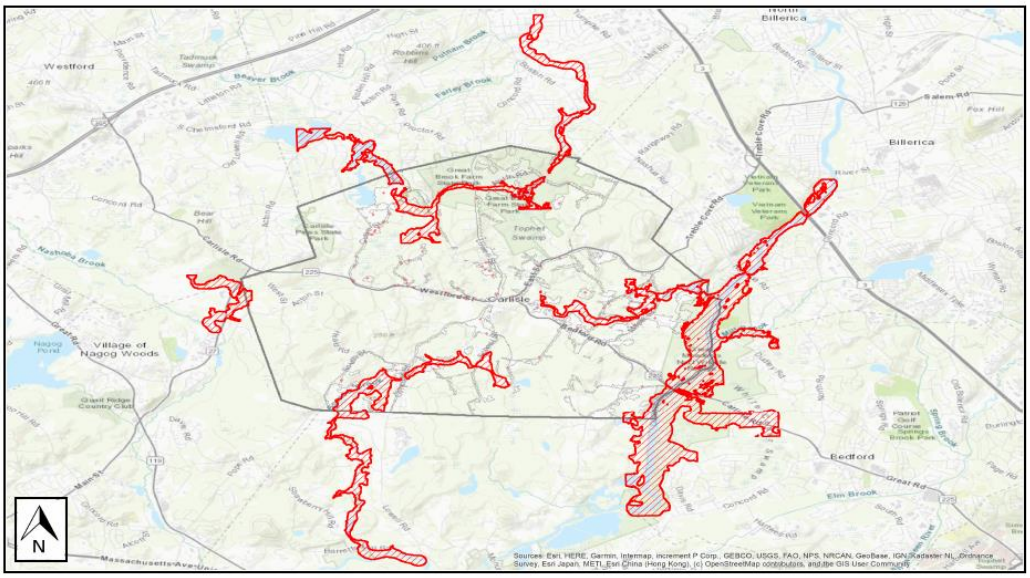



## Estimated Damages from Flooding

The HAZUS flood risk module was used to estimate damages to the municipality at the 100 and 500 return periods. These return periods correspond to flooding events that have a 1% and a 0.2% likelihood of occurring in any given year.

**Table 37: Estimated Damages from Flooding**

| | 100 Year | 500 Year |
|---|---|---|
| | | |
| **Building Characteristics** | | |
| Estimated total number of buildings | 1,889 | |
| Estimated total building replacement value (2014 $) (Millions of dollars) | $962,000,000 | |
| | | |
| **Building Damages** | | |
| # of buildings sustaining slight damage (1-10%) | 2 | 2 |
| # of buildings sustaining moderate damage (11-50%) | 0 | 1 |
| # of buildings sustaining substantial damage (>50%) | 0 | 0 |
| | | |
| **Population Needs** | | |
| # of households displaced | 53 | 65 |
| # of people seeking public shelter | 0 | 0 |
| | | |
| **Value of Damages** (Millions of dollars) | | |
| Total property damage (buildings and content) | $1.25 | $1.82 |
| Total losses due to business interruption | $1,52 | $1.78 |
| **Total** | **$2.77** | **$3.60** |



# SECTION 5: HAZARD MITIGATION GOALS

The goals from the 2012 Hazard Mitigation Plan were reviewed and updated. Two additional goals were added for this plan update, goals 9 and 10 below. All of the goals are considered important for the Town, and they are not listed in order of importance.

**GOAL 1:** Prevent and reduce the loss of life, injury, public health impacts, and property damages resulting from all major natural hazards

**GOAL 2:** Identify and seek funding for measures to mitigate or eliminate each known significant flood hazard area.

**GOAL 3:** Integrate hazard mitigation planning as an integral factor in all relevant municipal departments, committees, and boards

**GOAL 4:** Prevent and reduce the damage to public infrastructure resulting from hazards

**GOAL 5:** Identify areas without water supplies for fire. Identify natural water supplies that are drought resistant.

**GOAL 6:** Encourage the business community, institutions, and non-profits to work with the Town to develop, review, and implement the hazard mitigation plan.

**GOAL 7:** Work with surrounding communities to ensure regional cooperation and solutions for hazards affecting multiple communities.

**GOAL 8:** Ensure that future development meets federal, state, and local standards for preventing and reducing the impacts of natural hazards.

**GOAL 9:** Take maximum advantage of resources from FEMA and MEMA and MA EEA to educate Town staff and the public about hazard mitigation

**GOAL 10:** Educate the public about natural hazards, climate change, and mitigation measures.

**GOAL 11:** Consider the potential impacts of future climate change. Incorporate climate sustainability and resiliency in hazard mitigation planning.

# SECTION 6: EXISTING MITIGATION MEASURES

The existing protections in the Town of Carlisle are a combination of zoning, land use, and environmental regulations, open space preservation, infrastructure management, and drainage infrastructure improvement projects. Infrastructure maintenance generally addresses localized drainage problems. The Town's existing mitigation measures are listed by hazard type here and are summarized in Table 38 below.

## EXISTING TOWN-WIDE MITIGATION FOR FLOOD-RELATED HAZARDS

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

a) *Participation in the National Flood Insurance Program (NFIP)* – 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. The Town has 13 policies in force as of 2020, an increase of 5 since the 2012 plan. There is a total of $ 3,703,000.00 of insurance coverage in place, an increase of $1.3 million since the 2012 plan. As shown in Table 38, only $161,000 of the insurance coverage is for properties in Flood Hazard Zone A, with over $3.5 million in zone X. There was one flood loss in Carlisle, which was closed without payment.

**Table 38: Carlisle Flood Insurance Policy Data, 2020**

| | |
|---|---|
| Flood insurance policies in force | 13 |
| Coverage amount of flood insurance policies, total | $3,703,000 |
| Coverage in A Zone | 161,000 |
| Coverage in X Zone | 3, 542,000 |
| Premiums paid | $6,206 |
| Total losses (all losses submitted regardless of the status) | 1 |
| Closed losses (Losses that have been paid) | 0 |
| Open losses (Losses that have not been paid in full) | 0 |
| CWOP losses (Losses that have been closed without payment) | 1 |
| Total payments (Total amount paid on losses) | $0 |

There are no repetitive loss structures in Carlisle. As defined by the Community Rating System (CRS) of the National Flood Insurance Program (NFIP), a repetitive loss property is any property for which the NFIP has paid two or more flood claims of $1,000 or more in any given 10-year period since 1978.

b) *Drainage System Maintenance and improvements* – All streets are swept on a regular basis. The Public Works Department provides maintenance to culverts, drainage pipes, and other drainage infrastructure on an as-needed basis.

c) *Wetland / Flood Hazard District* – The town has a Wetland/Flood Hazard District (Section 5.2 of the Zoning Bylaw) to protect against flood hazards and to protect the groundwater table and water recharge areas that provide potable drinking water. Certain activities are restricted in these zones and other activities may require a special permit.

d) *Wetland Bylaw* – The town has a Wetland Bylaw (Article XII I of the General Bylaws) to protect the wetland and water resources of the Town of Carlisle by regulating activity in or near wetland resource areas.

e) *The Massachusetts Stormwater Policy* – This Policy is applied to developments within the jurisdiction of the Conservation Commission.

f) *Subdivision Development Drainage Design Controls* – The subdivision regulations require runoff from subdivision developments to not increase in proposed conditions more than in existing conditions for the 2-, 10-, 25-, and 100-year storm events. Stormwater Best Management Practices must meet the standards of the Massachusetts Stormwater Policy.

g) *Site Plan Development Drainage Design Controls* - The town has Site Plan Approval Regulations that state stormwater and drainage must comply with the requirements of the Subdivision Regulations.

h) *Cluster Developments* – The town zoning allows Conservation Clusters (Zoning section 5.5) to preserve natural resources. The town also has Rules and Regulations regarding Conservation Cluster Special Permits.

*i) Extensive Amounts of Conservation Land* – Carlisle already has large amounts of protected land that will never be developed, and as a result will not allow any flooding to worsen due to increased impervious area.

j) *Open Space Initiatives* – Carlisle has proactive land acquisition and preservation programs, including:

- Carlisle's previous *Open Space and Recreation Plan* (OS&RP) was published in 2013, and the Town has recently completed an updated 2021 *Open Space and Recreation Plan*, which has been approved through March 2028 by the state Division of Conservation Services.
- The Carlisle Conservation Foundation and the Carlisle Land Trust receive, acquire, and protect open land and promote conservation in Carlisle.
- The town adopted the Community Preservation Act.
- The Community Preservation Committee helps administer the Community Preservation Act.

k) *Public Education on Town Website* – The town provides information on flooding and links on the town's website at https://www.carlislema.gov/290/Flood-Map-Updates

## EXISTING DAM MITIGATION MEASURES

*The Comprehensive Emergency Management Plan (CEMP)* - The CEMP addresses dam safety, shows inundation areas and the number of homes and people that might be affected.

*Permits required for dam construction*–State law requires a permit for the construction of any dam.

*DCR dam safety regulations* – The state has enacted dam safety regulations mandating inspections and emergency action plans. The Emergency Management Agency is required to inspect dams as part of the CEMP updating process. The Lynn Water and Sewer Commission are also required to inspect their dams.

## EXISTING TOWN-WIDE MITIGATION FOR WIND-RELATED HAZARDS

a) Tree Maintenance by the Town – The Public Works Department acts as the town tree warden and trims trees in public areas and along Rights-of-Ways. The DPW keeps a list of problem areas and will prune problem trees as resources become available and if they receive some sort of notification of a priority area to maintain. Currently the process is more reactive than preventative, as the program has a small budget and is need of additional funding.

b) Tree Maintenance by NSTAR – NSTAR trims trees along the power lines. They have a routine program of full town pruning every 3 years.

c) Requirements for Burying Wires in New Developments – New subdivisions are required by the subdivision regulations to bury wires unless they can be screened.

***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.

## EXISTING TOWN-WIDE MITIGATION FOR WINTER-RELATED HAZARDS

a) Standard Snow-Plowing Operations – The Public Works Department provides standard snow plowing operations, including salting and sanding, but they have many low salt areas in town. The town owns eleven trucks and contracts out three - four more trucks and crew.

b) Removal of Vehicles from Public Way – Section 10.3 of the General Bylaws allows the Superintendent of Public Works, or his designee, to move any vehicle interfering with plowing or snow removal from a public way.

c) Tree Maintenance – Both the town and NSTAR provide tree trimming and removal in order to prevent limbs from coming down during heavy and wet snow events. (See more detailed description above under the Wind section)

## EXISTING TOWN-WIDE MITIGATION FOR FIRE-RELATED HAZARDS

a) Requirements for any new development of 3+ houses to include a fire cistern. All fire trucks include a tank, pump and are equipped to fight wildfires.

b) Open Burning Permits Required– Town bylaws allow controlled open burning in accordance with state regulations, but a permit is required from the Fire Chief for each day of intended burning. Permits are required for outdoor burning, and burning is only allowed during the statewide burning season January 15-April 30 each year. The town requires each applicant for a permit to come to the station and apply, and they must call each day to get permission. A permit is good for the entire season.

c) Public Education – The Fire Department maintains a website with public education on open burning at: https://www.carlislema.gov/faq.aspx?qid=123

d) Fire Department Review of Proposed Developments – The Fire department reviews subdivision and site plans for compliance with site access, water supply needs, and all other applicable regulations.

e) Statewide Fire Mobilization Plan – The state has a fire mobilization plan for wildland fires as well as a separate plan for Carlisle's fire district.

## EXISTING TOWN-WIDE MITIGATION FOR EARTHQUAKE HAZARDS

***a) 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, cannot be achieved economically for most buildings. Section 1612.2.5 of the MA Building Code sets up 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.

b) Backup Streams and Ponds for Firefighting – Streams, ponds, fire ponds, and cisterns in the town are backup firefighting water supplies.

c) Shelters and Backup Facilities – The town does have designated shelters and backup facilities (see multi-hazard mitigation below). The School is the shelter area, and the Board of Health helps coordinate in-home sheltering.

d) Evacuation Plan – The town does have an evacuation plan as specified in its Comprehensive Emergency Management Plan (CEMP).

## EXISTING TOWN-WIDE MITIGATION FOR LANDSLIDE HAZARDS

a) Subdivision Road Maximum Slopes – The subdivision regulations have maximum slope requirements for new roads.

b) Erosion Control Requirements – The subdivision regulations and site plan approval regulations have requirements for slope stabilization.

c) Earth Removal Requirements – Article VII of the General Bylaws outlines requirements and for earth removal, deposit, and stockpiling activities. In some instances, a license may be required.

## EXISTING TOWN-WIDE MITIGATION FOR MULTIPLE HAZARDS

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

b) 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, dam failures and winter storms. Therefore, the CEMP is a mitigation measure that is relevant to many of the hazards discussed in this plan.

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

d) Local Emergency Management Planning Committee (LEPC) – The town has both a local committee and is part of a Regional Emergency Planning Committee (REPC).

e) Backup Power Supplies at Communications Centers – There is an uninterrupted power supply, a generator and portable generator, at both communications centers in town, along with unlimited fuel supply.

f) In-Home Sheltering Coordination – The Board of Health voluntarily coordinates with neighborhoods for in-home sheltering.

## COMPILATION OF EXISTING MITIGATION MEASURES

Table 39 summarizes the many existing natural hazard mitigation measures already in place in Carlisle.

| Table 39: Update of Existing Carlisle Mitigation Measures | | |
|---|---|---|
| **Hazard Type** | **Mitigation Measure** | **Comments/Changes Needed?** |
| **Flood-Related** | A) The town participates in the National Flood Insurance Program, has adopted the FIRM maps, and actively enforces the floodplain regulations<br>B) Drainage System Maintenance and Improvements<br>C) Wetland / Flood Hazard District<br>D) Wetland Bylaw<br>E) Massachusetts Stormwater Policy<br>F) Subdivision Development Drainage Design Controls<br>G) Site Plan Development Drainage Design Controls<br>H) Cluster Developments<br>I) Extensive Amounts of Conservation Land<br>J) Open Space and Recreation Plan updated 2021<br>K) Flooding Public Education on Town Website | Periodically updater the Floodplain Zoning Overlay map to be consistent with changes in the current FIRM map. |
| **Dams** | A) DCR Dam Safety Regulations<br>B) Dam Construction Permits Required | Effective |
| | A) Greenough Pond Dam repair | Project in progress |
| **Wind-Related** | A) Tree Maintenance Program by the Town<br>B) Tree Maintenance by NSTAR<br>C) Requirements for Burying Wires in New Developments | Enhanced tree management program in coordination with NSTAR |

| Table 39: Update of Existing Carlisle Mitigation Measures | | |
|---|---|---|
| **Hazard Type** | **Mitigation Measure** | **Comments/Changes Needed?** |
| **Winter-Related** | A) Standard Snow Operations<br>B) Removal of Vehicles from Public Way<br>C) Tree Maintenance by the Town and NSTAR | Enhanced tree management program in coordination with NSTAR |
| **Fire-Related** | A) Open Burning Permits Requirements<br>B) Fire Department Review of Proposed Developments<br>C) Public Information on open burning on Fire Dept. website<br>D) Statewide Fire Mobilization Plan | Requirements for cisterns in new developments; Assessment of areas with insufficient water needed; Strategic plan for wildfires needed |
| **Geologic - *Earthquake*** | A) Backup Streams and Ponds for Firefighting<br>B) Shelters and Backup Facilities | Assess risk to public buildings |
| **Geologic - *Landslides*** | A) Subdivision Road Maximum Slopes<br>B) Erosion Control Requirements<br>C) Earth Removal Requirements | Effective |
| **Multi-Hazard** | A) Multi-Department Review of Developments<br>B) Comprehensive Emergency Management Plan (CEMP)<br>C) Enforcement of State Building Code<br>D) Local Emergency Management Planning Committee (LEPC)<br>E) Backup Power Supplies at Communications Centers<br>F) In-Home Sheltering Coordination | Periodically update the CEMP; assess needs for generators |

## MITIGATION CAPABILITIES AND LOCAL CAPACITY FOR IMPLEMENTATION

Under the Massachusetts system of "Home Rule," the Town of Carlisle is authorized to adopt and from time to time amend local bylaws and regulations that support the town's capabilities to mitigate natural hazards. These include Zoning Bylaws, Subdivision and Site Plan Review Regulations, Wetlands Bylaws, Stormwater Bylaws, Health Regulations, Public Works regulations, and local enforcement of the State Building Code.

