City of Cambridge Natural Hazard Mitigation Plan

2023 Update

Acknowledgments

The City of Cambridge's 2023 Natural Hazard Mitigation Plan (NHMP) was adopted by the City Council on DATE to update and replace the City of Cambridge's 2015 Natural Hazard Mitigation Plan. The 2023 NHMP was developed through a collaborative planning process that involved city staff across multiple departments, numerous stakeholders, and members of the public. We offer a special thanks to the following individuals and teams who contributed to the NHMP and most of all to the residents and business owners who contributed their knowledge and time.

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Contents

Chapter 1:

Introduction

1. Introduction

1.1. What is a Natural Hazard Mitigation Plan?

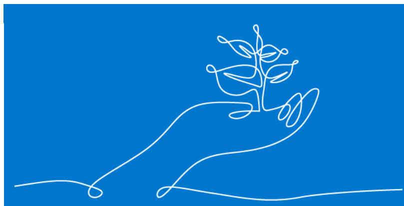
Hazard mitigation planning is an iterative process that seeks to reduce the impact of natural hazards on people and property. Cambridge has assessed a variety of natural hazards that pose a risk to the health and welfare of residents, identified specific vulnerabilities associated with those hazards and climate change, and identified local capabilities and specific mitigation actions to protect homes, businesses, and the critical infrastructure that keeps the city running. This process is tailored to address the issues affecting Cambridge residents now and into the future and is crucial to building community resilience.

What are Natural Hazards?
Natural hazards are a source of harm or difficulty created by a meteorological, environmental, or geological event (such as extreme wind events, tornadoes, winter weather as well as earthquakes flooding, and fires).

Vulnerability is a description of which community "assets" (e.g., people, structures, systems, natural resources, cultural resources, historic resources, etc.) are at risk from the effects of a natural hazard.

Hazard Mitigation is the effort to reduce impacts from natural hazards through community planning, policy changes, educational programs, infrastructure projects, and other activities.

Climate change refers to long-term fluctuations in regional temperatures and weather patterns. These fluctuations can be natural, due to events such as solar activity or volcanic eruptions. These fluctuations are also driven by human activities, primarily the burning of fossil fuels like coal, oil, and gas, which have been prominent since the 1800s. Increasing global temperatures have resulted in a multitude of impacts, including but not limited to rising sea levels, shrinking of the polar ice caps, receding glaciers, changes in seasonality, and shifting animal and plant populations (Climate Change Vulnerability Assessment (CCVA), 2015). Climate change has increased the frequency and intensity of many natural hazards creating a greater need for proactive planning. Chapter 3 includes additional information on natural hazard severity and risk.



Resilience is the ability to withstand and swiftly recover from an extreme event. Ideally, resilient systems "bounce forward" to create healthier, greener, and more equitable systems and spaces.

1.2. Benefits of Natural Hazard Mitigation Planning

Completing natural hazard mitigation planning provides benefits to Cambridge:

1. Increasing public awareness of natural hazards that may affect the community reduces overall risk. By providing education and outreach, individuals can understand how natural hazards may affect their lives and what the region, the city, and they as individuals can do and are doing to minimize impacts of those hazards.

2. Proactive planning creates efficiency beyond city limits. Developing a Natural Hazard Mitigation Plan (NHMP) allows state and local governments to work together and combine hazard risk reduction with other community goals and plans.

3. The community's greatest vulnerabilities can be prioritized to receive resources. Developing a plan of hazard mitigation measures considers a prioritization process that reflects the cost and benefit of safety, property protection, technical, political, legal, environmental, economic, social, administrative, and other community objectives, quantitatively and/or qualitatively.

4. The implementation of an NHMP saves taxpayer money. According to FEMA, one dollar spent on federal hazard mitigation grants saves an average of six dollars on disaster response (NIBS, 2019).

5. Maintaining a FEMA compliant NHMP also makes the municipality eligible for federal grant funding (FEMA, 2020). Hazard mitigation funding is available through the Federal Emergency Management Agency (FEMA). To be eligible for FEMA Grants, local governments must prepare an HMP that meets the requirements established in the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended by the Disaster Mitigation Act of 2000. The HMP also ensures that federally funded projects reflect a community's priorities and offer solutions to specific threats. Please refer to Chapter 7 for more information on FEMA grants and other potential funding sources.

1.3. Organization of the Natural Hazard Mitigation Plan

The report presents the results of the NHMP planning process, which was informed by data review and analysis, input received from the Steering Committee during and outside of the Steering Committee meetings, input from the NHMP stakeholder workshops, and input from public engagement activities. This report is organized as visualized in the diagram on the following page.