Local Bylaws may be amended by the Town Meeting to improve the town's capabilities, and changes to most regulations require a public hearing and a vote of the authorized board or commission. The Town of Carlisle has recognized several existing mitigation measures that require implementation or improvements and has the capacity within its local boards and departments to address these. Several departments including Public Works, Planning, and Conservation will address the many planning and infrastructure improvements identified in this plan. The Town can improve its hazard mitigation capabilities with the following measures:

- Update the Town's Master Plan and incorporate Hazard Mitigation and Climate Resilience as a formal component of the plan, equivalent to other components traditionally included in a Master Plan such as Land Use, Transportation, Housing, and Economic Development.

- As the Town implements its Open Space plan, prioritize hazard mitigation and climate resilience considerations. Identify opportunities for open space protection and land acquisition that would have specific hazard mitigation co-benefits, such as managing stormwater to reduce flooding, protecting vegetation for shade to mitigate extreme heat, and managing forests to mitigate climate impacts.

- Update the Floodway and Floodplain Ordinance to incorporate requirements of the new state model Floodplain Ordinance.

- The Public Works Department can conduct an assessment of roads and culverts that are vulnerable to flooding and drainage problems and prioritize drainage upgrades for implementation.

- The Town can consider adopting a Stormwater Utility or stormwater user fee to provide a dedicated, predictable revenue stream to finance upgrades to the stormwater infrastructure, many of which are needed to mitigate flooding risks.

- The Town can develop a plan for managing forest and land resources, assess the town's resources and prioritize management to maximize benefits for heat mitigation and resilience, water management, and climate related stress on forests.

- Enhance the Town's tree maintenance in coordination with National Grid. Conduct a survey of trees, assess conditions. Identify trees that could pose a hazard due to their condition and/or location; prioritize for trimming or removal

- The Town can reduce fire risk by assessing water sources and identify areas of risk. The Planning Board and Fire Department can create GIS maps and other resources identifying water resources for fire fighting, such as ponds and cisterns; noting any areas of elevated fire risk.

- Financing the implementation of mitigation measures: the Town can incorporate a program of mitigation measures into its Capital Investment Program to ensure that these receive priority along with other categories of municipal investment such as roadways and municipal buildings

- In reviewing and permitting new development projects, the Town can refer to the Hazard Mitigation Plan for guidance to incorporate mitigation into site design and construction.

- The Town can conduct strategic planning for fire safety, with the collaboration of the Fire Department and the Planning Board to ensure that this topic is adequately addressed in ongoing strategic planning efforts in town, such as the master plan and public facilities planning.

- The town can implement upgrades to key public infrastructure, including the Greenough Pond Dam and the Route 225 bridge over the Concord River.

# SECTION 7: MITIGATION MEASURES FROM PREVIOUS PLAN

## IMPLEMENTATION PROGRESS ON THE PREVIOUS PLAN

The Town of Carlisle has taken steps to incorporate issues raised in the 2012 Hazard Mitigation Plan into several of its ongoing planning and policy initiatives. To address issues with the Greenough Pond Dam, the Town has developed a project plan with a consultant and developed a cost estimate of $750,000. The Town is currently pursuing project funding through several potential sources, including the Massachusetts Dam and Seawall grant program and Carlisle Community Preservation Act funds.

The Town completed a new Open Space and Recreation Plan in 2021, which has been approved by the state through 2028. The Town is currently engaged in preparing a new Master Plan. The town also conducted a Municipal Vulnerability Preparedness (MVP) project in conjunction with this Hazard Mitigation Plan 2021 Update, with a Community Resilience Building workshop held on March 27, 2021 (the priority resilience actions identified at the workshop are shown in Appendix E). Other ways in which the town has implemented the previous plan include the installation of a generator at the school and improved communications through reverse 911 and emergency radio upgrades.

The Carlisle HMP/MVP Core Team, the town reviewed the mitigation measures identified in the 2012 Carlisle Hazard Mitigation Plan and determined whether each measure had been implemented, partially completed, or deferred. Of those measures that had been deferred, the committee evaluated whether the measure should be deleted or carried forward into this Hazard Mitigation Plan 2021 Update. 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. Table 39 summarizes the status of mitigation measures from the 2012 plan.

As indicated in Table 40, Carlisle made significant progress implementing or partially completing several of the mitigation measures identified in the 2012 Hazard Mitigation Plan. Several projects that were not completed will be continued into this 2021 plan update.

### Table 40: Mitigation Measures from the 2012 Plan

| Status of Carlisle Mitigation Measures from the 2012 Plan | | | | |
|---|---|---|---|---|
| **Mitigation Measure** | **Priority in 2012 Plan** | **Description** | **Current Status** | **Retain in 2021 Plan?** |
| **FLOODNG HAZARDS** | | | | |
| A. Greenough Pond Dam Improvements | High | While it is a low hazard dam, it is in disrepair with a failed spillway. The town did a study in 2004 that recommended repairs, which include removing stumps and roots from the embankment and restoring the slope. Current cost estimate for the project is $750,000. | **Partially Complete**, In Progress (Permits have been issued, funding being sought) | YES |
| B. Spencer Brook Dam Inspection and Study | High | This is an older dam and privately-owned. This dam should be inspected, and potential impacts to homes on Hartwell Avenue should be evaluated. Downstream is mostly open land, but there are questions if these homes could be impacted in the event of a breach. | **Not completed**; private dam, no Town project | NO |
| C. Update of FEMA Maps | Medium | The latest FEMA floodplain maps for Carlisle were developed in 1988. These maps are likely out of date due to development in the since then. The town would like to have the maps updated to reflect the current and correct floodplain information. . | **Completed** Map changes done in 2014 | NO |
| D. Open Space Protection and Land Acquisition | Other | The town should continue its efforts for open space protection and purchases. Further protection of open space in the wake of development is important to ensure that development does not increase flooding. | **In Progress** Assess land parcels that would provide flooding benefits | YES |

| Status of Carlisle Mitigation Measures from the 2012 Plan | | | | |
|---|---|---|---|---|
| **Mitigation Measure** | **Priority in 2012 Plan** | **Description** | **Current Status** | **Retain in 2021 Plan?** |
| **BRUSHFIRE HAZARDS** | | | | |
| E. Cistern at Great Brook State Park Farm | Medium | The park as an area of higher brush fire risk. Although it is owned by the state, the Carlisle Fire Dept. would be first to respond. Since Carlisle does not have a municipal water system or hydrants, they rely on fire ponds and cisterns for firefighting water. The town identified that a cistern, approximately 30,000 gallons, would be beneficial. | **Not completed.** Proposal and application made but not funded | YES |
| F. Requirements to Have Cisterns Installed on Future Developments | Medium | The Fire Department would like to see provisions in the subdivision and site plan regulations to require cisterns for all new developments. Requirements stating the size and type of cistern required would eliminate ambiguity for the developer, the Fire Dept, and the Planning Board. | **Partially complete.** Planning Board regulations include fire safety, but requirements need to be codified | YES |
| **WIND HAZARDS** | | | | |
| G. Resources for Further Tree Survey, Trimming, and Removal | Medium | The DPW keeps a list of problem areas and prunes trees as resources are available or if they receive notification of a priority area. Currently the process is more reactive than preventative. A more robust tree removal program and a system to regularly survey and monitor trees would help reduce downed trees, power outages, and roadway blockages during extreme storms. | **Partially Complete.** Increased tree trimming by utility company | YES |

| Status of Carlisle Mitigation Measures from the 2012 Plan | | | | |
|---|---|---|---|---|
| **Mitigation Measure** | **Priority in 2012 Plan** | **Description** | **Current Status** | **Retain in 2021 Plan?** |
| **MULTI-HAZARDS** | | | | |
| H. Generator at School | High | The school would act as the shelter in an emergency. However, it does not have a generator. During a power outage, the water and sewer systems would also be affected. | **Completed** | NO |
| I. Reverse 911 Across the Town | Medium | A Reverse 911 system is a useful tool to alert residents of emergency information. Residents can sign up to be on the Reverse 911 list through the town website. | **Completed** | NO |
| J. Satellite Radios | Medium | Town officials identified satellite radios for communication as a tool that would be useful for emergency communications. | **Completed** | NO |
| K. Assistance in Coordinating In-Home Sheltering | Other | The Board of Health volunteers with neighborhoods in the town to help coordinate in-home sheltering in the event of an emergency. A possible improvement would be additional funding for a student to help with these outreach efforts | **Not Completed** | YES |

Overall, six mitigation measures from the 2012 plan will be continued in this 2021plan update. Most will retain the same priority in this 2021 Update. 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. The challenges the Town faces in implementing these measures are primarily due to limited funding and available staff time. This plan should help the Town prioritize the best use of its limited resources for enhanced mitigation of natural hazards.

# SECTION 8: HAZARD MITIGATION STRATEGY

## WHAT IS HAZARD MITIGATION?

Hazard mitigation means to permanently reduce or alleviate the losses of life, injuries and property resulting from natural hazards through long-term strategies. These long-term strategies include planning, policy changes, education programs, infrastructure projects and other activities. FEMA currently has three mitigation grant programs: the Hazards Mitigation Grant Program (HGMP), the Pre-Disaster Mitigation program (PDM), and the Flood Mitigation Assistance (FMA) program. The three links below provide additional information on these programs.

https://www.fema.gov/hazard-mitigation-grant-program
https://www.fema.gov/pre-disaster-mitigation-grant-program
https://www.fema.gov/flood-mitigation-assistance-grant-program

Hazard Mitigation Measures can generally be sorted into the following groups:

- **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 storm water 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.

  (Source: FEMA Local Multi-Hazard Mitigation Planning Guidance)

## REGIONAL AND INTER-COMMUNITY CONSIDERATIONS

Some hazard mitigation issues are strictly local. The problem originates primarily within the municipality and can be solved at the municipal level. Other issues are inter-community and require cooperation between two or more municipalities. There is a third level of mitigation which is regional and may involve a state, regional or federal agency or three or more municipalities.

## REGIONAL PARTNERS

In developed urban and suburban communities such as the metropolitan Boston area, mitigating natural hazards, particularly flooding, is often more than a local issue. The drainage systems that serve these communities are complex systems of storm drains, roadway drainage structures, dams, pump stations and other facilities owned and operated by a wide array of agencies including the Town, the Department of Conservation and Recreation (DCR), and the Massachusetts Department of Transportation (MassDOT). The planning, construction, operation, and maintenance of these structures are integral to the hazard mitigation efforts of communities. These agencies should be considered the communities' regional partners in hazard mitigation. These agencies also operate under the same constraints as communities do including budgetary and staffing constraints and they must make decisions about numerous competing priorities.

Following, is a brief overview of regional facilities found in Carlisle and a discussion of inter-municipal issues.

## OVERVIEW OF REGIONAL FACILITIES WITHIN CARLISLE

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

- Route 225 (MassDOT)
- Bridge over Concord River connecting to Bedford (MassDOT)
- Great Brook Farm State Park (Mass DCR)
- Great Meadows National Wildlife Refuge (USFWS)
- O'Rourke Farm on Maple Street (USFWS)

## INTER-COMMUNITY CONSIDERATIONS

### Regional Climate Change Impacts

The potential future changes to the State's storm damage profile caused by climate change will likely be well outside of historic trends, making those trends uncertain predictors of future risk and vulnerability at best. Since the 2012 plan, Massachusetts has established a robust program to help communities address climate change through the Municipal Vulnerability Program (MVP). The state also launched a website providing the best available information to map and model climate change and sea level rise data in Massachusetts at www.resilientma.org. Carlisle and its neighboring communities have all participated in the MVP program, which raises the possibility of collaboration on issues of joint concern in the subregion.

Through a grant from MAPC's Accelerating Climate Resilience program, funded by the Barr Foundation, Carlisle, and surrounding towns in the Minuteman Group for Interlocal Cooperation (MAGIC) have formed a climate resiliency working group to share information and coordinate implementation of their local and regional resilience strategies. This should be an important initiative to advance climate resilience among these 12 communities.

Mitigation measures for the following regional issues should be taken into account as Carlisle continues to develop and implement its Hazard Mitigation Plan:

### Dam in Chelmsford That Impacts Cranberry Bog in Carlisle

A dam of regional concern is located at a cranberry bog in Chelmsford just north of Carlisle and upstream of other bogs in Carlisle. A couple of years ago, the dam collapsed in the springtime due to erosion. The flume was over 50 years old. A cranberry farmer downstream lost some of his bog and cranberry harvest as a result. The breach did not affect any roads, but just the bog. The town of Chelmsford owns the dam and repaired the damage, but the dam needs improvements to ensure a long-term solution. A future action might include a study of the drainage and suggestions for improvements in this area.

### Long-Term Regional Management to Control Beaver Activity

One regional issue of significance is the widespread effects of beaver dams in the area. Most streams, wetland areas, and ponds in the region have had some degree of beaver activity in the past several years. Much of the localized flooding that occurs is due to beaver activity. The towns will mitigate the problem temporarily by hiring trappers, removing dams, or installing pipes, but a long-term comprehensive approach should be considered. Legislation may be needed to make it easier for towns to handle beaver dams.

## NEW DEVELOPMENT AND INFRASTRUCTURE

As part of the process of developing recommendations for new mitigation measures for this plan update, the Town considered the issues related to new development, redevelopment, and infrastructure needs in order to limit future risks.

Taking into consideration the town's Comprehensive Plan, the Wetlands bylaw enforced by the Conservation Commission, the floodplain zoning overlay, the stormwater bylaw, and the Municipal Vulnerability Preparedness project, the town determined that existing regulatory measures are taking good advantage Home Rule land use regulatory authority to minimize natural hazard impacts of development. Priorities for the future include conducting a town-wide assessment of roads and culvers vulnerable to drainage problems and prioritize improvement projects.

## PROCESS FOR SETTING PRIORITIES FOR MITIGATION MEASURES

The last step in developing the Town's mitigation strategy is to assign a level of priority to each mitigation measure so as to guide the focus of the Town's limited resources towards those actions with the greatest potential benefit. At this stage in the process, the Local Hazard Mitigation Planning Team had limited access to detailed analyses of the cost and benefits of any given mitigation measure, so prioritization is based on the local team members' understanding of existing and potential hazard impacts and an approximate sense of the costs associated with pursuing any given mitigation measure.

Priority setting was based on local knowledge of the hazard areas, including impacts of hazard events, the extent of the area impacted, and the relation of a given mitigation measure to the Town's goals. In addition, consideration was given to factors such as road closures and what impact closures have on delivery of emergency services and the local economy, critical facilities, homes, and businesses impacted by hazards, anticipated project costs, whether any environmental constraints existed, and whether the Town would be able to justify the costs relative to the anticipated benefits.

Table 41 below demonstrates the prioritization of the Town's potential hazard mitigation measures. For each mitigation measure, the geographic extent of the potential benefiting area is identified as is an estimate of the overall benefit and cost of the measures. The benefits, costs, and overall priority were evaluated in terms of:

| Estimated Benefits | |
|---|---|
| High | Action will result in a significant reduction of hazard risk to people and/or property from a hazard event |
| Medium | Action will likely result in a moderate reduction of hazard risk to people and/or property from a hazard event |
| Low | Action will result in a low reduction of hazard risk to people and/or property from a hazard event |
| Estimated Costs | |
| High | Estimated costs greater than $250,000 |
| Medium | Estimated costs between $50,000 to $250,000 |
| Low | Estimated costs less than $50,000 and/or staff time |

| Overall Priority | |
|---|---|
| High | Action 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 |
| Medium | Action may have political and public support and necessary maintenance has potential to occur following the project |
| Low | Not clear if action has political and public support and not certain that necessary maintenance can occur following the project |

**Table 41: Mitigation Measures Prioritization**

| Mitigation Prioritization for the Carlisle 2021 Plan Update | | | | |
|---|---|---|---|---|
| **Mitigation Measures** | Geographic Coverage | Estimated Benefit | Estimated Cost | Priority |
| **FLOODING HAZARDS** | | | | |
| 1) **Greenough Pond Dam** Improvements. The project involves removing a failed spillway and replacing it with 3 new spillways for better flow control. Permits have been issued for the project. Project is ready for constructions; Town Meeting authorized Community Preservation Act funding and a Dams and Seawall grant is being sought | Greenough Pond Dam | HIGH | HIGH | HIGH |
| 2) **Update of FEMA Maps**: Periodically amend Floodplain Overlay Zoning to be consistent with FIRM map changes | Town wide | MED | LOW | MED |
| 3) **Prioritize Open Space Protection** and land acquisition of parcels that mitigate stormwater runoff and have flood mitigation benefits | Town wide | MED | HIGH | MED |
| 4) **Roads and Culverts:** conduct an assessment of those that are vulnerable and prioritize upgrades, repairs, and right-sizing. Prioritize main arteries in and out of town. Address drainage basins to avoid flooding and ice ponds that block roads. | Town wide | HIGH | MED/HIGH | HIGH |
| 5) **Upgrade Route 225 bridge** to support essential services/equipment (fire trucks, etc.), and maintain access in and out of town. This is a state-owned facility so the Mass. Dept. of Transportation (MassDOT) would need to implement any improvements. | Route 225 Bridge | HIGH | HIGH | HIGH |

| Mitigation Prioritization for the Carlisle 2021 Plan Update | | | | |
|---|---|---|---|---|
| **Mitigation Measures** | Geographic Coverage | Estimated Benefit | Estimated Cost | Priority |
| **BRUSHFIRE HAZARDS** | | | | |
| 6) **Codify requirements for cisterns to be installed on future developments:** The Planning Board should work with the Fire Department to write updated and more specific regulations in the area of fire safety for subdivisions and common driveway developments. | Town wide | HIGH | LOW | HIGH |
| 7) **Assess and map water sources and identify areas of risk:** the Planning Board and Fire Department should work together to assess and create GIS maps and other resources listing water resources such as ponds and cisterns; noting any areas of elevated fire risk arising from any other factors besides lack of water access, and rank the areas lacking water resources in terms or risk and difficulty of getting water to the location. | Town wide | HIGH | LOW/MED | HIGH |
| 8) **Conduct strategic planning for fire safety:** The Planning Board should engage with the Fire Department to carry out strategic planning in the area of fire safety and ensure that this topic is adequately addressed in ongoing strategic planning efforts in town, such as the master plan and public facilities planning. | Town wide | HIGH | LOW | HIGH |
| 9) **Fire Protection measures:** The Planning Board, Fire Department and Building Commissioner should evaluate if additional fire protection measures such as sprinklers are warranted for new developments permitted by the town.. | Town wide | HIGH | LOW | HIGH |
| 10) **Increase public education** on brush fire hazards, landscaping near homes, vegetation maintenance. | Town wide | LOW | LOW | LOW |

| Mitigation Prioritization for the Carlisle 2021 Plan Update | | | | |
|---|---|---|---|---|
| **Mitigation Measures** | Geographic Coverage | Estimated Benefit | Estimated Cost | Priority |
| **WIND HAZARDS** | | | | |
| 11) **Enhanced Resources for Tree Management:** A robust tree management program and a system to regularly survey and monitor trees would reduce downed trees, power outages, and roadway blockages during extreme storms. Enhance the Town's tree maintenance in coordination with National Grid. Conduct a survey of trees, assess conditions. Identify trees that could pose a hazard due to their condition and/or location; prioritize for trimming or removal | Town wide | HIGH | MED/HIGH | HIGH |
| **WINTER HAZARDS** | | | | |
| 12) **Snow Load Assessment:** Identify public buildings that may be vulnerable to damage from snow loads and conduct a structural assessment if needed. | Public Buildings | LOW | LOW | LOW |
| 13) **Ice Dams: Provide public education** on preventing ice dams that could cause damage to homes and other privately owned structures | Town wide | LOW | LOW | LOW |
| **GEOLOGIC HAZARDS** | | | | |
| 14) **Earthquake Assessment:** Identify public buildings that may be vulnerable to earthquakes and assess options to make them more resistant to earthquakes | Public Buildings | LOW | LOW | LOW |
| **DROUGHT HAZARDS** | | | | |
| 15) **Adopt landscaping guidelines** for new development to promote native plants in landscaping and site design measures. Refer to the Conservation Commission's list of native plants and the Board of Health's Irrigation Policy in Item #15 as part of the development and adoption of landscaping guidelines.. | Town wide | MED | LOW | MED |

| Mitigation Prioritization for the Carlisle 2021 Plan Update | | | | |
|---|---|---|---|---|
| **Mitigation Measures** | Geographic Coverage | Estimated Benefit | Estimated Cost | Priority |
| 16) **Monitor groundwater** to identify potential water resources for a municipal water supply. The O'Rourke property was tested and has the potential of supporting a municipal water supply for a portion of the town. (consult with Mass DEP) | Town wide | MED | MED | MED |
| **EXTREME TEMPERATURE HAZARDS** | | | | |
| 17) **Conduct a public awareness** on the risks of extreme temperatures and resources available to residents during extreme events. | Town wide | MED | LOW | MED |
| **MULTI HAZARDS** | | | | |
| 18) **Forest and Land Management**: Establish town-wide goals and develop a plan for managing forest and land resources. Assess the town's resources and prioritize planning to maximize **benefits for heat mitigation and resilience, water management, and climate related stress on forests.** Coordinate the town's planning effort with stakeholders and other landowners. | Town wide | HIGH | MED | HIGH |
| 19) **Assistance in Coordinating In-Home Sheltering:** Develop a town educational program for how shelter in place with a grant funded student intern. Also look to realtors to sponsor an informational brochure for new residents. Encourage neighborhood social gatherings to increase social resiliency. Getting to know neighbors should not have to wait until a disaster. | Town wide | HIGH | LOW | HIGH |
| 20) **Address emergency shelter needs:** Research options for independent power supply. Need a place that provides beds; improve showers at the school. -Make use of Town Hall in emergencies, needs a generator | Town wide | HIGH | MED | HIGH |

| Mitigation Prioritization for the Carlisle 2021 Plan Update | | | | |
|---|---|---|---|---|
| **Mitigation Measures** | Geographic Coverage | Estimated Benefit | Estimated Cost | Priority |
| 21) **Upgraded or New Police and Fire facilities** are needed to accommodate the workforce and efficient operations. | Town wide | HIGH | HIGH | HIGH |

## Introduction to Potential Mitigation Measures (Table 42)

- **Description of the Mitigation Measure** – The description of each mitigation measure is brief and cost information is given only if cost data were already available from the community. The cost data represent a point in time and would need to be adjusted for inflation and for any changes or refinements in the design of a mitigation measure.

- **Priority** – As described above and summarized in Table 41, the designation of high, medium, or low priority was done considering area covered by the mitigation measures and their potential benefits and preliminary estimated project costs.

- **Implementation Responsibility** – The designation of implementation responsibility was done based on a general knowledge of what each municipal department is responsible for. It is likely that many mitigation measures will require several departments to work together and assigning staff is the responsibility of the governing body of the community.

- **Time Frame** – The time frame was based on a combination of the priority for that measure, the complexity of the measure and whether or not the measure is conceptual, in design, or already designed and awaiting funding. Because the time frame for this plan is five years, the timing for all mitigation measures has been kept within this framework. The identification of a likely time frame is not meant to constrain a community from taking advantage of funding opportunities as they arise.

- **Potential Funding Sources** – This column attempts to identify the most likely sources of funding for a specific measure. The information on potential funding sources in this table is preliminary and varies depending on a number of factors. These factors include whether or not a mitigation measure has been studied, evaluated or designed, or if it is still in the conceptual stages. Each grant program and agency have specific eligibility requirements that would need to be taken into consideration. In most instances, the measure will require a number of different funding sources. Identification of a potential funding source in this table does not guarantee that a project will be eligible for or selected for funding. Upon adoption of this plan, the local team responsible for its implementation should begin to explore the funding sources in more detail.

- **Additional information on funding sources** – The best way to determine eligibility for a particular funding source is to review the project with a staff person at the funding agency. The following websites provide an overview of programs and funding sources.

  Massachusetts Emergency Management Agency (MEMA) – The grants page https://www.mass.gov/hazard-mitigation-assistance-grant-programs describes the various Hazard Mitigation Assistance Program, including the FEMA's Building Resilient Infrastructure and Communities (BRIC) grant. Massachusetts Municipal Vulnerability

Preparedness Action Grants—Communities designated by the state as MVP certified are eligible to apply for MVP Action Grants. These grants are intended to assist with the implementation of mitigation and resilience actions identified in a community's MVP Report. Since Carlisle conducted and MVP project in conjunction with this 2021 Hazard Mitigation Plan Update, it is expected that the town should be eligible for MVP Action Grants in the next grant round of 2022. https://resilientma.org/mvp/

Army Corps of Engineers (ACOE) – The website for the North Atlantic district office is http://www.nae.usace.army.mil/ The ACOE provides assistance in a number of types of projects including shoreline/streambank protection, flood damage reduction, flood plain management services and planning services.

## BACKGROUND ON WILDFIRE MITIGATION MEASURES

Table 42 includes some new and revised mitigation measures on wildfire mitigation since the town evaluated this as a more significant hazard than in the previous plan. Background descriptions on these measures follow.

- **Codify requirements for cisterns to be installed on future developments** (#6 in Table 42)**.** Although this measure was included in the previous plan, the town is further elaborating what is needed. This calls for the Planning Board to work with Fire Department to write updated and more specific regulations in the area of fire safety for subdivisions and common driveway developments. Currently, the Planning Board's regulations are general regarding fire safety. The subdivision rule calls for "all lots and dwellings…[to] have adequate provisions for fire protection, including access to an adequate source of water, as determined by the Planning Board, in consultation with the Fire Chief." But in practice, a cistern is generally required for roads or driveways with three or more houses. Both the Planning Board and the Fire Department, as well as applicants, would benefit from more transparent and comprehensive standards in this area, which codify best practices.

- **Assess and map water sources and identify areas of risk** (#7 in Table 42): Virtually all of Carlisle has heavy forest and tree cover, including most residential areas. This creates the pre-conditions for significant fire risk throughout the town. Since there is no town-wide water system, the greatest fire risk arises from the relative access of different areas of town to water sources. To quantify and understand the relative risk of fire damage of different areas of town, the Planning Board and Fire Department should work together to assess and create GIS maps and other resources listing water resources such as ponds and cisterns; noting any areas of elevated fire risk arising from any other factors besides lack of water access, and rank the areas lacking water resources in terms or risk and difficulty of getting water to the location. The Planning Board and Fire Department should explore using in-town resources to create this assessment and GIS map, as well as consider seeking a grant to hire an outside consultant to carry out this assessment.

- **Evaluate building code updates on fire protection** (#8 in Table 42)**:** This new measure calls for the Planning Board, Fire Department and Building Commissioner to assess and determine whether any updates to the Town's building code in the area of fire protection, such as sprinkler systems, may be warranted, either in all newly constructed or renovated buildings, or in specific instances in new subdivisions and/or common driveway developments.

- **Conduct strategic planning for fire safety** (#9 in Table 42): The Planning Board should engage with the Fire Department to carry out strategic planning in the area of fire safety and ensure that this topic is adequately addressed in ongoing strategic planning efforts in town, such as the master plan and public facilities planning. The Planning Board and Fire Department should work to define worst case scenario that needs to be planned for, for example, two simultaneous wildfires at a time when other towns cannot assist. This planning effort should consider different means to achieve the capacity needed to respond to the worst-case scenario. For example, locating more cisterns throughout town might be one alternative. Another means could be to provide two tanker trucks and ensure that the town has sufficient on-call fire fighters to respond. The benefits and features of an on-call fire department with the dynamic staffing model this represents, should be integrated into town planning efforts.

**Table 42: Mitigation Measures Prioritization**

| Mitigation Recommendations for the Carlisle 2021 Plan Update | | | | | |
|---|---|---|---|---|---|
| **Mitigation Measures** | **Priority** | **Implementation Responsibility** | **Time Frame (2021-2026)** | **Estimated Cost** | **Potential Funding Sources** |
| **FLOODING HAZARDS** | | | | | |
| 1) **Greenough Pond Dam** Improvements. The project involves removing a failed spillway and replacing it with 3 new spillways for better flow control. Permits have been issued for the project. Project is ready for constructions, subject to pending funding. | HIGH | Conservation Commission | 2021-2022 | $750,000 | Community Preservation; State Dam and Seawall grant |
| 2) **Update of FEMA Maps**: Periodically amend Floodplain Overlay Zoning to be consistent with FIRM map changes | MED | Conservation Commission | 2021-2026 | LOW Staff Time | Carlisle General Fund |
| 3) **Prioritize Open Space Protection** and land acquisition of parcels that mitigate stormwater runoff and have flood mitigation benefits | MED | Select Board, Planning Board, Conservation Commission | 2021-2026 | HIGH | Carlisle General Fund; Land Donations; Open Space grants |
| 4) **Roads and Culverts:** conduct an assessment of those that are vulnerable and prioritize upgrades, repairs, and right-sizing. Prioritize main arteries in and out of town. Address drainage basins to avoid flooding and ice ponds that block roads. | HIGH | Public Works | 2022-2024 | MED/HIGH | Carlisle General Fund; Chapter 90 |
| 5) **Upgrade Route 225 bridge** to support essential services/equipment (fire trucks, etc.), and maintain access in and out of town. This is a state-owned facility so the Mass. Dept. of Transportation (MassDOT) would need to implement any improvements. | HIGH | MassDOT | 2022-2026 | HIGH | MassDOT Transportation Improvement Program (TIP) |

| Mitigation Recommendations for the Carlisle 2021 Plan Update | | | | | |
|---|---|---|---|---|---|
| **Mitigation Measures** | **Priority** | **Implementation Responsibility** | **Time Frame (2021-2026)** | **Estimated Cost** | **Potential Funding Sources** |
| **BRUSHFIRE HAZARDS** | | | | | |
| 6) **Codify requirements for cisterns to be installed on future developments:** The Planning Board should work with the Fire Department to write updated and more specific regulations in the area of fire safety for subdivisions and common driveway developments. | HIGH | Planning Board and Fire Dept. | 2021-2023 | LOW Staff Time | Carlisle General Fund |
| 7) **Assess and map water sources and identify areas of risk:** the Planning Board and Fire Department should work together to assess and create GIS maps and other resources listing water resources such as ponds and cisterns; noting any areas of elevated fire risk arising from any other factors besides lack of water access, and rank the areas lacking water resources in terms or risk and difficulty of getting water to the location. | HIGH | Planning Board and Fire Dept. | 2021-24 | LOW/MED | Carlisle General Fund/Grants |
| 8) **Conduct strategic planning for fire safety:** The Planning Board should engage with the Fire Department to carry out strategic planning in the area of fire safety and ensure that this topic is adequately addressed in ongoing strategic planning efforts in town, such as the master plan and public facilities planning. | HIGH | Planning Board and Fire Dept. | 2021-24 | LOW | Carlisle General Fund |
| 9) **Fire Protection measures:** The Planning Board, Fire Department and Building Commissioner should evaluate if additional fire protection measures such as sprinklers are warranted for developments permitted by the town. | HIGH | Planning Board, Fire Dept, and Building Commissioner | 2021-23 | LOW Staff Time | Carlisle General Fund |
| 10) **Increase public education** on brush fire hazards, landscaping near homes, vegetation maintenance. | LOW | Fire Dept. | 2022-2023 | LOW Staff Time | Carlisle General Fund |

| Mitigation Recommendations for the Carlisle 2021 Plan Update | | | | | |
|---|---|---|---|---|---|
| **Mitigation Measures** | **Priority** | **Implementation Responsibility** | **Time Frame (2021-2026)** | **Estimated Cost** | **Potential Funding Sources** |
| **WIND HAZARDS** | | | | | |
| 11) **Enhanced Resources for Tree Management:** A more robust tree management program and a system to regularly survey and monitor trees would help reduce downed trees, power outages, and roadway blockages during extreme storms. Enhance the Town's tree maintenance in coordination with National Grid. Conduct a survey of trees, assess conditions. Identify trees that could pose a hazard due to their condition and/or location; prioritize for trimming or removal | HIGH | Dept. of Public Works | 2022-2026 | MED | Carlisle General Fund |
| **WINTER HAZARDS** | | | | | |
| 12) **Snow Load Assessment:** Identify public buildings that may be vulnerable to damage from snow loads and conduct a structural assessment if needed. | LOW | Building Commissioner | 2023-2025 | LOW | Carlisle General Fund |
| 13) **Ice Dams: Provide public education** on preventing ice dams that could cause damage to homes and other privately owned structures | LOW | Planning Board, Building Commissioner | 2022-2023 | LOW Staff Time | Carlisle General Fund |
| **GEOLOGIC HAZARDS** | | | | | |
| 14) **Earthquake Assessment:** Identify public buildings that may be vulnerable to earthquakes and assess options to make them more resistant to earthquakes | LOW | Building Commissioner | 2022-2023 | LOW Staff Time | Carlisle General Fund |
| **DROUGHT HAZARDS** | | | | | |