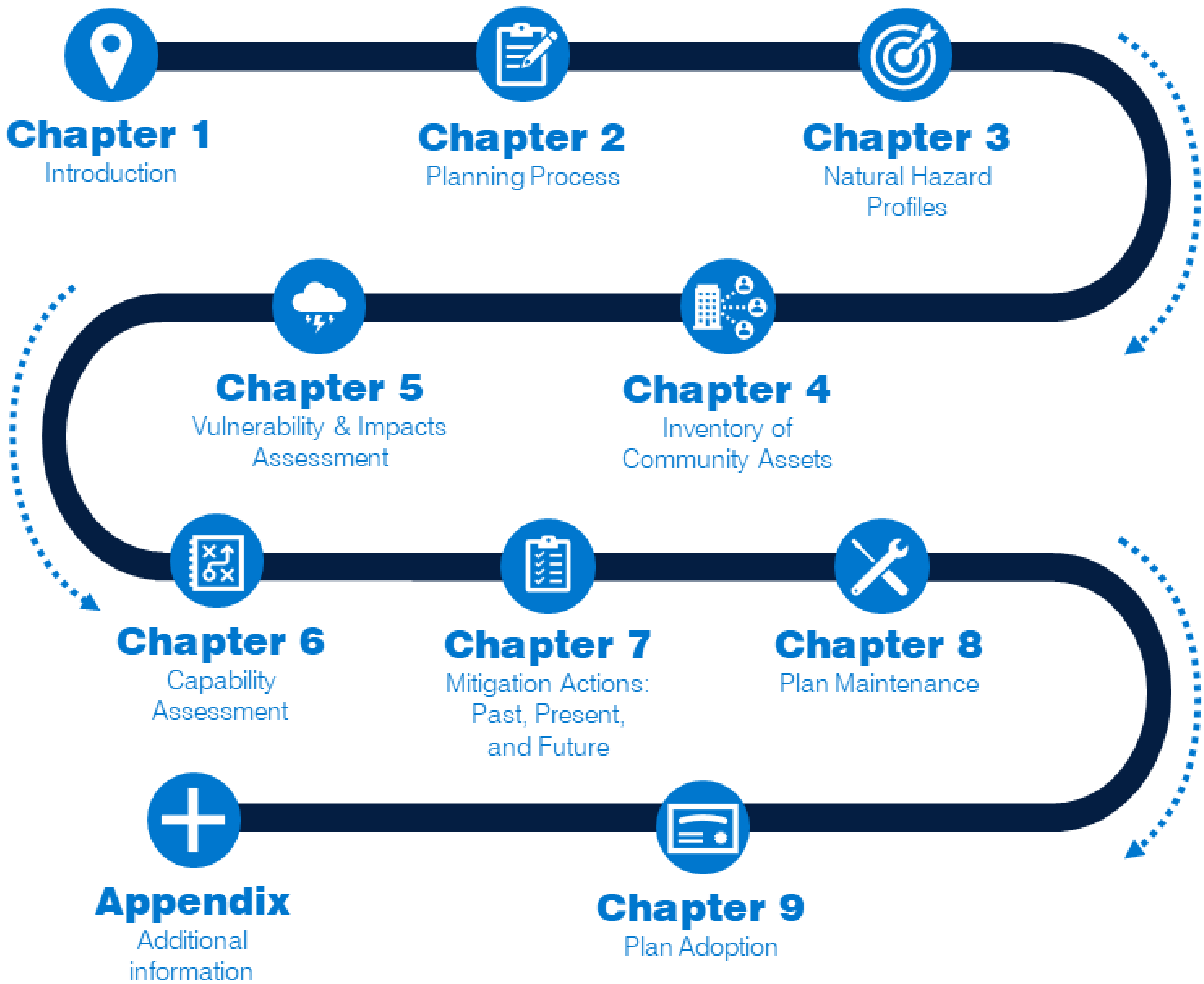


Figure 1-1 A diagram of NHMP report chapters

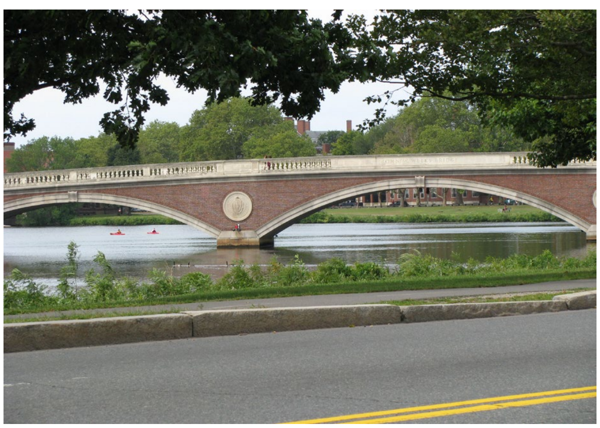


Figure 1-2 The Charles River, photo by Weston & Sampson

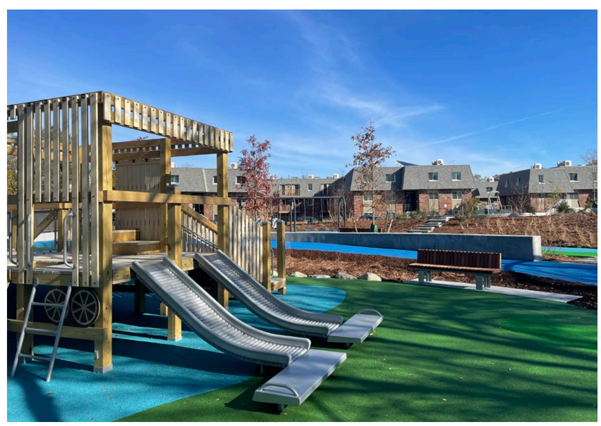


Figure 1-3 Danehy Park Universal Playground, photo by Weston & Sampson

1.4. Natural Hazard Mitigation & Climate Adaptation Goals

On April 24, 2023, the Cambridge Hazard Mitigation Steering Committee established the goals and objectives for natural hazard mitigation planning in Cambridge. The committee reviewed and endorsed the goals at their subsequent meeting on May 22, 2023. This effort included a review and update of the goals listed in the 2015 Hazard Mitigation Plan. The goals were restructured to better represent the current hazard mitigation efforts in Cambridge, create consistency with other climate resilience planning processes, and provide simplified messaging to the public. The following presents the goal, on the left, and the supporting objectives, on the right. Goals are broad, long-term policy and vision statements that explain what is to be achieved by implementing the natural hazard mitigation strategy described in Chapter 7. Objectives are more specific and are indicators that a community uses to understand if the goal is being addressed. Objectives are not meant to be specific mitigation actions. Objectives will be evaluated and tracked as part of the plan maintenance process described in Chapter 8.

1. Equitably *Protect* Health and Safety of the Community

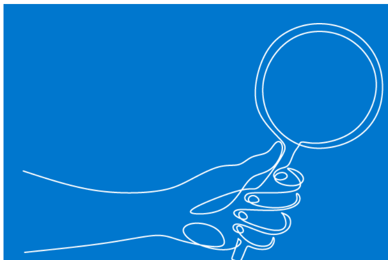
- Identify and reduce impacts to the health and safety of vulnerable populations from natural hazards.
- Provide resources for residents and businesses to make their buildings and properties more disaster resistant.
- Ensure critical infrastructure, facilities, and services are protected from natural hazards and incorporate resiliency, to facilitate efficient recovery, evacuation, public health, and safety.
- Ensure that future development/ redevelopment does not make existing properties more vulnerable to hazards.
- Identify mitigation strategies that preserve and restore the function of natural systems and minimize secondary impacts from hazards.

2. Promote Public Preparedness and Resilience Through *Communication*

- Improve outreach to non-English speakers and other vulnerable populations before, during and after hazard events.
- Encourage people to be prepared before, during, and after hazard events.
- Increase awareness and provide information for hazard mitigation and climate resilience to businesses and residents through outreach and education, including promoting community-based mitigation strategies.

3. *Coordinate and Collaborate* among City Departments and with Community Partners on Hazard Mitigation Planning and Climate Adaptation

- Develop internal strategies to review and update current emergency preparedness, outreach, and response activities to anticipate future changes in vulnerabilities.
- Encourage private property-owners, institutions, and local businesses to implement measures to protect their own property.
- Work regionally with state, regional and federal agencies as well as surrounding communities to mitigate impacts from natural hazards and to respond and recover from hazard events.



4. *Plan for and Sustainably Invest in* Priority Hazard Mitigation Implementation

- Continue to program mitigation projects in the Cambridge capital improvement planning.
- Identify and seek funding for priority measures to mitigate or eliminate significant hazards and impacts.

5. Improve Capacity to *Monitor* Natural Hazards and *Respond* to Changes

- Continue to identify and understand how climate change may alter where and how Cambridge is vulnerable to natural hazards.
- Ensure City departments, committees, and boards have adequate data, guidance, staff, training, and equipment to respond to natural hazard events, maintain preparedness, and anticipate future changes in vulnerabilities.

Chapter 2:

Planning Process

2. Planning Process

The Cambridge NHMP Update was informed by data review and analysis, input received from the Steering Committee during and outside of the Steering Committee meetings, input from the Natural Hazard Mitigation Plan Workshops held with targeted stakeholders, and input from public engagement activities. The NHMP planning process proceeded according to the timeline below. The subsequent pages describe the involvement of the Steering Committee, Natural Hazard Mitigation Planning Team, and the public in the NHMP planning process in more detail.

Figure 2-1. NHMP Planning Timeline

	Task	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	Project Initiation										
2	Engagement										
3	Hazard Profiles										
4	Facility/Asset Inventory										
5	Vulnerability Assessment										
6	Mitigation Goals & Capabilities										
7	Develop Actions										
8	Plan Implementation										
9	Public Review										
10	Adoption										
	Meetings	**K**	**S**	**S**	**S**	**PS H**	**HS H**	**S**		**P**	

Legend:

K Kickoff Meeting	**P** Public Meeting	**S** STC Meeting	**H** HMPT Workshop

2.1. Plan Updates to Reflect Community Priorities

Cambridge is a hub for innovation and research that is constantly evolving. The city's technology market is thriving, leading to an increase in population and invigorating the economy. The community in Cambridge is becoming more vibrant and diverse with a growing immigrant population. However, Cambridge is also facing challenges such as economic disparities and a shortage of affordable housing. Additionally, the changing climate and stresses on aging infrastructure and natural systems add complexity to the situation. To address these challenges, the city has undertaken several planning processes and programs that consider economic disparities, affordable housing, climate change, and the diverse needs of the community.

Since the last update of the Hazard Mitigation Plan, Cambridge released its first climate change resilience plan in June 2021 called Resilient Cambridge. The plan provided a solid foundation for the city government and all sectors of the community to do the necessary work to create closer neighborhoods, better buildings, stronger infrastructure, and a greener city. This NHMP reflects these considerations and Resilient Cambridge.