| Mitigation Recommendations for the Carlisle 2021 Plan Update | | | | | |
|---|---|---|---|---|---|
| **Mitigation Measures** | **Priority** | **Implementation Responsibility** | **Time Frame (2021-2026)** | **Estimated Cost** | **Potential Funding Sources** |
| 15) **Adopt landscaping guidelines** for new development to promote native plants in landscaping and site design measures. Refer to the Conservation Commission's list of native plants and the Board of Health's Irrigation Policy in Item #15 as part of the development and adoption of landscaping guidelines. | MED | Planning Board; Conservation Commission | 2022-2023 | LOW Staff Time | Carlisle General Fund |
| 16) **Monitor groundwater** to identify potential water resources for a municipal water supply. The O'Rourke property was tested and has the potential of supporting a municipal water supply for a portion of the town. (Consult with Mass DEP) | MED | Board of Health; Conservation Commission; Planning Board | 2022-2026 | MED | Carlisle General Fund |
| **EXTREME TEMPERATURES HAZARDS** | | | | | |
| 17) **Conduct a public awareness campaign** on the risks of extreme temperatures and resources available to residents during extreme events. | MED | Board of Health | 2022-2024 | LOW Staff Time | Carlisle General Fund |
| **MULTI HAZARDS** | | | | | |
| 18) **Forest and Land Management Plan**: Establish town-wide goals and develop a plan for managing forest and land resources. Assess the town's resources and prioritize planning to maximize **benefits for heat mitigation and resilience, water management, and climate related stress on forests**. Coordinate the town's planning effort with stakeholders and other landowners. | HIGH | Planning Board; Conservation Commission | 2022-2024 | MED | Carlisle General Fund; MVP Grant |

| Mitigation Recommendations for the Carlisle 2021 Plan Update | | | | | |
|---|---|---|---|---|---|
| **Mitigation Measures** | **Priority** | **Implementation Responsibility** | **Time Frame (2021-2026)** | **Estimated Cost** | **Potential Funding Sources** |
| 19) **Assistance in Coordinating In-Home Sheltering** Develop a town educational program for how shelter in place with a grant funded student intern. Also look to realtors to sponsor an informational brochure for new residents. Encourage neighborhood social gatherings to increase social resiliency. Getting to know neighbors should not have to wait until a disaster. | HIGH | Board of Health | 2021-2023 | LOW | Carlisle General Fund; |
| 20) **Address emergency shelter needs** - Research options for independent power supply. Need a place that provides beds; improve showers at the school. -Make use of Town Hall in emergencies, needs a generator | HIGH | Dept. of Public Works | 2021-2024 | MED | Carlisle General Fund |
| 21) **Upgraded or New Police and Fire facilities** are needed to accommodate the workforce. | HIGH | Police Dept.; Fire Dept | 2021-2025 | HIGH | Carlisle Capital Fund |

For COST ESTIMATES, where specific cost estimates are not available, use the following categories:

| | |
|---|---|
| Low: | Less than $50,000 |
| Medium: | $50,000 to $250,000 |
| High: | More than $250,000 |

# SECTION 9: PLAN ADOPTION & MAINTENANCE

## PLAN ADOPTION

The *Carlisle Hazard Mitigation Plan 2021 Update* was adopted by the Carlisle Select Board 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*].

## PLAN MAINTENANCE

MAPC worked with the Carlisle HMP/MVP Core Team to prepare this plan. After approval of the plan by FEMA, the Town of Carlisle will convene a Hazard Mitigation Implementation Committee to coordinate the implementation and evaluation of the Hazard Mitigation Plan and seek funding for mitigation projects in the plan. The committee will include the Chair of the Planning Board, the Fire Chief, the Health Agent and/or a member of the Board of Health, and the Conservation Administrator and/or a member of the conservation community. Additional members may be added to the committee from local businesses, non-profits, and institutions. The Town will encourage public participation during the next 5-year planning cycle. As a mid-term review of the plan conducted by the committee, this will be placed on the Town's web site, and any meetings of the committee will be publicly noticed in accordance with town and state open meeting laws.

## IMPLEMENTATION AND EVALUATION SCHEDULE

**Mid-Term Review of Progress** – The Carlisle Hazard Mitigation Implementation Committee will prepare and distribute a survey in year three of the plan. The survey will be distributed to the members of the Carlisle HMP/MVP Core Team and other interested stakeholders in the Town. The survey will poll the participants on progress and accomplishments for implementation of the plan to date, changes or revisions to the plan that may be needed, and any new hazards or problem areas that have been identified.

This information will be used to prepare a report or addendum to the Hazard Mitigation Plan in order to evaluate its effectiveness in meeting the plan's goals and identify areas that need to be revised in the next plan update. The Hazard Mitigation Implementation Committee, coordinated by the Chair of the Planning Board, will have primary responsibility for tracking progress, evaluating, and updating the plan.

**Begin to Prepare for the next Plan Update** – FEMA's approval of this plan is valid for five years, by which time an updated plan must be approved by FEMA in order to maintain the town's eligibility for FEMA mitigation grants. Given the lead time needed to secure FEMA grant funding and conduct the plan update process, the Hazard Mitigation Implementation Committee will begin to prepare for an update of the plan in year three. This will help the Town avoid a lapse in its approved plan status and grant eligibility when the current plan expires.

The Hazard Mitigation Implementation Committee will use the information from the annual review to identify the needs and priorities for the plan update and seek funding for the plan update process. A potential source of funding an updated plan is the FEMA Building Resilient Infrastructure and Communities grant (BRIC), which will pay for 75% of a planning project, with a 25% local cost share required.

**Prepare and Adopt an Updated Local Hazard Mitigation Plan** – Once the resources have been secured to update the plan, the Hazard Mitigation Implementation Committee will need to review the current FEMA hazard mitigation plan guidelines for any changes. When it is drafted, the next updated Carlisle Hazard Mitigation Plan will be forwarded to MEMA and FEMA for review and approval.

## INTEGRATION OF THE PLANS WITH OTHER PLANNING INITIATIVES

Upon approval of this Carlisle Hazard Mitigation Plan 2021 Update by FEMA, the Hazard Mitigation Implementation Committee will provide all interested parties and implementing departments with a copy of the plan and will initiate a discussion regarding how the plan can be integrated into that department's ongoing work. At a minimum, the plan will be reviewed and discussed with the following departments:

- Town Administrator's office
- Fire Department
- Emergency Management
- Police Department
- Public Works Department
- Planning Board
- Conservation Commission
- Board of Health
- Building Commissioner

Other groups that will be coordinated with include large institutions, local businesses and farms, land conservation organizations and watershed groups. The plan will also be posted on the Town's website. The posting of the plan on the website will include a mechanism for citizen feedback such as an e-mail address to send comments.

The Hazard Mitigation Plan will be integrated into other Town plans and policies as they are updated and renewed, including the Comprehensive Emergency Management Plan, Master Plan, Open Space and Recreation Plan, and Capital Plan.

# SECTION 10: LIST OF REFERENCES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Carlisle Zoning Bylaws

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Kocin, Paul J. and Uccellini, Louis W. 2004. A snowfall impact scale derived from Northeast storm snowfall distributions. American Meteorological Society. October 14, 2003.

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# APPENDIX A: HAZARD MAPPING

The MAPC GIS (Geographic Information Systems) Lab produced a series of maps for each community. Some of the data came from the Northeast States Emergency Consortium (NESEC). More information on NESEC can be found at http://www.serve.com/NESEC/. Due to the various sources for the data and varying levels of accuracy, the identification of an area as being in one of the hazard categories must be considered as a general classification that should always be supplemented with more local knowledge. The documentation for some of the hazard maps was incomplete as well.

The map series consists of eight panels displaying the following information:

| | |
|---|---|
| Map 1. | Population Density |
| Map 2. | Potential Development |
| Map 3. | Flood Zones |
| Map 4. | Earthquakes and Landslides |
| Map 5. | Hurricanes and Tornadoes |
| Map 6. | Average Snowfall |
| Map 7. | Composite Natural Hazards |
| Map 8. | Hazard Areas |
| Map 9 | High Land Surface Temperature and Tree Cover |

***Map1: Population Density*** – This map uses the US Census block data for 2010 and shows population density as the number of people per acre in seven categories with 60 or more people per acre representing the highest density areas.

***Map 2: Potential Development –*** This map shows potential future developments, and critical infrastructure sites. MAPC consulted with town staff to determine areas that were likely to be developed or redeveloped in the future.

***Map 3: Flood Zones*** – The map of flood zones used the FEMA NFIP Flood Zones for Middlesex County as its source. For more information, refer to the FEMA Map Service Center website http://www.msc.fema.gov. The definitions of the flood zones are described in detail on this site as well. The flood zone map for each community also shows critical infrastructure and municipally owned and protected open space.

***Map 4: Earthquakes and Landslides –*** This information came from NESEC. For most communities, there was no data for earthquakes because only the epicenters of an earthquake are mapped.

The landslide information shows areas with either a low susceptibility or a moderate susceptibility to landslides based on mapping of geological formations. This mapping is highly general in nature. For more information on how landslide susceptibility was mapped, refer to http://pubs.usgs.gov/pp/p1183/pp1183.html.

***Map 5: Hurricanes and Tornadoes –*** This map shows a number of different items. The map includes the storm tracks for both hurricanes and tropical storms. This information must be viewed in context. A storm track only shows where the eye of the storm passed through. In most

cases, the effects of the wind and rain from these storms were felt in other communities even if the track was not within that community. This map also shows the location of tornadoes with a classification as to the level of damages. What appears on the map varies by community since not all communities experience the same wind-related events. These maps also show the 100-year wind speed.

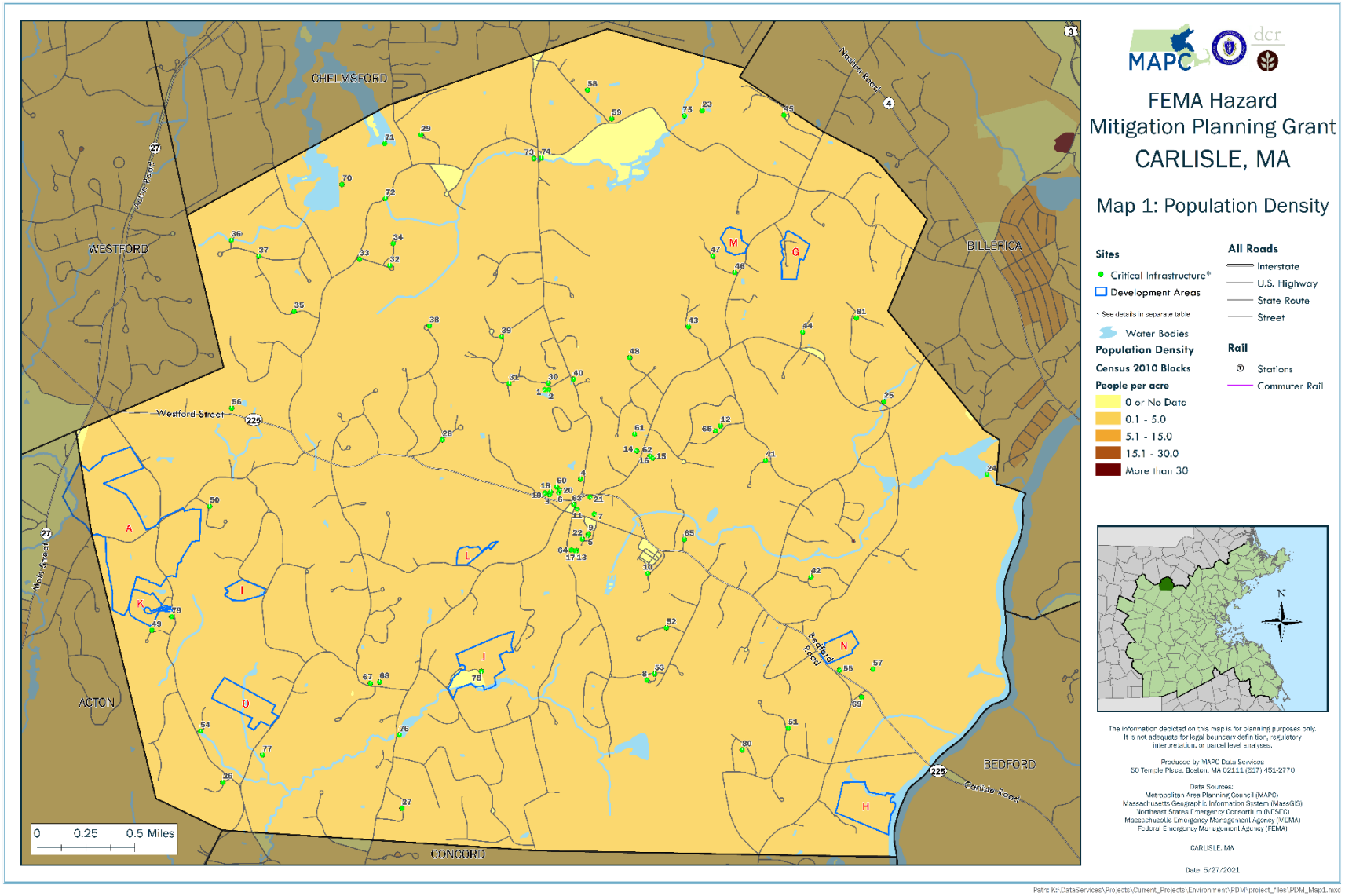
***Map 6: Average Snowfall - -*** This map shows the average snowfall and open space. It also shows
storm tracks for nor'easters if any storms tracked through the community.

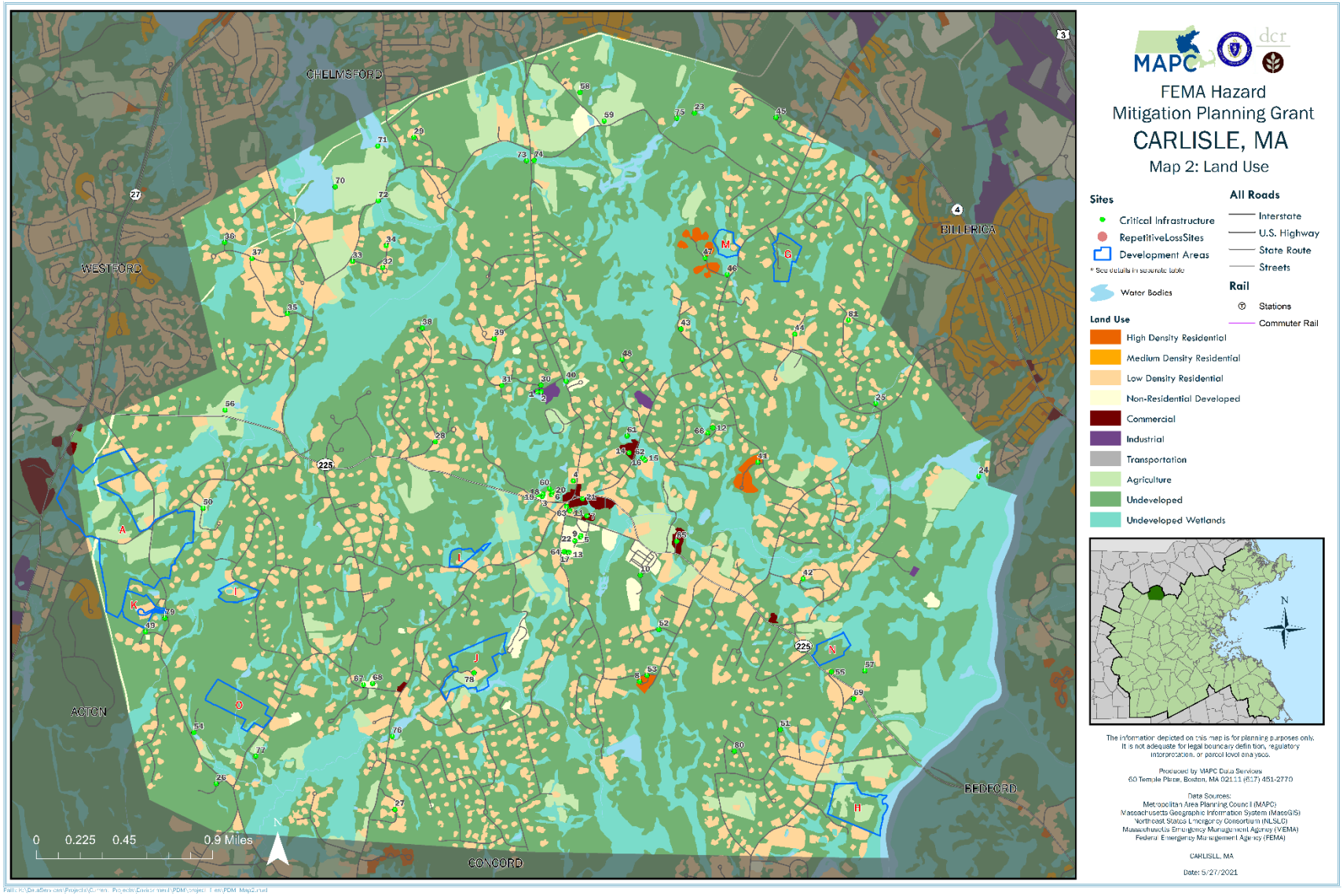
***Map 7: Composite Natural Hazards -*** This map shows four categories of composite natural hazards for areas of existing development. The hazards included in this map are 100-year wind speeds of 110 mph or higher, low, and moderate landslide risk, FEMA Q3 flood zones (100 year and 500 year) and hurricane surge inundation areas. Areas with only one hazard were considered to be low hazard areas. Moderate areas have two of the hazards present. High hazard areas have three hazards present and severe hazard areas have four hazards present.

***Map 8: Hazard Areas –*** For each community, locally identified hazard areas are overlaid on an aerial photograph. The critical infrastructure sites are also shown. The source of the aerial photograph is Mass GIS.

***Map 9: Sea Level Rise–*** Not applicable to Carlisle, this map is not included.

***Map 10: High Land Surface Temperature*** - MAPC uses LANDSAT 30m spatial resolution satellite data to extract land surface temperature to assess a community's exposure to present-day extreme heat and any vulnerabilities to rising temperatures with climate change. The extreme heat analysis uses date from 2016 with satellite images on days of 90° or higher at Logan Airport, July 13, and August 30, 2016, and created land surface temperature using a methodology development by Walawender, Hajto, and Iwaniuk (2012) called Landsat TRS Tools. This map illustrates the hottest areas in the top fifth percentile for the 101 towns in Metropolitan Boston.


CHELMSFORD
WESTFORD
BILLERICA
ACTON
BEDFORD
CONCORD
Westford Street
Bedford Road
Carlisle Road
Nashua Road
Acton Road
Main Street
0 0.25 0.5 Miles
MAPC
dcr
FEMA Hazard Mitigation Planning Grant
CARLISLE, MA
Map 1: Population Density
Sites
Critical Infrastructure*
Development Areas
* See details in separate table
Water Bodies
Population Density
Census 2010 Blocks
People per acre
0 or No Data
0.1 - 5.0
5.1 - 15.0
15.1 - 30.0
More than 30
All Roads
Interstate
U.S. Highway
State Route
Street
Rail
Stations
Commuter Rail
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel level analyses.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
CARLISLE, MA
Date: 5/27/2021
Path: K:\DataServices\Projects\Current_Projects\Environment\PDM\project_files\PDM_Map1.mxd


MAPC
dcr
FEMA Hazard
Mitigation Planning Grant
CARLISLE, MA
Map 2: Land Use
Sites
Critical Infrastructure
RepetitiveLossSites
Development Areas
* See details in separate table
Water Bodies
All Roads
Interstate
U.S. Highway
State Route
Streets
Rail
Stations
Commuter Rail
Land Use
High Density Residential
Medium Density Residential
Low Density Residential
Non-Residential Developed
Commercial
Industrial
Transportation
Agriculture
Undeveloped
Undeveloped Wetlands
CHELMSFORD
WESTFORD
BILLERICA
ACTON
CONCORD
BEDFORD
0 0.225 0.45 0.9 Miles
N
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel level analysis.
Produced by MAPC Data Services
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Data Sources:
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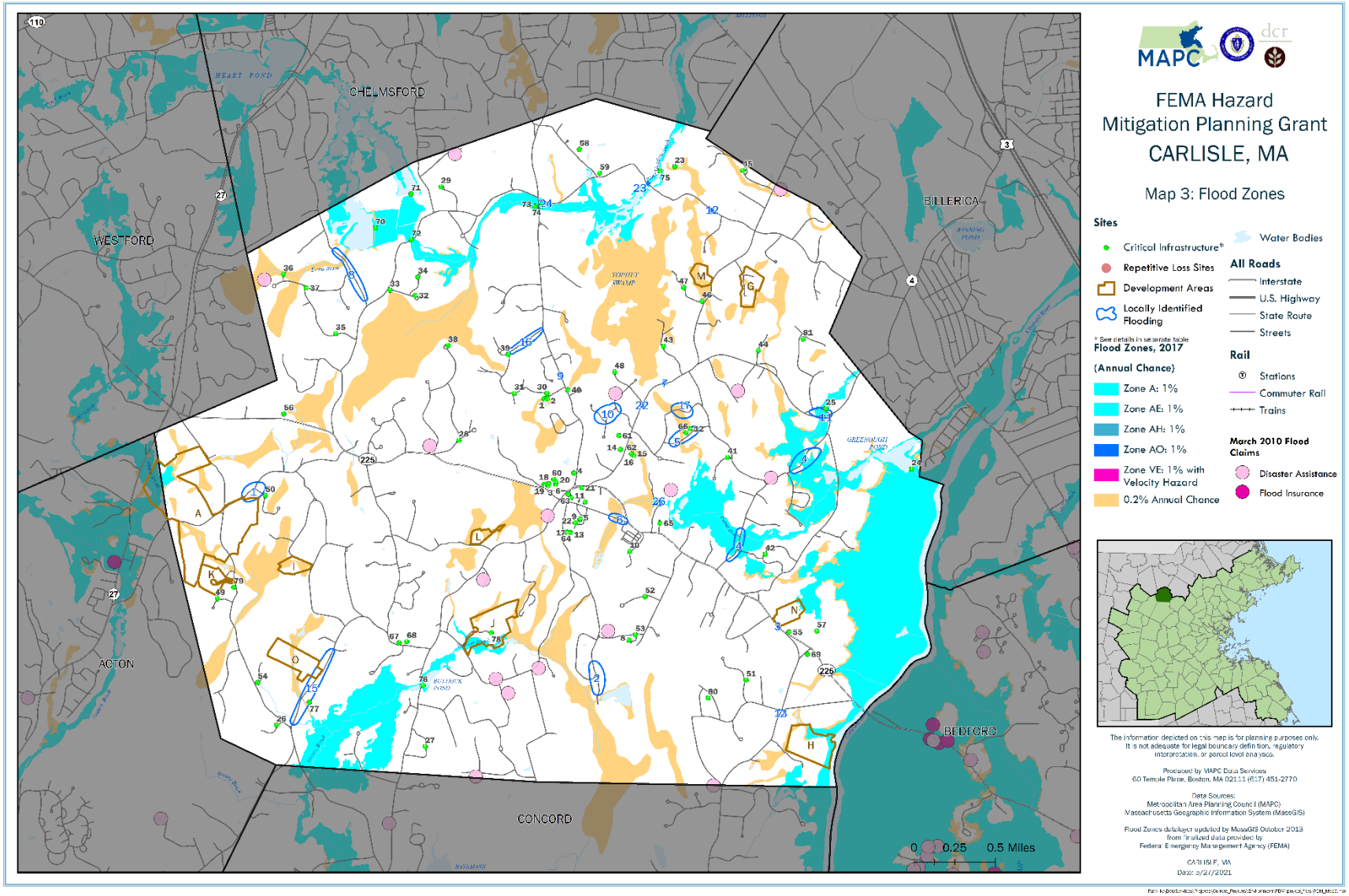
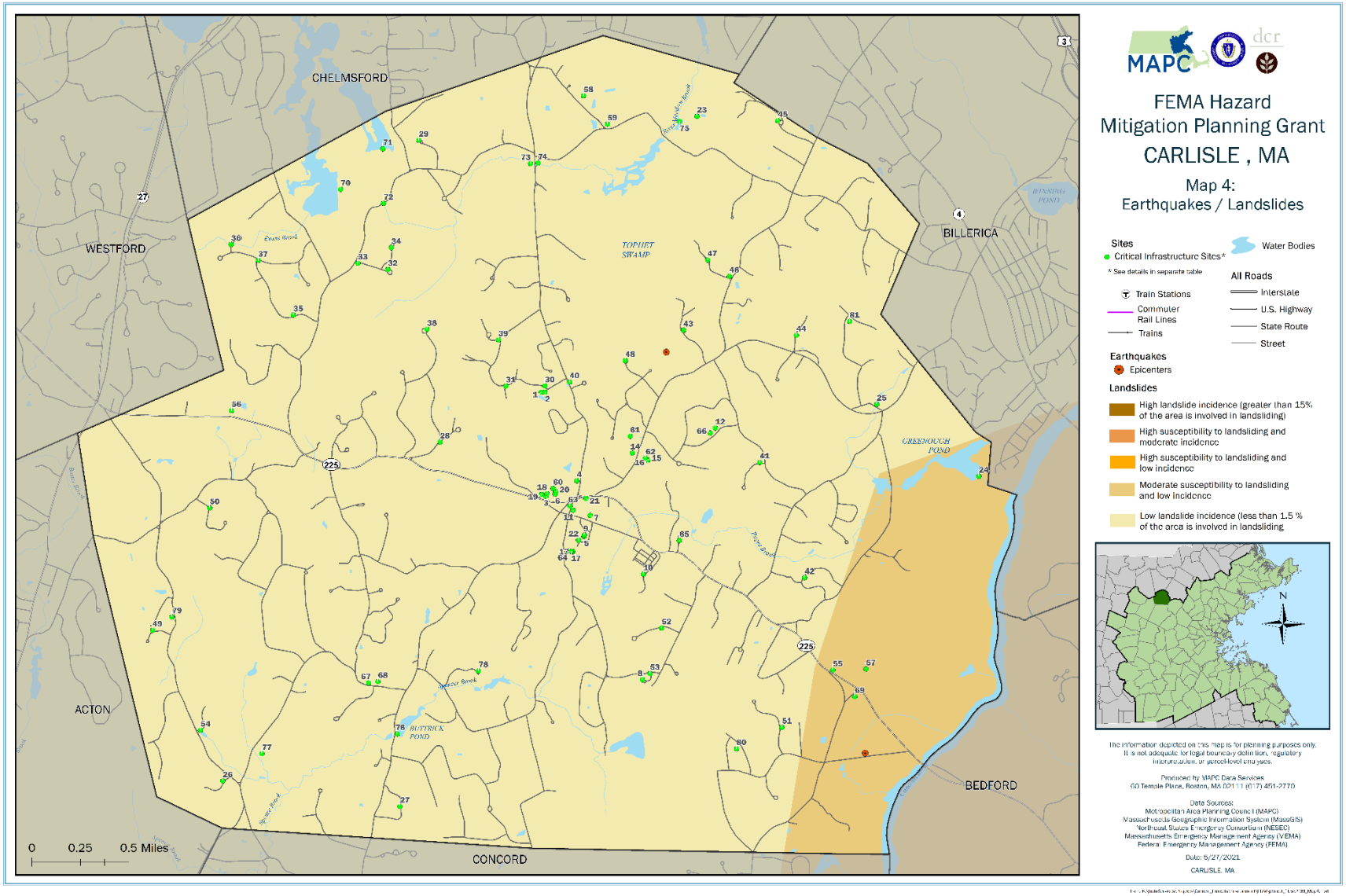
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
CARLISLE, MA
Date: 5/27/2021


CHELMSFORD
WESTFORD
BILLERICA
ACTON
CONCORD
BEDFORD
HEART POND
TOPHET SWAMP
GREENOUGH POND
BUTTRICK POND
0 0.25 0.5 Miles
MAPC
dcr
FEMA Hazard Mitigation Planning Grant
CARLISLE, MA
Map 3: Flood Zones
Sites
Critical Infrastructure*
Repetitive Loss Sites
Development Areas
Locally Identified Flooding
* See details in separate table
Flood Zones, 2017
(Annual Chance)
Zone A: 1%
Zone AE: 1%
Zone AH: 1%
Zone AO: 1%
Zone VE: 1% with Velocity Hazard
0.2% Annual Chance
Water Bodies
All Roads
Interstate
U.S. Highway
State Route
Streets
Rail
Stations
Commuter Rail
Trains
March 2010 Flood Claims
Disaster Assistance
Flood Insurance
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel level analysis.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Flood Zones datalayer updated by MassGIS October 2013 from finalized data provided by Federal Emergency Management Agency (FEMA)
CARLISLE, MA
Date: 3/27/2021


CHELMSFORD
WESTFORD
BILLERICA
ACTON
CONCORD
BEDFORD
TOPHET SWAMP
GREENOUGH POND
BUTTRICK POND
0 0.25 0.5 Miles
MAPC
dcr
FEMA Hazard Mitigation Planning Grant
CARLISLE , MA
Map 4:
Earthquakes / Landslides
Sites
Critical Infrastructure Sites*
* See details in separate table
Train Stations
Commuter Rail Lines
Trains
Water Bodies
All Roads
Interstate
U.S. Highway
State Route
Street
Earthquakes
Epicenters
Landslides
High landslide incidence (greater than 15% of the area is involved in landsliding)
High susceptibility to landsliding and moderate incidence
High susceptibility to landsliding and low incidence
Moderate susceptibility to landsliding and low incidence
Low landslide incidence (less than 1.5 % of the area is involved in landsliding
N
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary delineation, regulatory interpretation, or parcel-level analyses.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
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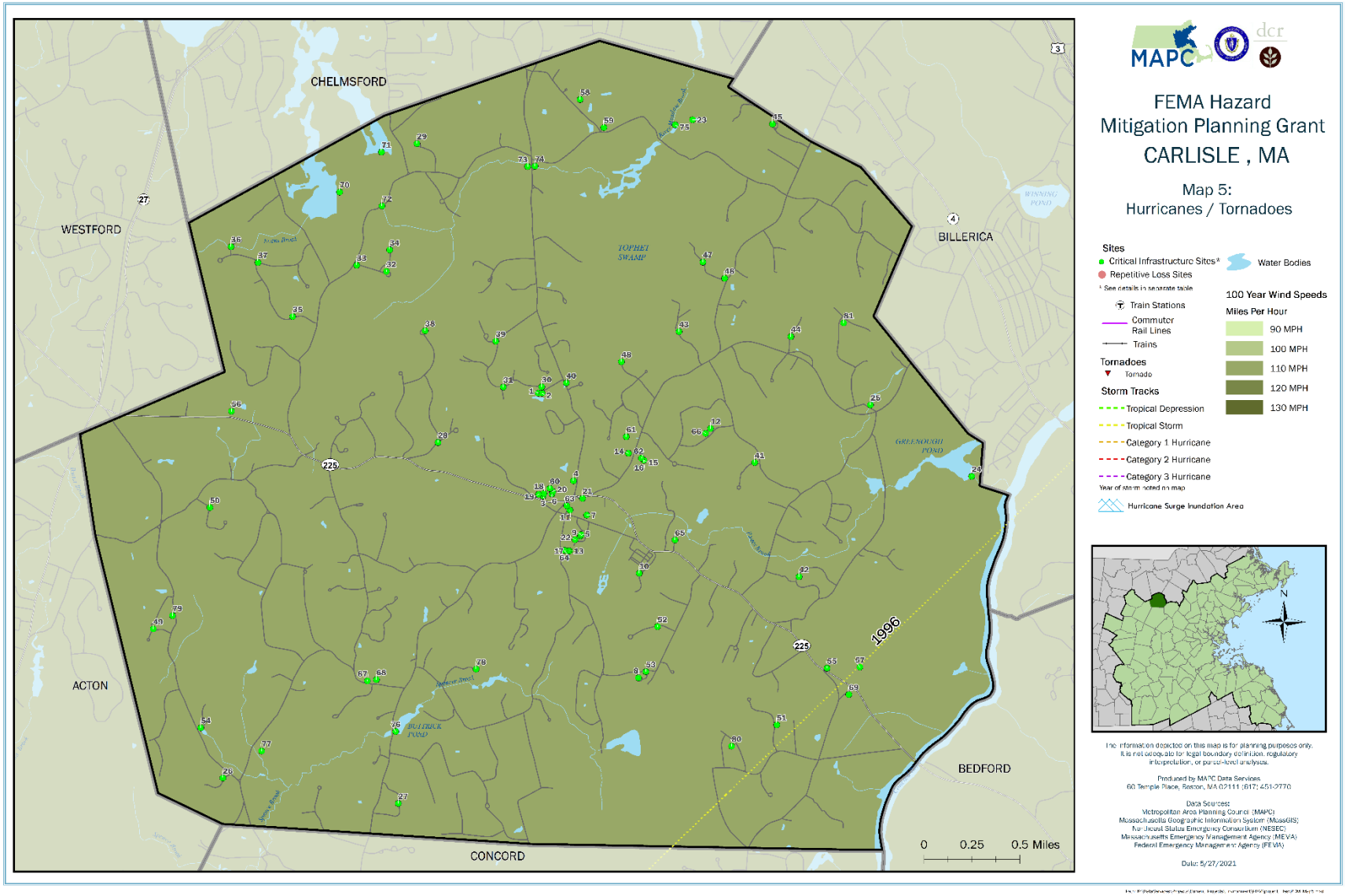
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (VEMA)
Federal Emergency Management Agency (FEMA)
Date: 5/27/2021
CARLISLE, MA