2.2. Community Engagement Approach

The goal of public engagement for this NHMP process was to center the experiences of those who are most vulnerable to natural hazards in Cambridge. To truly mitigate hazards, the city must develop strategies for protecting and supporting those who are most exposed. In 2023, the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) edited the terminology and definition of "climate vulnerable populations" to "priority populations."

In the Commonwealth, EJ populations (or EJ neighborhoods) have been identified as census block groups (divisions of larger census tracts that are made up of about 600 to 3000 people) that meet one or more of the following criteria:

- The annual median household income is not more than 65% of the statewide annual median household income.
- Individuals who identify themselves as Latino/Hispanic, Black/ African American, Asian, Indigenous people, and people who otherwise identify as non-white comprise 40% or more of the population.
- 25% or more of households lack English language proficiency.
- Individuals who identify themselves as Latino, Hispanic, Black, African American, Asian, or Indigenous, and people who otherwise identify as non-white comprise 25% or more of the population and the annual median household income of the municipality in which the neighborhood is located does not exceed 150% of the statewide annual median household income; or
- A geographic portion of a neighborhood designated by the Secretary as an Environmental Justice population in accordance with law (An Act Creating a Next-Generation Roadmap for Massachusetts Climate Policy, Chapter 8 of the Acts of 2021)

According to EEA, priority populations also include people or communities who may be disproportionately impacted by climate change due to life circumstances that systematically increase their exposure to climate hazards or make it harder to respond. In addition to factors that contribute to EJ status (i.e., income, race, and language), other factors like disability status, access to transportation, health status, and age shape whether someone or their community will be disproportionately affected by climate change. This is because of underlying contributors such as racial inequality, financial insecurity, or accessibility barriers that create vulnerability. The term priority populations acknowledges that the needs of people with these experiences and expertise must take precedence when developing resilience solutions to reduce vulnerability to climate change and natural hazards. All communities have priority populations even if they do not have a mapped EJ neighborhood. To better understand the experiences of the residents and businesses of Cambridge, the engagement strategy included a multitude of approaches including:

The Steering Committee: A group of City staff whose work focuses on specific related groups and issues and who met regularly to consult on the NHMP

The Hazard Mitigation Planning Team: A team of representatives of a wide variety of groups and experiences

Public Engagement: Outreach, public surveys, and public meetings open to all community members and neighbors

Within these activities, some engagement strategies include:

- Being intentional about participants in the HMPT so that the group's participants are more representative of Cambridge's neighborhoods, community knowledge, and more.
- Tracking information about demographics in public surveys to inform gaps in reach to the community and use information to inform engagement approach.
- Identifying approaches to engage residents with the understanding that already limited time and resources have been stressed post COVID-19. The team worked with STC and HMPT to respectfully and meaningfully ask for community input through existing channels and partnership with the Community Engagement Team.
- The team worked to address barriers to participation through translation of surveys and printed materials, offering interpretation for meetings, and conducting accessibility reviews of language and visuals.

- Understanding the community context and local initiatives through interactive engagement techniques focused on listening and collecting stories, ideas, and input from residents, businesses, and other stakeholders.
- Avoid "planning fatigue" by building on previous and ongoing efforts as well as considering ways to continue natural hazard preparedness beyond this project.

These engagement activities and the input gathered from the community were invaluable to the development of the NHMP. The STC, HMPT, and community members helped shape the asset inventory, vulnerability assessment, mitigation actions, and other elements of the plan.

For the Asset Inventory, community members gave input on assets that are critical to them or their community. For the Vulnerability Assessment, community members gave feedback on specific experiences they or others have had in a variety of hazards. They also brought attention to potential vulnerabilities in the face of a changing climate. Additionally, community members helped develop specific mitigation actions to address these vulnerabilities and strengthen the resilience of the community. These assets, vulnerabilities, and actions have all been incorporated into the NHMP.

Bringing as many people, particularly vulnerable people, as possible into the hazard mitigation process and implementation will help Cambridge be more equitable and resilient in the future.

2.3. Steering Committee

The City of Cambridge convened a Steering Committee (STC) for the development of the NHMP. The STC met six times to guide the planning process and make final planning decisions. More information on these meetings and a list of STC members is included in Appendix A. The STC played a key role in identifying critical infrastructure, involving key stakeholders, and documenting the City's capacity to mitigate hazards alongside ongoing operations. To assist in drafting the plan, the STC also suggested or made available reports, maps, and other pertinent information related to natural hazards in Cambridge.

Table 2.1 Steering Committee Meeting Schedule

Meeting	Date	Meeting Topics
Kickoff Meeting	February 27, 2023	• Overview of Natural Hazard Mitigation Planning • Scope and Schedule • Engagement • Questions/ Discussion/ Action Items
Steering Committee Meeting #1	March 27, 2023	• Overview of work in progress • Chapter 3 Hazard Profiles • Stakeholder Outreach and Engagement Plan • Capabilities Assessment • Next Steps

Meeting	Date	Meeting Topics
Steering Committee Meeting #2	April 24, 2023	• Overview of work in progress • Mitigation Goals • Mitigation Actions: Past • Outreach and HMPT Meetings • Next Steps
Steering Committee Meeting #3	May 22, 2023	• Overview of Work in progress • Hazard Mitigation Goals • Capabilities Assessment • Asset Inventory • Outreach and HMPT Meetings • Next Steps
Steering Committee Meeting #4	June 26, 2023	• Overview of work in progress • Outreach and HMPT Meetings • Mitigation Actions • Plan Evaluation and Maintenance • Next Steps
Steering Committee Meeting #5	July 24, 2023	• Overview of work in progress • Prioritization Criteria and Process for Prioritizing Mitigation Actions • Asset Inventory Discussion • Draft Report Template • Next Steps
Steering Committee Meeting #6	August 8, 2023	• Results of Asset Inventory • Results of Vulnerability Assessment • Targeted Review of Draft NHMP • Next Steps

2.4. Natural Hazard Mitigation Planning Team (HMPT)

Stakeholders with subject matter expertise and local knowledge and experience were invited to join the Natural Hazard Mitigation Planning Team (HMPT) and attend a series of three workshops. These stakeholders included City of Cambridge affiliates, state and regional agencies, representatives of business/academia/private organizations, nonprofit organizations, community groups, and neighboring communities.

Local + Regional Agencies

- Public Works
- Emergency Management
- Local Floodplain Administration
- GIS Departments

Representatives of businesses, academic, and other private organizations

- Private utilities or major employers that sustain community lifelines

Stakeholders

Entities that have the authority to regulate development.

- Zoning
- Planning
- Community and economic development departments
- Building officials
- Planning commissions
- Other elected officials

Neighboring Communities

- Adjacent local governments, including special districts, such as those that are affected by similar hazard events or may share a mitigation action or project that crosses boundaries.
- Neighboring communities may be partners in hazard mitigation and response activities, or may be where critical assets, such as dams, are located

Representatives of nonprofit organizations,

- Including community-based organizations, which work directly with and/or provide support to underserved communities and socially priority populations, among others.
- Housing, healthcare, or social service agencies

Figure 2-2. Example List of Categories of NHMP Update Stakeholders

During the HMPT workshops, Weston & Sampson provided information about local features and hazards impacting the City of Cambridge and reviewed the City's vulnerability to these hazards. Participants identified and prioritized key actions that will improve the City's resilience to natural and climate-related hazards.

The full list of community representatives who were invited and those who participated in the process are presented in Appendix B, along with the agenda from each workshop. The broad representation of local and regional entities that participated in these workshops helps align the NHMP update with the operational policies and hazard mitigation strategies at various levels of government and implementation. A summary of key findings from each workshop is included on the following pages.