CHELMSFORD
WESTFORD
BILLERICA
ACTON
BEDFORD
CONCORD
TOPHET SWAMP
GREENOUGH POND
BUTTRICK POND
1996
0 0.25 0.5 Miles
MAPC
dcr
FEMA Hazard Mitigation Planning Grant
CARLISLE , MA
Map 5:
Hurricanes / Tornadoes
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
* See details in separate table
Train Stations
Commuter Rail Lines
Trains
Tornadoes
Tornado
Storm Tracks
Tropical Depression
Tropical Storm
Category 1 Hurricane
Category 2 Hurricane
Category 3 Hurricane
Year of storm noted on map
Hurricane Surge Inundation Area
Water Bodies
100 Year Wind Speeds
Miles Per Hour
90 MPH
100 MPH
110 MPH
120 MPH
130 MPH
N
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Produced by MAPC Data Services
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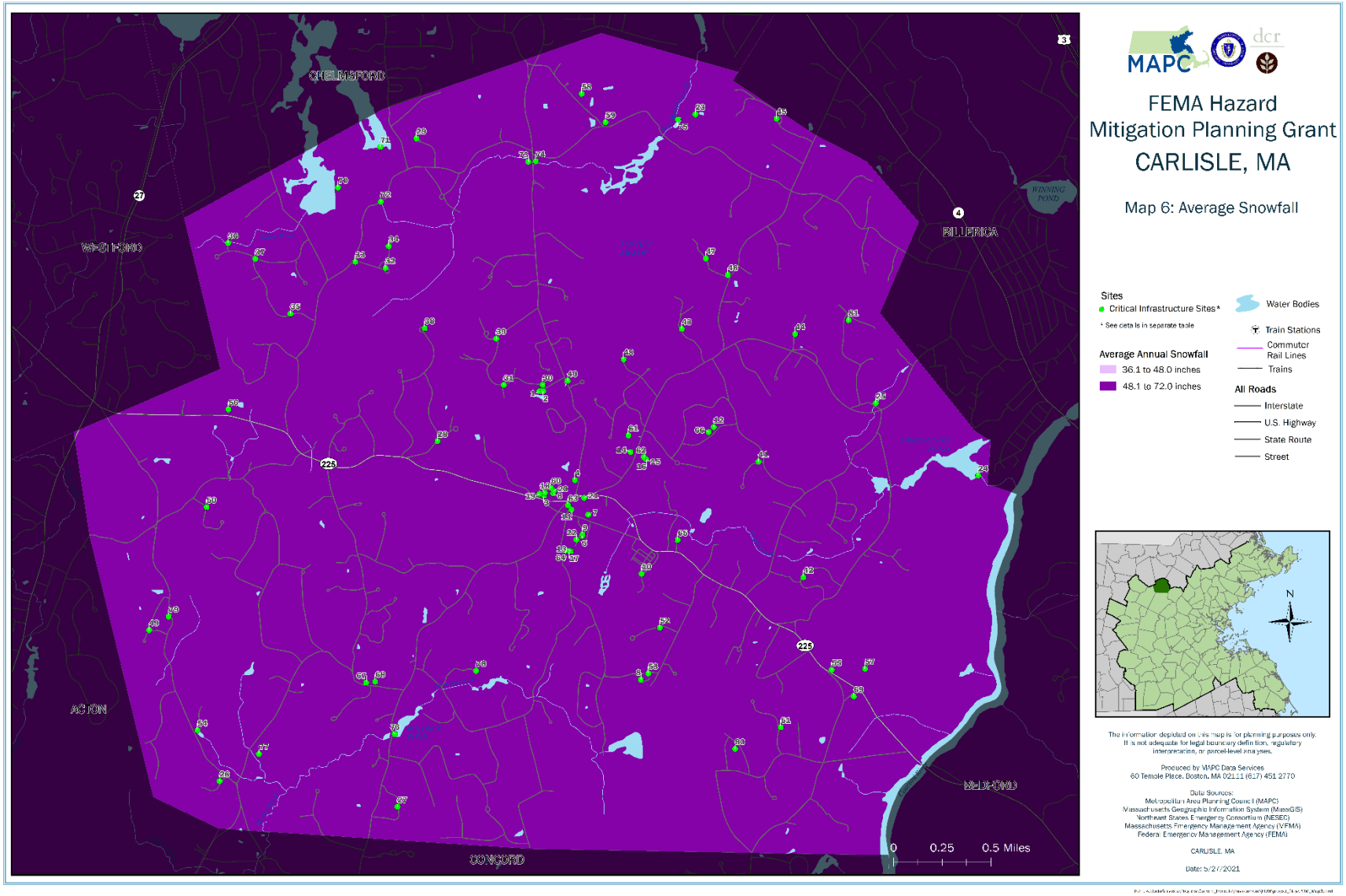
MAPC
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FEMA Hazard
Mitigation Planning Grant
CARLISLE, MA
Map 6: Average Snowfall
Sites
Critical Infrastructure Sites *
* See data is in separate table
Average Annual Snowfall
36.1 to 48.0 inches
48.1 to 72.0 inches
Water Bodies
Train Stations
Commuter Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
CHELMSFORD
WESTFORD
BILLERICA
ACTON
CONCORD
BEDFORD
WINNING POND
0 0.25 0.5 Miles
N
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel-level analyses.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451 2770
Data Sources:
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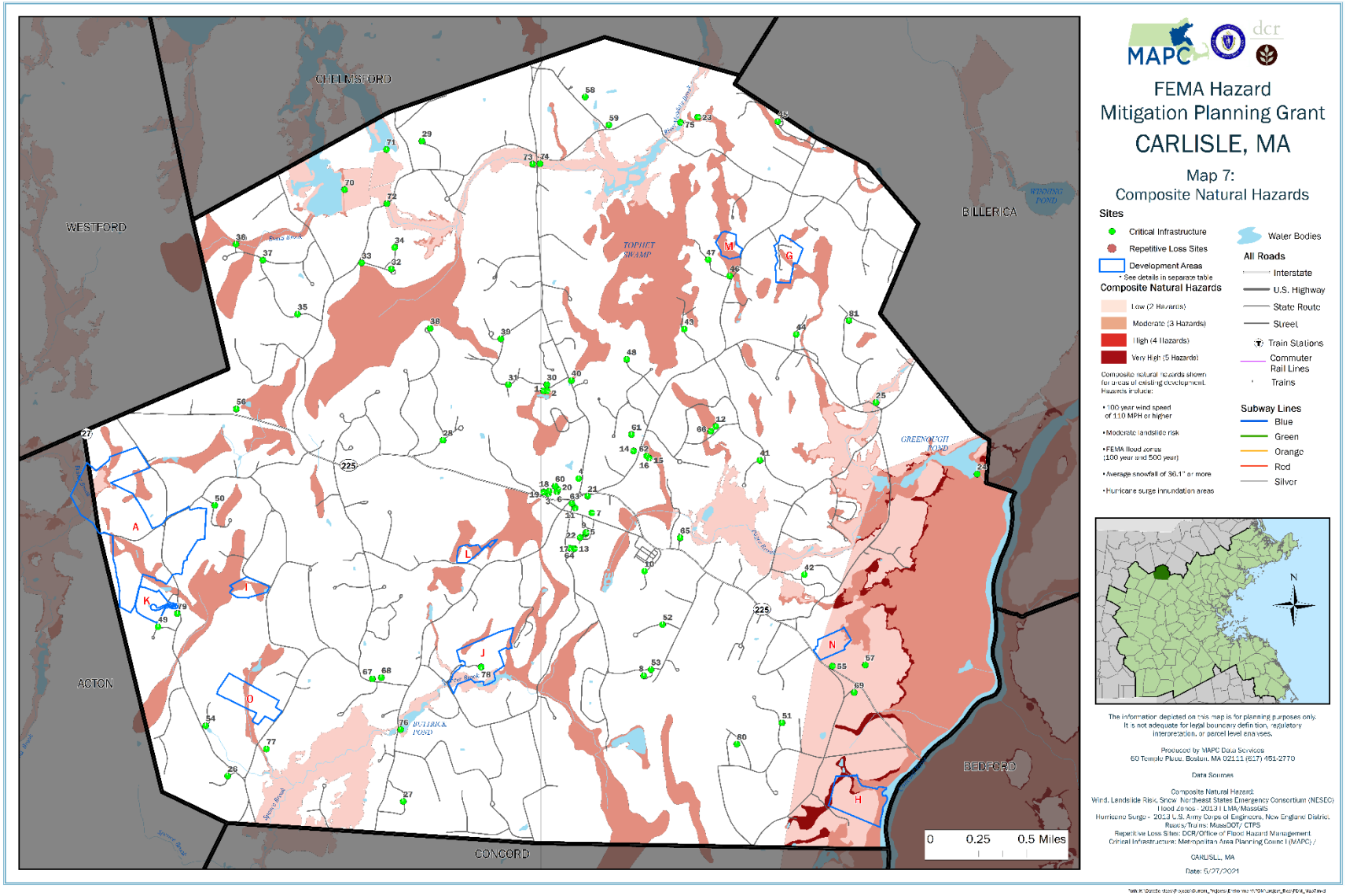
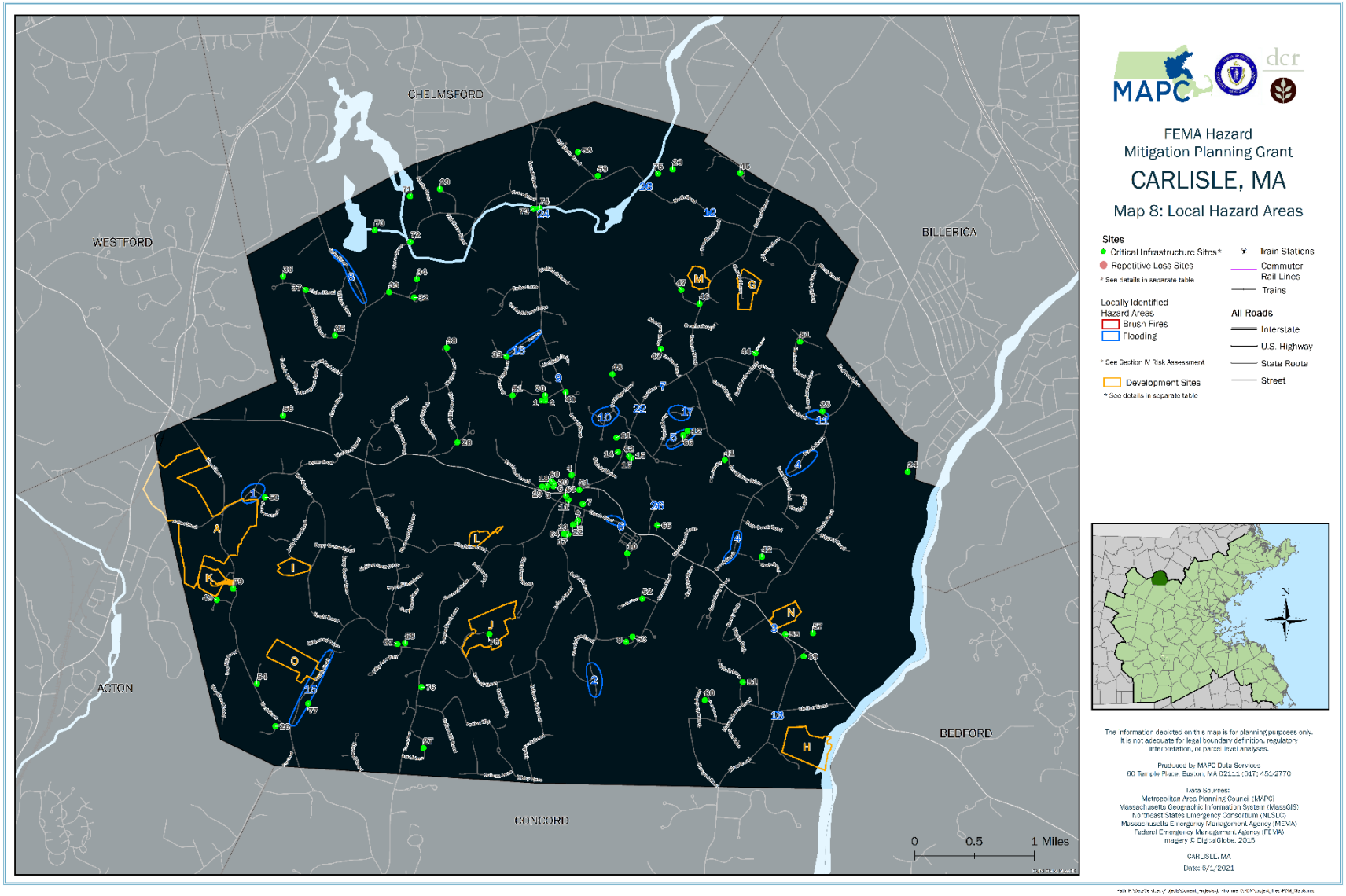
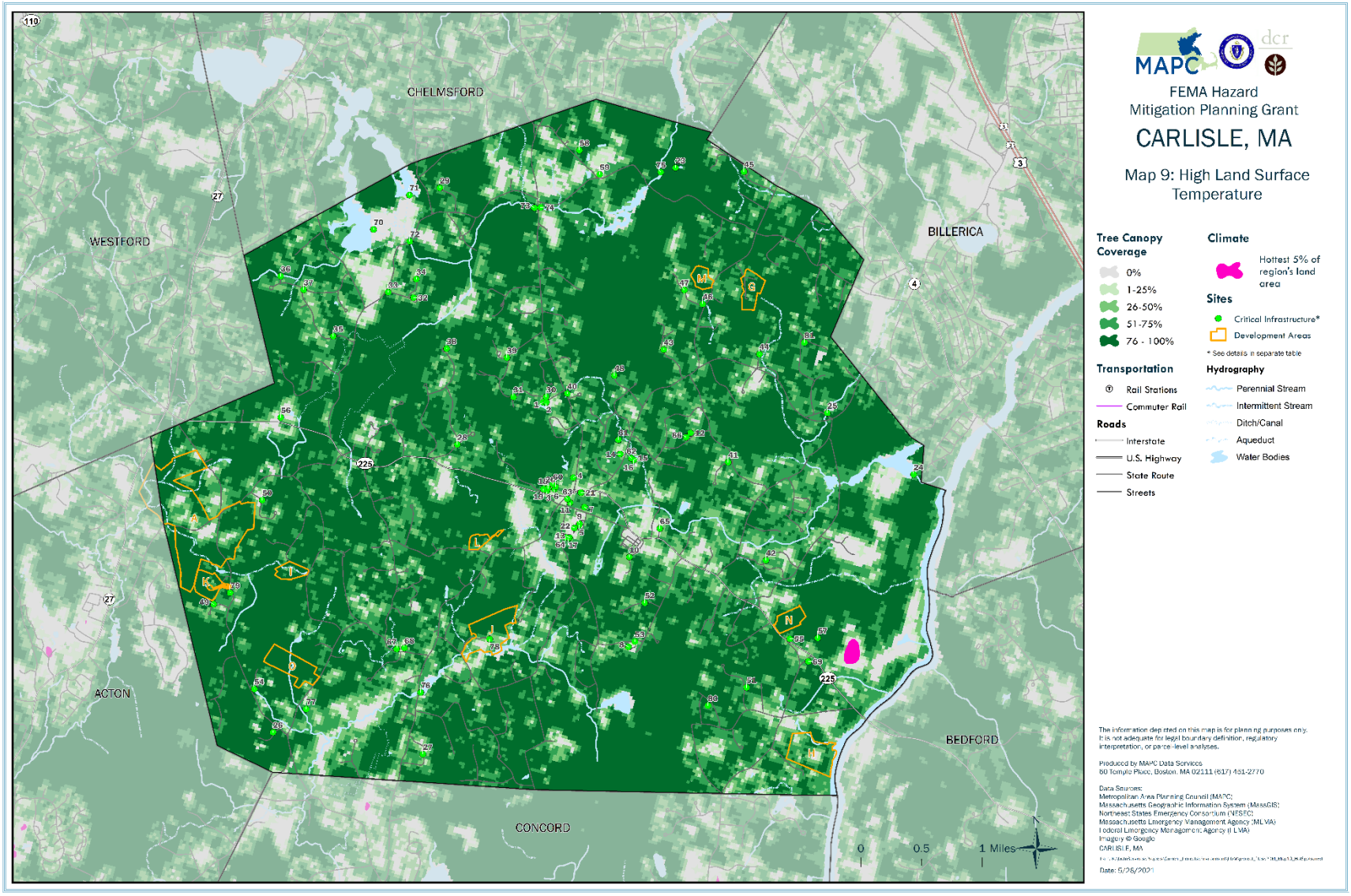
Federal Emergency Management Agency (FEMA)
CARLISLE, MA
Date: 5/27/2021


CHELMSFORD
WESTFORD
BILLERICA
ACTON
CONCORD
BEDFORD
TOPHET SWAMP
GREENOUGH POND
BULLERICA POND
WINNING POND
0 0.25 0.5 Miles
MAPC
dcr
FEMA Hazard Mitigation Planning Grant
CARLISLE, MA
Map 7:
Composite Natural Hazards
Sites
Critical Infrastructure
Repetitive Loss Sites
Development Areas
• See details in separate table
Composite Natural Hazards
Low (2 Hazards)
Moderate (3 Hazards)
High (4 Hazards)
Very High (5 Hazards)
Composite natural hazards shown for areas of existing development. Hazards include:
• 100 year wind speed of 110 MPH or higher
• Moderate landslide risk
• FEMA flood zones (100 year and 500 year)
• Average snowfall of 36.1" or more
• Hurricane surge inundation areas
Water Bodies
All Roads
Interstate
U.S. Highway
State Route
Street
Train Stations
Commuter Rail Lines
Trains
Subway Lines
Blue
Green
Orange
Red
Silver
N
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel level analyses.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources
Composite Natural Hazard:
Wind, Landslide Risk, Snow: Northeast States Emergency Consortium (NESEC)
Flood Zones - 2013 | LMA/ Massgis
Hurricane Surge - 2012 U.S. Army Corps of Engineers, New England District.
Roads/Trains: MassDOT/ CTPS
Repetitive Loss Sites: DCR/Office of Flood Hazard Management
Critical Infrastructure: Metropolitan Area Planning Council (MAPC)
CARLISLE, MA
Date: 5/27/2021


CHELMSFORD
WESTFORD
BILLERICA
ACTON
BEDFORD
CONCORD
0 0.5 1 Miles
MAPC
dcr
FEMA Hazard
Mitigation Planning Grant
CARLISLE, MA
Map 8: Local Hazard Areas
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
* See details in separate table
Locally Identified
Hazard Areas
Brush Fires
Flooding
* See Section IV Risk Assessment
Development Sites
* See details in separate table
Train Stations
Commuter
Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
N
The information depicted on this map is for planning purposes only.
It is not adequate for legal boundary definition, regulatory
interpretation, or parcel level analyses.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
Imagery © DigitalGlobe, 2015
CARLISLE, MA
Date: 6/1/2021


MAPC
dcr
FEMA Hazard
Mitigation Planning Grant
CARLISLE, MA
Map 9: High Land Surface Temperature
Tree Canopy Coverage
0%
1-25%
26-50%
51-75%
76 - 100%
Climate
Hottest 5% of region's land area
Sites
Critical Infrastructure*
Development Areas
* See details in separate table
Transportation
Rail Stations
Commuter Rail
Roads
Interstate
U.S. Highway
State Route
Streets
Hydrography
Perennial Stream
Intermittent Stream
Ditch/Canal
Aqueduct
Water Bodies
CHELMSFORD
WESTFORD
BILLERICA
ACTON
CONCORD
BEDFORD
0
0.5
1 Miles
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel-level analyses.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
Imagery © Google
CARLISLE, MA
Date: 5/26/2021

# APPENDIX B: TEAM MEETING AGENDAS

**Carlise** Municipal Vulnerability Preparpedness and Natural Hazard Mitigation

Virtual Core Team Meeting #1
November 18, 2020 7:00-9:00 PM
Join Zoom Meeting
https://zoom.us/j/97798222848?pwd=VTFlVWdvT1djb01JSzZ6RVFFeW04QT09

Meeting ID: 977 9822 2848
Passcode: 239261
Dial by your location
+1 646 876 9923 US (New York)

## Agenda

**Introductions and Ice Breaker (10 minutes)**

**MVP and HMP Project Overview (5 minutes)**

**Natural Hazard Mitigation Planning Meeting (50) minutes)**

1. Intro Natural Hazard Mitigation Planning
2. Update Critical Facilities Inventory and Mapping
3. Identify/update local hazards:
    a) Flood Hazard Areas
    b) Fire Hazard Areas (brushfires/wildfires)
    c) Dams
    d) Other hazards
4. Identify/Update New and Potential Development Sites

**Municipal Vulnerability Preparedness Meeting (40 minutes)**

1. MVP overview
2. MVP Goals for Carlisle
3. Virtual Workshop Format and Materials
4. Discussion on workshop participants and outreach

**Questions and Next Steps (15 minutes)**

1. Date for next Core Team meeting

## Carlise Municipal Vulnerability Preparpedness and Hazard Mitigation Plan

**Virtual Core Team Meeting #2**
Wednesday, January 6, 2021, 7:00-9:00 PM

**Join Zoom Meeting**
https://zoom.us/j/99308165788?pwd=TmJJdTVBRHMrd1F1cld6Om1ueWRFZz09

**Meeting ID: 993 0816 5788**
**Passcode: 127740**

**Dial by your location**
1 646 876 9923 US (New York)

# Agenda

### Introductions ~ New Year's Greetings (5 minutes)

### Municipal Vulnerability Preparedness Meeting (45 minutes)

1. Set MVP Workshop date and time
2. Virtual Workshop Format
3. Review sample workshop materials
4. Develop list of participants (see MVP suggested categories)
5. Invitations and outreach to ensure participation

### Hazard Mitigation Plan (45 minutes)

1. First Public Meeting on the Hazard Mitigation Plan
2. Request to FEMA for Repetitive Loss data
3. Review new development sites (list provide by the Town)

### Questions and Next Steps (10 minutes)

1. Date for next Core Team meeting

## Carlise Municipal Vulnerability Preparpedness and Hazard Mitigation Plan

**Virtual Core Team Meeting #3**
Tuesday, March 16, 2021, 7:00-9:00 PM

**Join Zoom Meeting**
https://zoom.us/j/99308165788?pwd=TmJJdTVBRHMrd1F1cld6Qm1ueWRFZz09

**Meeting ID: 993 0816 5788**
**Passcode: 127740**

**Dial by your location**
**1 646 876 9923 US (New York)**

# Agenda

### Preparing for the MVP Workshop on March 27

1. Review RSVPs, assign attendees to breakout groups
2. Virtual Workshop Agenda and Format
3. Pre-workshop Survey
4. Questions?

### Post-workshop Next Steps

5. Post-workshop survey: prioritizing top actions (April)
6. Public Listening Session, MVP report (May)
7. 'Next Core Team: HMP Recommendations (May)
8. Final Public meeting on HMP (early June)
9. Submit draft HMP to MEMA (June)

**Carlise Municipal Vulnerability Preparpedness and Hazard Mitigation Plan**

**Carlisle Core MVP/HMP Team Meeting #4 (Final)**
Wednesday, May 26, 2021, 7:15-8:45 PM

**Join Zoom Meeting**
**https://zoom.us/j/94007122641**

**Meeting ID: 940 0712 2641**

**Dial by your location**
**1 646 876 9923 US (New York)**

# Agenda

## 1. Mitigation Recommendations for the Hazard Mitigation Plan

- Review Table 1, Status of Mitigation Action from the 2012 Plan
- Review Table 2, Draft Mitigation Actions for the 2021 Plan Update
- Finalize recommended mitigation actions
- Add time frame, estimated cost, local agency, funding

## 2. Prepare for MVP Listening Session and final HMP Public Meeting

- Scheduled for **Wednesday, June 16**, 7:30 to 8:30 PM via Zoom
- Outreach to stakeholders-MVP invitees and any others?

## 3. Next Steps: Finalize plans and submit to EEA and MEMA

- MEMA and FEMA Review of the HMP
- Town vote of adoption of HMP after FEMA approval
- Implement! Consider FEMA BRIC grants and MVP Action Grants

# APPENDIX C: PUBLIC MEETINGS

## Carlisle Hazard Mitigation Plan and Municipal Vulnerability Preparedness

## Public Meeting

*Natural hazards and climate change can have serious impacts on Carlisle's residents and businesses*



The Town of Carlisle is preparing a FEMA Hazard Mitigation Plan as well as a Municipal Vulnerability Preparedness (MVP) project to reduce the Town's vulnerability to natural hazards such as flooding, hurricanes, and blizzards, and to increase its resilience to the impacts of climate change. Please join the Town for a public presentation about Hazard Mitigation Plan and MVP project at an online meeting of the Select Board.

**Date:** Tuesday, February 9, 2021 at 7:30 PM

**Meeting via Zoom:** Please send an email to townhall@carlislema.gov to request the Zoom information.

MAPC

Amanda Linehan, Communications Manager, Metropolitan Area Planning Council
617-933-0705, alinehan@mapc.org

**CALENDAR LISTING / MEDIA ADVISORY**

# CARLISLE'S HAZARD MITIGATION PLAN TO BE DISSUSSED AT FEBRUARY 9 PUBLIC MEETING

**What:** On February 9, 2021 at 7:30 PM the Carlisle Select Board will host an online public meeting via Zoom to discuss the town's Hazard Mitigation Plan and Municipal Vulnerability Preparedness project.

The Town of Carlisle is preparing a FEMA Hazard Mitigation Plan as well as a Municipal Vulnerability Preparedness (MVP) project to reduce the town's vulnerability to natural hazards such as flooding, hurricanes, and blizzards, and increase resilience to the impacts of climate change. Please join the meeting for a public presentation about Hazard Mitigation Plan and MVP project at a virtual meeting of the Select Board. The presentation will be made by the Metropolitan Area Planning Council, which is preparing both projects for the Town.

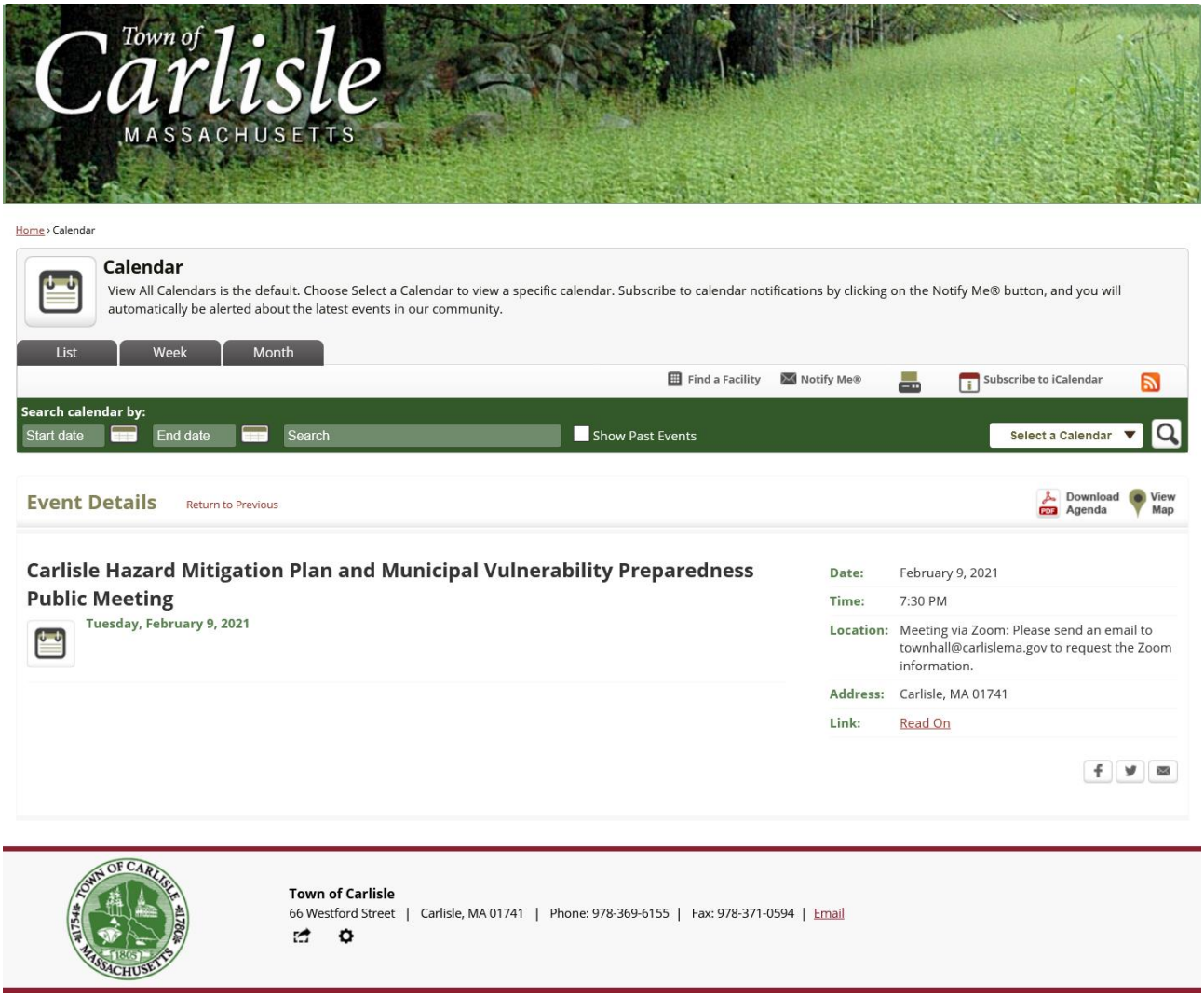
**Who:** Carlisle residents, business owners, civic organizations and institutions are invited to participate in the public meeting and provide their questions and comments as part of this on-going effort to plan for a resilient future for the Town of Carlisle.

**When:** Tuesday, February 9, 2021, 7:30 PM

**Where:** Online meeting via Zoom
Please send an email to townhall@carlislema.gov to request the Zoom information.

MAPC is the regional planning agency for 101 communities in the metropolitan Boston area, promoting smart growth and regional collaboration. More information about MAPC is available at www.mapc.org.