To enhance accessibility, stakeholder workshops were conducted as a series of three online sessions. HMPT workshops were organized around topic areas that included:

1. Asset, vulnerability, and impact identification
2. Mitigation action development
3. Mitigation action prioritization

Table 2.2 Natural Hazard Mitigation Planning Team Workshop Schedule

Meeting	Date	Meeting Topics
HMPT Workshop #1	June 29, 2023	• Overview of plan • Discussion of natural hazards • Asset inventory • Identify vulnerabilities. • Review all groups who may be impacted (focusing on those with limited resources)
HMPT Workshop #2	July 11, 2023	• Review climate adaptation strategies and mitigation goals. • Solicit feedback on how well these goals protective of all groups. • Initial discussion to identify mitigation actions. Incorporate input from public surveys.
HMPT Workshop #3	July 25, 2023	• Review hazards, vulnerabilities, and community concerns. • Review proposed mitigation actions and confirm prioritization of actions.

2.4.1 | HMPT Workshop #1: Hazards, Vulnerabilities, and Assets

Thirty-seven participants joined the workshop virtually and brainstormed key local assets in Cambridge, how those assets might be impacted by hazards, and who would be the most vulnerable to those impacts. A follow-up survey was also sent to participants to capture additional input. The assets were categorized by *people, structures, systems, resources*, and *activities*. The workshop format started with a presentation of natural hazards, an overview of the Natural Hazard Mitigation Plan, and an overview of assets. The participants were then broken into four groups to focus on one of the first four categories. After this exercise, the participants came back together to consider *activities* as a group.

Figure 2-3. HMPT Workshop #1 Presentation and Participants

Key Findings

- The most concerning natural hazards were flooding, winter storms, and extreme temperatures.
- Assets in the *people* category that would be most impacted by natural hazards, especially for more vulnerable groups (such as people with disabilities, currently unhoused people, seniors, and low-income families), were shelters, housing, schools, and food distribution.
- Assets in the *structures* category that would be most impacted by natural hazards, especially for vulnerable groups, were faith community buildings, grocery stores, medical facilities, transportation infrastructure, schools, and Fresh Pond Water Treatment Plant.
- Assets in the *systems* category that would be most impacted by natural hazards were the power grid, cell towers, transit routes, MWRA facilities, and water/sewer system.
- Assets in the *resources* category that would be most impacted by natural hazards, especially for vulnerable groups, were parks, open spaces, community gardens, and arts and cultural facilities.
- *Activities* included several Cambridge festivals and events like Head of the Charles, Cambridge Science Fest, farmers markets, Honk Fest, block parties, and other community-building activities that strengthen social capital and resilience.

2.4.2 | HMPT Workshop #2: Mitigation Actions

Sixteen participants joined the second workshop virtually and brainstormed mitigation actions that would prevent the impacts discussed in Workshop #1. The mitigation actions used corresponding categories as the assets: structure, people, systems, and resources. The workshop format started with an overview presentation of the Natural Hazard Mitigation Planning process, assets, and mitigation actions. Then, there was a short introductory presentation on mitigation actions for structures followed by a brainstorming exercise where participants were assigned groups to create mitigation actions for structures. This format (presentation then breakout group brainstorming activity) repeated for all four categories and resulted in mitigation actions in all four categories.

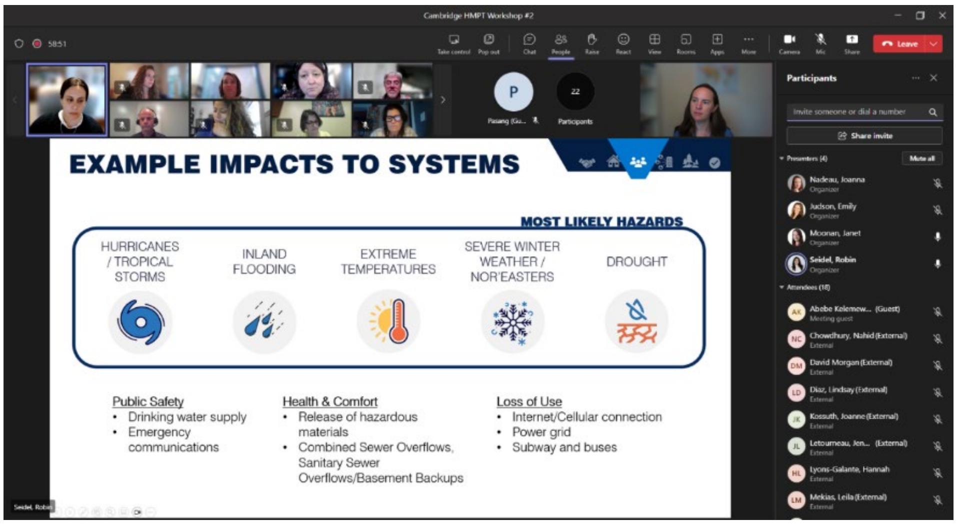


Figure 2-4. HMPT Workshop #2 Presentation and Participants

Spotlight On Engagement

[1] Some actions are reliant on staffing a supply availability which may not be available. A shortage was experienced during the Covid-19 pandemic and serves as an example of what could happen in a global or regional emergency.

[2] It was noted that although non-electrical communications were utilized successfully in the past, this process should not be the only method of communication as it limits the experience of those who are deaf or hard of hearing.

Key Findings

- Key mitigation actions for *structures* included coordinated emergency planning, an emergency & extreme weather shelter assessment plan, and back-up power/generator plans.
- Key mitigation actions for *people* included public campaigns for hazard preparedness, neighbor buddy system and community connections, and warming/cooling centers or resources.[1]
- Key mitigation actions for *systems* included non-electrical communications systems (i.e., loudspeaker or door-knocking)[2], redundancies in the water supply system, and energy system flood resiliency.
  Key mitigation actions for resources included improving parks and public pools, incorporating resiliency education into public art projects, and assessing tree vulnerability to pests.

2.4.3 | HMPT Workshop #3: Mitigation Action Prioritization

Twenty-three participants joined the third workshop virtually and worked on prioritizing the mitigation actions that were generated in Workshop #2 (along with mitigation actions from other city plans). The workshop started with an overview presentation of the Natural Hazard Mitigation Plan, mitigation actions, and the prioritization process. Then, the group was polled on the most important or critical mitigation actions in eleven distinct categories: communications, drinking water + snow removal, housing + public health, community facilities + structures, cooling + tree canopy, stormwater + sewer, energy + back up power, transportation + evacuation, miscellaneous, and equitable emergency response planning.

Figure 2-5. HMPT Workshop #3 Presentation and Participants

Key Findings

- *Communications*: The action voted most critical was developing an enhanced communication plan and program related to natural hazards in collaboration with the community.
- *Drinking Water + Snow Removal*: The action voted most critical was improving and updating the cybersecurity measures for the public water supply system.
- *Housing + Public Health*: The action voted most critical creating a list of health services which are operational during extreme events for community reference.
- *Community Facilities + Structures*: The actions voted most critical were (1) ensure building renovations for priority populations are incorporated into resiliency strategies and (2)

evaluate the resiliency of community services on a case-by-case basis (e.g., individual food pantries).

- *Cooling + Tree Canopy*: The actions voted most critical were (1) identify areas for green stormwater infrastructure and reducing impervious surface and (2) identify Cambridge housing development community rooms that have commercial kitchens and use them as cooling centers and shelters during storms.
- *Stormwater + Sewer*: The actions voted most critical were (1) update and improve the Cambridge Floodplain Viewer online map and (2) inspect and maintain targeted infrastructure before storm events.
- *Energy + Back Up Power*: The action voted most critical was prioritize clean energy solutions for power (i.e., solar, battery, geothermal) where feasible.
- *Transportation + Evacuation*: The action voted most critical was coordinating with adjacent communities for hazards preparation and response.
- *Miscellaneous*: The action voted most critical was to develop a historic resources resilience plan.
- *Equitable Emergency Response Planning*: The actions voted most critical were to (1) ensure emergency response plan is multi-lingual and (2) develop a centralized emergency response management system (i.e., communications and coordination).

2.5. Public Engagement

2.5.1 | Equitable Public Engagement

Equitable public engagement in the planning process is a crucial aspect of ensuring that all members of the community have a voice and are represented in decision-making. The City of Cambridge has recognized the importance of inclusive and equitable engagement and has taken steps to redefine community engagement practices. Elements of this commitment include dedicated public engagement and community access teams. Leaders of this work were included in the development process of the Natural Hazard Mitigation Plan by participating on the steering committee.

To strengthen existing social infrastructure and to support a more equitable and resilient future, the engagement team prioritized stakeholders, residents, and community organizations early in the process. The project-specific equity goals include:

- Being intentional about the composition of the HMPT so that it better reflected the communities in Cambridge neighborhoods and community knowledge.
- Tracking success metrics such as attendance at meetings, social media engagement, and participation in surveys.
- Identifying approaches to engage residents with the understanding that time and resources are stressed by other issues. Respectfully and meaningfully asking for community input, addressing barriers to participation (including technology, time, and language barriers).

- Understanding the community context and local initiatives through interactive engagement techniques.
- Avoid “planning fatigue” by building on previous and ongoing efforts, leveraging local expertise, and empowering residents, and the HMPT, to continue considering natural hazard preparedness beyond the duration of this project.
- Developing accessible engagement materials by using visuals and text, using multilingual designs, increasing the use of plain language, and providing translation.

2.5.2 | Fact Sheet & Public Survey

The project team developed a visual fact sheet summarizing project information, along with an online survey to collect information on the local experience of natural hazards and needs to increase resilience.

The Natural Hazard Mitigation Plan public survey was distributed to community members through virtual, hard copy, and community outreach network methods. These included the City Daily Update email, social media, virtual and hard copy flier distribution, and promotion in partnership with Cambridge Community Corp, and the Community Engagement Team. The survey was also distributed through the Natural Hazard Mitigation Planning Team and Steering Committee networks.

The fact sheet, at right, was distributed through social media networks and aimed at capturing a snapshot of the project as well as promoting the public survey.

Over 150 residents responded to the survey in July 2023. All the responses were in English, although additional languages were provided. All Cambridge neighborhoods were represented among the Survey respondents. A variety of ages, racial identities, and amount of time spent living in Cambridge were also represented among the Survey respondents. A full report of survey responses can be found in Appendix C.

Responses indicated that winter storms/nor’easters were the top hazard of concern for over 90% of respondents, followed by extreme heat at over 80%.

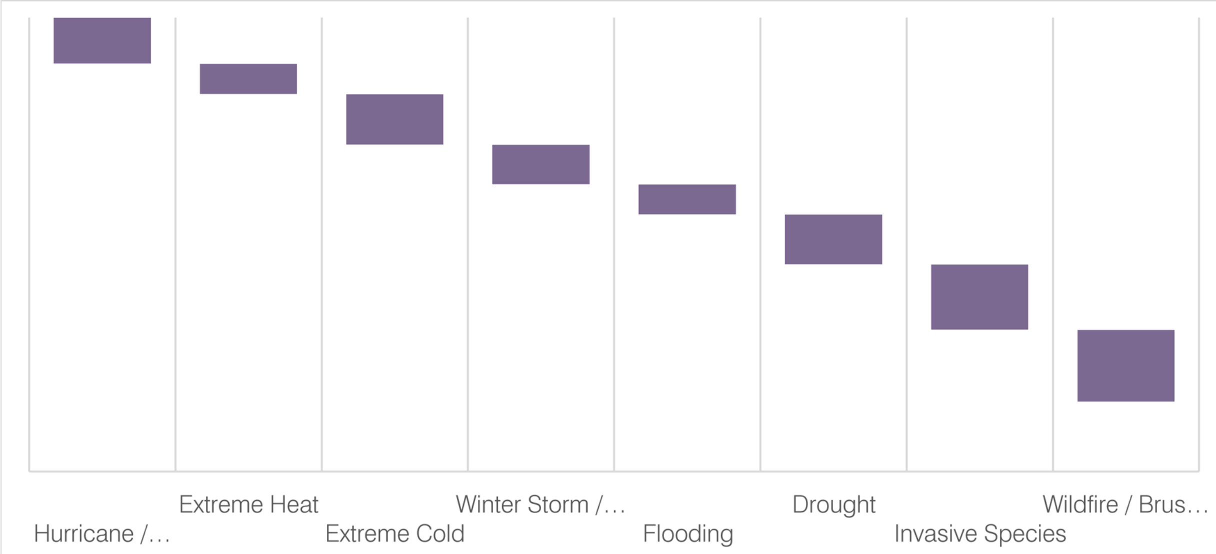


Figure 2-6. Survey Responses: Natural Hazards You Are Most Concerned About

The hazard impacts that were of top concern to respondents were power outages (>75%), damage to the home (72%), or contaminated drinking water (69%), although fewer than 10% reported having experienced contaminated drinking water from natural hazards. Seventy-two percent of respondents indicated that they had experienced power outages, 49% experienced property damage, and 32% experienced limited access to transportation. Limited access to medical care was a concern for more than 27% of respondents, although only 9% had experienced this from natural hazards in the past.

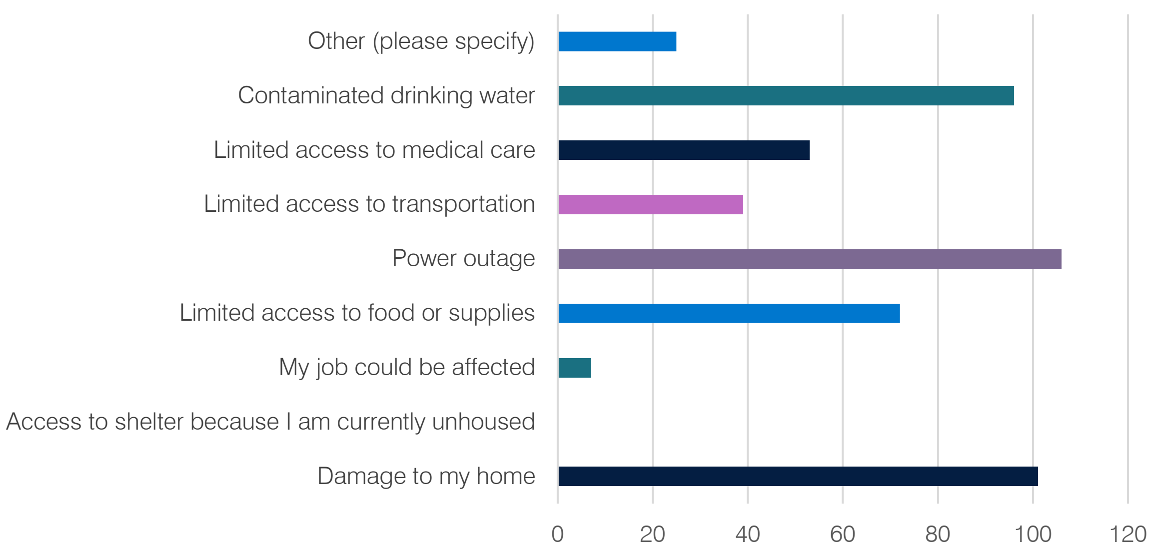


Figure 2-7. Survey Responses to the question, "What problems from natural hazards concern you the most?"