##


Town of Carlisle
MASSACHUSETTS
Home › Calendar
Calendar
View All Calendars is the default. Choose Select a Calendar to view a specific calendar. Subscribe to calendar notifications by clicking on the Notify Me® button, and you will automatically be alerted about the latest events in our community.
List
Week
Month
Find a Facility
Notify Me®
Subscribe to iCalendar
Search calendar by:
Start date
End date
Search
Show Past Events
Select a Calendar
Event Details
Return to Previous
Download Agenda
View Map
Carlisle Hazard Mitigation Plan and Municipal Vulnerability Preparedness Public Meeting
Tuesday, February 9, 2021
Date: February 9, 2021
Time: 7:30 PM
Location: Meeting via Zoom: Please send an email to townhall@carlislema.gov to request the Zoom information.
Address: Carlisle, MA 01741
Link: Read On
Town of Carlisle
66 Westford Street | Carlisle, MA 01741 | Phone: 978-369-6155 | Fax: 978-371-0594 | Email

Carlisle Mosquito
A nonprofit newspaper serving Carlisle, Massachusetts

## Planning for climate change and natural disasters

by Emily Smith, February 12, 2021r

Martin Pillsbury of the Metropolitan Area Planning Council (MAPC) joined the February 9 Select Board meeting to present an overview of the town's Municipal Vulnerability Preparedness (MVP) project, for which the town received a $27K grant last year. His organization was hired to assist a committee of local officials and volunteers. This long-range planning effort will consider ways the town might better prepare for weather extremes associated with climate change, such as flooding, storms, heat waves or drought. Completion of the project will earn eligibility for state MVP implementation grants. Along with the effort, the committee and consultant will also look into updating the town's Hazard Mitigation Plan (HMP), which has expired.

Pillsbury explained that the HMP is a Federal Emergency Management Agency (FEMA) initiative that examines natural hazards based on historic evidence such as floods or hurricanes. The MVP, a Massachusetts Executive Office of Energy and Environmental Affairs program, looks at similar hazards, but through the lens of how these issues may be impacted and/or exacerbated by climate change. The two projects combined can give a thorough, comprehensive understanding of what risks and challenges the community may face, and how to prepare for them.

Planning Board Chair Madeleine Blake later explained that the town received an additional $5K in grant-funding to include an update to the HMP within the MVP project. She said that Pillsbury is acting as the project manager and will produce both an MVP and HMP report for the town.

MVP project tasks

The MVP will seek to identify strengths and weaknesses by sectors—Carlisle's infrastructure, environment and society. The major categories of climate risks that the MVP will assess for Carlisle are inland flooding, extreme heat, winter storms and droughts. The program draws upon an MVP workshop, which is scheduled for March 27 and anticipated to run for about four hours. The purpose of the workshop is to develop actions for addressing each hazard and each sector.

Blake later called the MVP workshop "the main event for this whole process," with the goal to "collectively identify and rank Carlisle's vulnerabilities to climate change." She noted that the workshop is by invitation only and invitations will be sent out in late February. "Although it is by invitation," she said, "I doubt we would refuse an invitation to any Carlisle resident who is willing to participate. Developing the invitation list is more like an exercise to make sure we have thought about how to get knowledgeable people, and different viewpoints and areas of focus, to participate."


Municipal Vulnerability Preparedness
and Hazard Mitigation Plan
MAPC
Martin Pillsbury
Metropolitan Area Planning Council
Carlisle Select Board
February 9, 2021
TOWN OF CARLISLE
1754
2001
MASSACHUSETTS

# Carlisle Hazard Mitigation and Municipal Vulnerability Preparedness

# Public Listening Session

*Natural hazards and climate change can have serious impacts on Carlisle's residents and businesses*

The Town of Carlisle has conducted a Community Resilience Building workshop to increase its resilience to the impacts of climate change and has also prepared a FEMA Hazard Mitigation Plan to reduce the Town's vulnerability to natural hazards such as flooding, hurricanes, and blizzards. Please join the Town for a public listening session and presentation about these two important related projects. Your input is important to the Town, and your questions and comments are welcome.

**Date:** Wednesday, June 16, 2021, at 7:30 PM

**Meeting via Zoom:** Please send an email to planning@carlislema.gov to request the Zoom information.

Amanda Linehan, Communications Manager, Metropolitan Area Planning Council
617-933-0705, alinehan@mapc.org

**CALENDAR LISTING / MEDIA ADVISORY**

# CARLISLE'S MUNICIPAL VULNERABILITY PREPAREDNESS AND DRAFT HAZARD MITIGATION PLAN TO BE DISSUSSED AT JUNE 16 PUBLIC LISTENING SESSION

**What:** On June 16, 2021, at 7:30 PM the Carlisle Planning Board will host an online public meeting via Zoom to discuss the town's Municipal Vulnerability Preparedness project and present its draft Hazard Mitigation Plan.

The Town of Carlisle has conducted a Community Resilience Building workshop to increase its resilience to the impacts of climate change and has also prepared a draft FEMA Hazard Mitigation Plan to reduce the Town's vulnerability to natural hazards such as flooding, hurricanes, and blizzards.

Please join the Planning Board meeting on June 6 at 7:30 PM for a public listening session and presentation about these two important related projects. The presentation will be made by the Metropolitan Area Planning Council, which is preparing both projects for the Town of Carlisle.

**Who:** Carlisle residents, business owners, civic organizations and institutions are invited to participate in this public listening session on the Town's efforts to plan for a resilient future and mitigate natural hazards. Participants' questions and comments are welcome.

**When:** Wednesday, June 16, 2021, 7:30 PM

**Where:** Online meeting via Zoom
Please send an email to planning@carlislema.gov to request the Zoom information.

MAPC is the regional planning agency for 101 communities in the metropolitan Boston area, promoting smart growth and regional collaboration. More information about MAPC is available at www.mapc.org.

##

**Notice of Public Meeting on Carlisle Hazard Mitigation Plan, June 16, 2020, at 7:30 PM**

TO: Town Clerks in Acton, Billerica, Bedford, Chelmsford, Concord, and Westford, MA

PUBLIC MEETING NOTICE
TOWN OF CARLISLE PLANNING BOARD
MEETING ON HAZARD MITIGATION PAN

The Town of Carlisle has prepared its draft FEMA *Hazard Mitigation Plan 2021 Update* to reduce the town's vulnerability to natural hazards such as flooding, hurricanes, and winter storms.

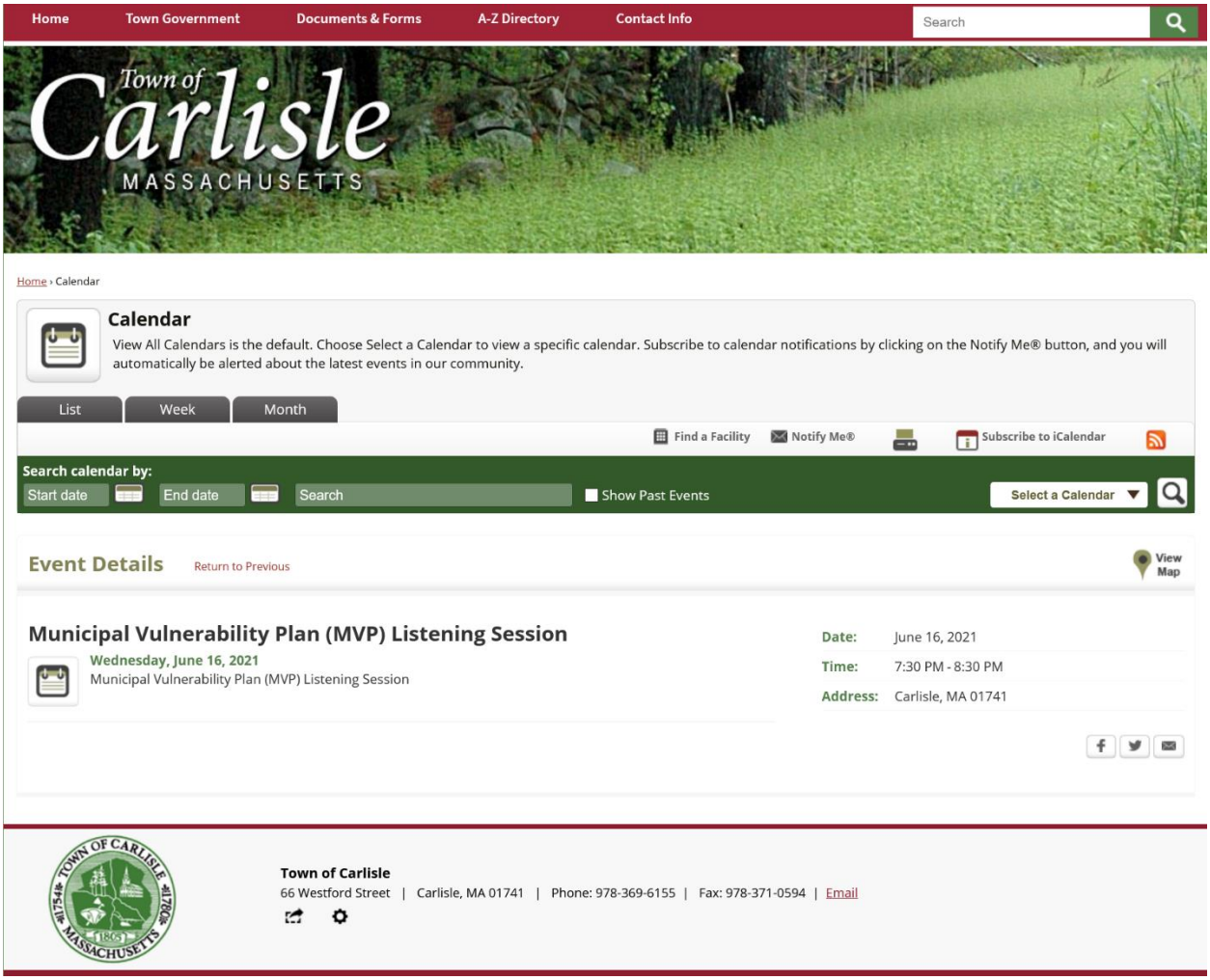
As part of the planning process, all neighboring communities to Carlisle are being notified of a public meeting on the draft plan to be hosted by the Carlisle Planning Board as follows:

**Wednesday, June 16, 2021 at 7:30 PM**
**Carlisle Planning Board**
**Remote meeting via Zoom:**
***Please send an email to planning@carlislema.gov to request the Zoom link***

A flyer announcing the meeting details and Zoom link is attached. If you have any questions about this, please feel free to contact me.

Best regards,

**Martin Pillsbury**
Director of Environmental Planning
Metropolitan Area Planning Council
60 Temple Place
Boston, MA 02111
617-939-3896
mpillsbury@mapc.org


Home
Town Government
Documents & Forms
A-Z Directory
Contact Info
Search
Town of Carlisle
MASSACHUSETTS
Home › Calendar
Calendar
View All Calendars is the default. Choose Select a Calendar to view a specific calendar. Subscribe to calendar notifications by clicking on the Notify Me® button, and you will automatically be alerted about the latest events in our community.
List
Week
Month
Find a Facility
Notify Me®
Subscribe to iCalendar
Search calendar by:
Start date
End date
Search
Show Past Events
Select a Calendar
Event Details
Return to Previous
View Map
Municipal Vulnerability Plan (MVP) Listening Session
Wednesday, June 16, 2021
Municipal Vulnerability Plan (MVP) Listening Session
Date: June 16, 2021
Time: 7:30 PM - 8:30 PM
Address: Carlisle, MA 01741
Town of Carlisle
66 Westford Street | Carlisle, MA 01741 | Phone: 978-369-6155 | Fax: 978-371-0594 | Email

# APPENDIX D: PLAN ADOPTION


Town of Carlisle

*Office of*

***SELECT BOARD***

66 Westford Street

Carlisle, Massachusetts 01741

Phone: (978) 369-6136


**CERTIFICATE OF ADOPTION**

**SELECT BOARD**

**TOWN OF CARLISLE, MASSACHUSETTS**

A RESOLUTION ADOPTING THE
TOWN OF CARLISLE HAZARD MITIGATION PLAN 2021 UPDATE

WHEREAS the Town of Carlisle established a committee to prepare the *Town of Carlisle Hazard Mitigation Plan 2021 Update*; and

WHEREAS the *Town of Carlisle Hazard Mitigation Plan 2021 Update* contains several potential future projects to mitigate impacts from natural hazards in the Town of Carlisle, and

WHEREAS, duly noticed public meetings were held by the Carlisle Planning Board on February 9, 2021, and June 16, 2021, and

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

NOW, THEREFORE the Town of Carlisle adopts the *Town of Carlisle Hazard Mitigation Plan 2021 Update*, in accordance with M.G.L. 40 Sec. 4 and the Charter and Bylaws of the Town of Carlisle.

ADOPTED AND SIGNED this Date. Barbara T. C

November 23, 2021

**Barbara T. Arnold, Chair**

**Carlisle Select Board**

# APPENDIX E: SUMMARY OF CRB WORKSHOP

## HIGHEST PRIORITY ACTIONS IDENTIFIED BY THE CARLISLE COMMUNITY RESILIENCE BUILDING (CRB) WORKSHOP MARCH 27, 2021

*See the full set of resilience and mitigation actions, along with strengths and vulnerabilities identified by Carlisle CRB Workshop in the MVP Final Report that accompanies this plan in a separate volume.*

## INFRASTRUCTURE

1. **Roads:** Upgrade design specifications for new roads; create a list of the most vulnerable roads to prioritize upgrades; coordinate with Emergency Preparedness Council; the CIP may need to prioritize roads, especially main arteries in and out of town; drainage basins need to be addressed to avoid ice ponds, backed up roads

2. **Gas leaks:** Conduct a multi-town effort to address gas leaks; they are being ignored and they need to be fixed! Need to be classified as a gas leak, it is a threat to public safety

3. **Wells and Septic Systems:** Conduct a public outreach program on managing septic systems and well water use

4. **Storm debris:** Create a town chipping service

5. **Build new facilities** for Police and Fire Departments to accommodate the workforce

6. **Energy Efficiency:** Develop an educational program to help weatherize and improve energy efficiency and resiliency of residences; encourage the installation of solar energy and heat pumps

7. **Power outages:** Research options for strengthening resilience to power outages (ex. Partnering with Concord, etc.)

8. **Improved communication:** Update the emergency call system to include cell phones and landlines; Improve Town communication before weather events; coordinate with the

schools to create redundancy in Town communications; conduct stronger outreach/promotion of Town's opt-in communication strategies

9. **Culverts:** Conduct an assessment of culverts (including beaver activity); identify and rightsize culverts to minimize roadway vulnerability, accommodate increasing precipitation volume, and support wildlife crossing

10. **Upgrade the Route 225 bridge** to support essential services/emergency equipment (fire trucks, etc.), and maintain access in and out of town

## SOCIETAL

11. **Community connectivity:** Improve connectivity in the community: Designate neighborhood reps to establish communication across town (through fun avenues like neighborhood party kits)

12. **Address Emergency Shelter needs:** Research potential options for self-generated and independent power supply; need a place that also provides beds/place for sleeping; improve the showers at school to improve access/adults; better leverage Town Hall in emergencies--it is comfortable and welcoming but does not have a generator

13. **Senior Services:** Explore additional resources and services to support the growing senior population (staffing, financial, etc.)

14. **Social gathering:** Create social gathering spots - expanded COA, and develop community gathering spaces

## ENVIRONMENTAL

15. **Water resources** - Water ban days, night watering; conduct more regular testing of drinking water wells (via Board of Health) and more tracking over time to see which properties have changed water quality; help educate residents on monitoring water use, or maybe install more technology; consider well zoning, plan and protect well areas; update well standards (how deep wells should be) and check existing ones; work with schools to start education around this topic; develop agreements with local towns on aquifer use

16. **Tree Management:** If trees are near wetlands use the Conservation Commission's Tree Removal Policy, this policy is evolving and in progress; reintroduce native species to town (very expensive); conduct more constant monitoring/maintenance of invasive species (includes trees) along roadsides (West Street, lots of Oriental Bittersweet), address impacts

of deer and beavers

17. **Water Resources:** Create a GIS database to inventory and assess water availability (including seasonable availability of natural sources) for firefighting

18. **Land and Forest Management**: Develop a land and forest management plan; coordinate with landowners and other key stakeholders including state, municipal, NGO, and private landowners

19. **Support Farms:** Protect farmland and food supply through supporting economic viability of farms; partner with the Town to supply the' school food program; address drainage issues; review bylaws to reform any that have negative impacts and amend to better support agricultural uses

20. **Water Resources:** reintroduce the voluntary well water testing program with stronger promotion/marketing, in conjunction with the education about individual wells/septic; research benefits/risks of pesticide regulation; conduct public education about water conservation, dumping, etc.