The most common answers to the question, **"What do you typically do, if anything, to prepare for a natural hazard event?"** were:

1) I have an emergency kit with supplies, food, flashlight, batteries, etc. (77%).
2) I check on a vulnerable neighbor and help them with food, snow removal, or other support (40%); and
3) I have a backup generator in case of power outage (10%).

The most common answers to the question, **"What could the city improve on to prepare for natural hazards?"** were:

- Flood protection and response (55%)
- Climate resilience planning (50%)
- Reliable public transportation (45%)
- Tree planting (42%)
- Renewable energy implementation (41%)

The survey also provided the city with guidance on existing natural hazard mitigation measures that were working well, and information about the best ways to reach residents during future emergencies, shown below.

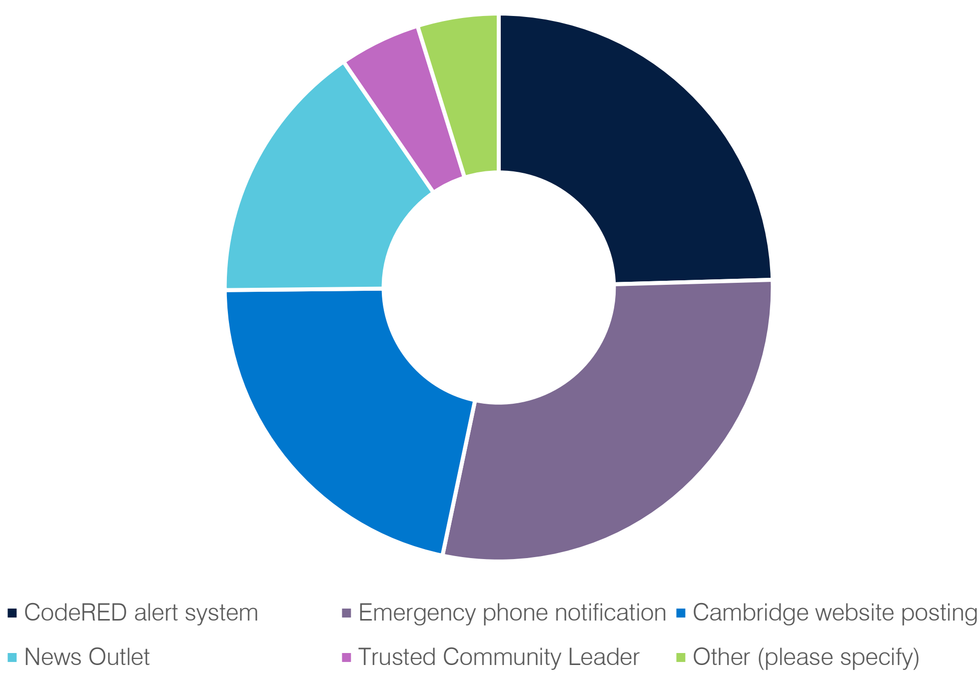


Figure 2-8. Survey Responses: How Would You Like to Receive Information in an Emergency?

2.5.3 | Public Meetings

Community input was also collected through a series of three public meetings with the help of the STC and HMPT. Public Meetings were announced to community members through virtual, hard copy, and community outreach network methods. These included several notices in the Daily Update email from the City Manager's office, posting on Cambridge social media and the project webpage, virtual and hard copy flier distribution, and promotion in partnership with local networks and the community engagement teams from various city departments.

The first meeting was held on June 13, 2023, from 6:00 to 7:00 PM, and was primarily focused on informing the public about the history and purpose of the NHMP update, FEMA mitigation funding programs, project work plan, and the overall planning process. The meeting included a discussion of local vulnerabilities, strengths, historic hazard impacts on the community, and potential adaptation action items.

The second and third meetings were held on October 25, 2023, to present the initial results and review the draft NHMP Update. The second public meeting was held virtually from 12:00 to 1:00 PM on October 25, 2023, and the third public meeting was held in a hybrid in-person and virtual format from 6:00 to 7:00 PM on October 25, 2023.

2.5.3.1. Addressing Challenges to Virtual Engagement

The project team planned each webinar to encourage participation and engagement. Equitable engagement modifiers were used to facilitate participation during meetings, including:

Working closely with the HMPT and the City's social media to advertise opportunities for engagement and identify stakeholders, additional equitable engagement modifiers, and appropriate meeting times, locations, and formats

Sharing directions for joining virtual meetings. Providing interpretation, contact information for tech support, an optional

call-in number, and

Scheduling meetings at times that allow working parents and adults with multiple jobs to attend

Webinars started with an

icebreaker for attendees to

introduce themselves as they joined the call, share their favorite thing about the city, and test out the webinar's audio and "chat" function

The team also created a presentation that prioritized accessible language and graphically engaging visuals over text-heavy slides

2.6. Local Long-Range Plans Related to Hazard Mitigation

The City of Cambridge has undertaken significant long-range planning efforts related to hazard mitigation, climate resilience, and sustainability. Key focus areas of these efforts include reducing the city's carbon footprint, preparing the community for extreme events and chronic impacts, and mitigating risks to the built and natural environments from natural hazards. The following plans, studies, reports, and technical information were reviewed and incorporated into the update of this NHMP. Specifically, the information is used in developing portions of Chapter 3 Hazard Profiles, Chapter 4 Asset Inventory, and Chapter 5 Vulnerability and Impact Assessment.

There are also a variety of ordinances and regulations, as well as committees and task forces, that further the city's efforts to proactively address natural hazards and climate change, which are discussed in Chapter 6 in the Capabilities Assessment.

2015 Cambridge Natural Hazard Mitigation Plan

The City of Cambridge completed a Hazard Mitigation Plan in 2015. This plan was led by the Cambridge Local Hazard Mitigation Planning Committee (LHMPC), staff from city departments, and in collaboration with the Massachusetts Office of Emergency Management (MEMA) and Department of Conservation and Recreation (DCR). The LHMPC helped determine where natural hazards most significantly impact the city, developed goals pertaining to hazard mitigation, and identified strategies and actions to limit the impacts of hazards on Cambridge residents. Primary goals of this plan include protecting the health and safety of Cambridge residents, protecting properties and structures, ensuring continuity of essential services, promoting effective communication, collaborating regionally, and protecting natural resources. The strategies identified in this plan were informed by a risk assessment of flooding, high winds, winter storms, brush fires, and geological hazards. The 2023 NHMP update builds on the foundations of this plan with updated information regarding hazards, capabilities, and actions that have been completed during the last several years.

Resilient Cambridge Plan

The Resilient Cambridge Plan is a citywide plan to mitigate the impact of potentially devastating rain fall events, riverine flooding, winter storms, and rising temperatures. The Resilient Cambridge Plan is organized into four focus areas – Closer Neighborhoods, Better Buildings, Stronger

Infrastructure, and a Greener City. Each focus area includes strategies organized by scale including regional, citywide, neighborhood-level, and property-level actions. These actions are intended to be implemented by a variety of stakeholders including city departments, agencies, community-based organizations, and residents. The strategies identified were informed by public meetings, workshops, focus groups, surveys, and technical studies, including the Climate Change Vulnerability Assessment (CCVA). The actions presented in Resilient Cambridge were incorporated into the Mitigation Actions presented in Chapter 7.

Climate Vulnerability Assessment

To establish the technical foundation for the Resilient Cambridge Plan, the city conducted a climate change vulnerability assessment, focusing on the risks from increasing temperatures, precipitation, and sea level rise. This assessment focused on Cambridge's physical and social vulnerabilities under the future conditions of climate change. This assessment was completed in two parts in 2015 and 2017 and is accompanied by an online web-viewer for flooding. Components of this vulnerability assessment are cited throughout the description of natural hazards presented in Chapter 3 and the vulnerability and impact assessment presented in Chapter 5. In addition, the inventory of assets supported the updated asset inventory prepared in Chapter 4 and used for the NHMP vulnerability and impact assessment.

Neighborhood Climate Resilience Plans for the Port and Alewife

Prior to the development of the citywide Resilient Cambridge Plan, the city created two detailed neighborhood plans for its most vulnerable areas - the Port and Alewife. These plans were informed by the Climate Change Vulnerability Assessment and include strategies to make infrastructure, natural resources, buildings, and communities more resilient in each neighborhood. The Port and Alewife are home to many of Cambridge's priority populations.

Envision Cambridge

The Envision Cambridge Plan is a citywide comprehensive plan focused on the city's growth and development through 2030. The Envision Cambridge Plan has a dedicated section on climate and environment. This section of the plan includes analysis and strategies related to greenhouse gas emissions reductions and renewable energy, waste reduction, ecological protection, climate change preparedness, water quality, and environmental justice.

Urban Forest Master Plan

The Urban Forest Master Plan (UFMP) was completed in 2019 and is intended to guide's the city's development of the urban forest into the future and will include a strategic plan to evaluate, maintain and expand the urban forest canopy while being more resilient to climate change, reducing the urban heat island effect, mitigating stormwater runoff, reducing nutrient runoff, and contributing to community well-being.

Net Zero Action Plan

The city's Net Zero Action Plan was adopted in 2015 and includes detailed recommendations to reduce greenhouse gas emissions from the built environment, improve energy efficiency, support renewable energy generation on and off-site, and employ best practices to engage and educate residents about occupant behavior. In 2020, the city began a five-year review process to evaluate its progress on its goal of being carbon neutral by 2050, and in 2021 began updating this plan.

Climate Action Plan

The City of Cambridge Climate Action Plan (CAP) was written in 2018 and is based on a community-wide greenhouse gas (GHG) inventory completed in 2016. Using the GHG inventory, the CAP identified actions for achieving deep carbon reductions in the buildings, transportation, and waste sections. The CAP was updated in 2018.

Cambridge also developed a citywide sustainability dashboard to accompany this plan as a way of interactively tracking its progress on GHG reduction measures. The dashboard tracks progress on climate, transportation, and energy initiatives. The dashboard is an accessible tool to help residents get involved and visually comprehend the impact on carbon reductions.

Climate Protection Plan

The Climate Protection Plan was developed in 2002, preceding the city's Climate Action Plan. This plan was informed by an inventory of the city's emissions from 1990 and 1998. The impetus for the plan was that the City Council voted to join Cities for Climate Protection (CCP), an international consortium of communities working to reduce greenhouse gas emissions in 1999.

Climate Resilience Zoning Amendment

Cambridge City Council adopted the Climate Resilience Zoning Amendment on February 27, 2023. The updates to the city's zoning regulations were stewarded by a task force appointed by the City Manager in 2018. The purpose of this task force was to develop recommendations to make development in Cambridge more resilient to climate change risks. The new zoning includes regulations related to flooding and heat.

2.7. State Long-Range Plans Related to Hazard Mitigation

Massachusetts Integrated State Hazard Mitigation & Climate Adaptation Plan

The Commonwealth of Massachusetts adopted a state hazard mitigation and action plan in 2018. This plan integrates climate adaptation and hazard mitigation into one statewide plan that complies with FEMA's federal requirements for state Hazard Mitigation Planning. Adoption and maintenance of this plan makes Massachusetts eligible for federal disaster recovery and mitigation funding under the Stafford Act. The state's Hazard Mitigation Plan (called ResilientMass Plan) five-year update was released in the fall of 2023. The ResilientMass Plan is based on the Massachusetts Climate Change Assessment, a statewide assessment of climate vulnerability, informed by the best available data and climate science at the time of publication. The ResilientMass Plan is an important document referenced in this NHMP and many other local planning efforts.

Massachusetts Climate Change Assessment

The Massachusetts Climate Change Assessment was completed in 2022. The assessment is organized into seven geographic regions of the Commonwealth including the Cape Islands, and South Coast, North and South Shores, Boston Harbor, Eastern Inland, Central, Greater Connecticut River Valley, and Berkshires and Hilltowns. For each region, the assessment includes an evaluation of thirty-seven impacts on five sectors that include human, infrastructure, natural environment, governance, and economy. This statewide assessment was the basis for the SHMCAP.

Massachusetts Climate Resilience Design Standards Tool

The Resilient Massachusetts Action Team (RMAT) created a Climate Resilience Design Standards tool that is publicly available online to any residents, locality, or agency in the Commonwealth of Massachusetts. The tool provides parcel-level climate data for all properties in Massachusetts. The Tool was created to advance the goals of the SHMCAP. The tool provides climate projections in addition to a recommended planning horizon and return period for critical assets on a parcel input into the Tool by a user. This tool is intended to help agencies with state capital planning and make grants across Massachusetts respond to local climate data. Specifically, the tool provides:

- A preliminary climate change exposure and risk rating
- Recommended climate resilience design standards for projects with physical assets
- Guidance of best practices to support implementation.

The tool was developed with climate science data for Massachusetts and will be updated overtime to incorporate the best available information.

2.8. FEMA Review Tool

All aspects of the planning process were created and implemented in accordance with the updated FEMA Local Mitigation Planning Policy Guide (FEMA, 2022).

Chapter 3:

Natural Hazard Profiles

3. Natural Hazard Profiles

"Natural hazards are a source of harm or difficulty created by a meteorological, environmental or geological event. Natural hazards, such as flooding and earthquakes, impact the built environment, including dams and levees"

- (FEMA, 2022)

Natural hazards have the potential to induce damage or loss to physical assets, such as buildings, infrastructure, or natural, historic, and cultural resources, within the city. Natural hazards also have the potential to affect people, including underserved communities and priority populations, city processes and workflows, and activities that have value to the community. Analysis conducted through the Environmental Protection Agency (EPA) reveals that socially priority populations are disproportionately affected by the impacts of natural hazards (EPA, EPA Report Shows Disproportionate Impacts of Climate Change on Socially Vulnerable Populations in the United States, 2021).

For each natural hazard profile, the following components of the hazard are identified in this chapter:

I. **Description:** A description for each natural hazard stemming from the Massachusetts 2018 State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) (EEA & EOPSS, 2018) and the existing City of Cambridge Hazard Mitigation Plan 2015 Update (City of Cambridge & MAPC, 2015).

The following hazard profiles were developed based on the natural hazards that can affect the jurisdiction (i.e. Cambridge):

Flooding Hazards

- Inland Flooding (Stormwater and Riverine)
- Coastal Flooding

Dam Hazards

- Dam Failure

Wind-Related Hazards

- Hurricanes / Tropical Storms
- Tornadoes

Winter Storm Hazards

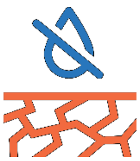
- Winter Storms / Nor'easters

Geological Hazards

- Earthquakes
- Landslides
- Tsunami

Temperature-Related Hazards

- Average/Extreme Temperatures



Drought Hazards

- Drought

Fire-Related Hazards

- Brushfire

Invasive Species Hazards

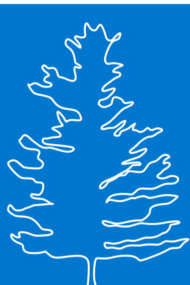
- Invasive Species

II. **Previous Occurrence(s) of the Hazard Event:** A list of historical occurrences of the natural hazard event, in chronological order. Understanding the history of a hazard in the city or Middlesex County, including the extent, frequency, and location of occurrence, aids in planning processes.

i. *Extent (Severity or Magnitude):* FEMA defines extent, "as the range of anticipated intensities of the identified hazards" (FEMA, 2022). This can be expressed in varying scientific charts and scales, as relevant to the hazard and city. Extent can be summarized as "how serious the hazard event is."

ii. *Frequency:* Frequency refers to the likelihood of occurrence over a given period of time.

iii. *Location:* The geographic boundary in which a hazard occurs. This may include areas larger or smaller than the City of Cambridge's jurisdiction.



Common Hazard Impacts

- Flooding basement
- Tree limbs falling and causing damage to house or car
- Extreme heat – health impact
- Mobility and transit difficulty in extreme weather
- Power outages
- Poor air quality

III. **Probability of Future Hazard Events due to Climate Change:** Climate projections indicate a change in long-term weather patterns. This section identifies how climate change may affect the extent, frequency, and location of natural hazard events occurring, and to what degree in which they change. Future climate change projections for the city, and climate change preparedness planning, design and engineering that the city conducted to date have focused on the 2030 planning horizon as defined by the bounding years 2015-2044, and the 2070 planning horizon as defined by the bounding years 2055-2084. In 2018, MA EOEEA created ResilientMA, an online clearinghouse for local governments and the public to explore climate change science and data, information on community resilience, and decision support tools. The climate change planning efforts that ResilientMA has undertaken have focused on the 2030, 2050, 2070 and 2090 planning horizons, which are defined by the bounding years 2020-2039, 2040-2059, 2060-2079 and 2080-2099, respectively. Since there is overlap in years between the city and the state's planning efforts for the 2030 and the 2070 planning horizons, we are using these to characterize future hazards.

  i. *Extent (Magnitude/Intensity):* Future changes in the extent of a hazard event may differ from what was previously described.
  ii. *Probability:* Future changes in the probability of a hazard event may differ from what was previously described. For example, the intensity and frequency of precipitation-based events are expected to increase in the future.
  iii. *Location:* Future changes in the location of a hazard event may differ from what was previously described.

Table 3.1 provides definitions of hazard location, extent, frequency, and probably. The definitions support the basis of determination in Table 3.2. In accordance with guidance from FEMA, quantification and definitions are necessary,

Table 3.1: Summary of Natural Hazard Risks for the City of Cambridge (Continued) (City of Cambridge & MAPC, 2015)

Points	Description
Hazard Extent (Severity/Intensity)	
Minor	Limited damages to property, no damage to public infrastructure (roads, bridges, trains, airports, public parks, etc.); contained geographic area (i.e., one or two neighborhoods); essential services (utilities, hospitals, schools, etc.) not interrupted; no injuries or fatalities.
Serious	Scattered major property damage (more than 10% destroyed); some minor infrastructure damage; wider geographic area (several communities); essential services briefly interrupted up to 1 day; some minor injuries.
Extensive	Consistent major property damage (more than 25%); major damage public infrastructure damage (up to several days for repairs); essential services are interrupted from several hours to several days; many injuries and possible fatalities.
Catastrophic	Property and public infrastructure destroyed (more than 50%); essential services stopped for 30 days or more, multiple injuries and fatalities.

Points	Description
Present Frequency of Hazard	
Very Low	Events that occur less frequently than once in 100 years (less than 1% chance per year).
Low	Events that occur from once in 50 years to once in 100 years (1% to 2% chance per year).
Medium	Events that occur from once in 5 years to once in 50 years (2% to 20% chance per year).
High	Events that occur more frequently than once in 5 years (greater than 20% chance per year).
Future Probability of Hazard	
Very Low	Events that are projected to occur less frequently than once in 100 years (less than 1% chance per year).
Low	Events that are projected to occur from once in 50 years to once in 100 years (1% to 2% chance per year).
Medium	Events that are projected to occur from once in 5 years to once in 50 years (2% to 20% chance per year).
High	Events that are projected occur more frequently than once in 5 years (greater than 20% chance per year).
Location of Hazard	
N/A	Hazard has not yet affected city area
Small	Less than 10% of the city is or could be affected by the hazard
Medium	Between 10-50% of the city is or could be affected by the hazard
Large	More than 50% of the city is or could be affected by the hazard

Table 3.2, below, provides a summary of the natural hazards affecting Cambridge. This evaluation takes into account historical records, the extent (severity and magnitude), frequency, and location, and anticipated future probability and location. Information regarding future projections for specific scenarios is not available for every natural hazard. Each hazard section contains best available science, and discusses projections in the context of specific future scenarios when available and appropriate.

“I am concerned about climate change above all other issues.”

- Public Survey Respondent

Table 3.2: Summary of Natural Hazard Risks for the City of Cambridge

Natural Hazard	Previous Occurrence of Hazard Event in Cambridge	PRESENT			FUTURE		
		Extent	Frequency	Location	Extent	Probability of Occurrence	Location
Inland Flooding	Yes	Serious	High	Medium	Serious	High	Large
Winter Storms & Nor’easters	Yes	Serious	High	Large	Serious	High	Large
Coastal Flooding as a result of Dam Failure	No	Extensive	Low	N/A	Extensive	High	Medium
Hurricanes & Tropical Storms	Yes	Extensive	Medium	Large	Extensive	High	Large
Tornadoes	No	Catastrophic	Low	N/A	Catastrophic	Low	Small
Earthquakes	No	Catastrophic	Low	N/A	Catastrophic	Low	Large
Landslides	No	Minor	Very Low	N/A	Minor	Very Low	Small
Tsunamis	No	Catastrophic	Very Low	N/A	Catastrophic	Very Low	Medium
Extreme Temperatures	Yes	Serious	High	Large	Serious	High	Large
Drought	Yes	Minor	High	Large	Serious	High	Large
Wildfire / Brush Fire	Yes	Serious	Low	Small	Extensive	Medium	Small

Natural Hazard	Previous Occurrence of Hazard Event in Cambridge	PRESENT			FUTURE		
		Extent	Frequency	Location	Extent	Probability of Occurrence	Location
Invasive Species	Yes	Minor	High	Large	Serious	High	Large

"Global warming is going to accelerate faster than we can really imagine."

- Public Survey Respondent

3.1. Inland Flooding (Stormwater and Riverine)

3.1.1 | Description

Flooding occurs when normally dry land is inundated by the rising or overflowing of water. Inland (riverine or stormwater) flooding poses a major threat to the city. Identified as the "most prevalent serious natural hazard identified by local officials" in the 2015 Cambridge NHMP. The frequency and severity of flooding from riverine and stormwater sources is expected to increase as the climate changes. Inland flooding is a result of combined effects of river overbank flooding and flooding from drainage infrastructure capacity issues. Representation of this hazard is best understood using the city's flood model, discussed further in this section.

3.1.2 | Previous Occurrences of Hazard Event(s)

The City of Cambridge has experienced ongoing flood hazard events throughout recent history. For example, during 2010, the months of March and July were some of the most intense rainfall Cambridge has experienced in recent history. In March of 2010, a ten-day stretch brought torrential rainfall of over 14.83 inches of rainfall in accumulation and on July 10, 2010 an hour long storm caused a rainfall accumulation of 3.58 inches in Cambridge (City of Cambridge, 2015). The July 10, 2010 storm corresponds to a 500-yr return period which implies an annual probability of 0.2% or less based on precipitation intensity data from NOAA Atlas 14 (NOAA-Atlas14, 2015).

The following indicated events represent significant historic flood events in Cambridge, with widespread flooding.

- March 1968
- The blizzard of 1978
- January 1979
- April 1987
- October 1991 ("The Perfect Storm")
- October 1996

- June 1998
- March 2001
- April 2004
- May 2006
- April 2007
- March 2010
- July 2010
- July 2018
- Hurricane Ida, September 2021
- April 19, 2022
- June 22, 2022
- August 16, 2022
- October 13, 2022
- November 30, 2022
- Various dates during Summer 2023

3.1.2.1. Extent

Before storm severity can be assessed, average conditions must be understood as the baseline for the city.

Table 3.3: Precipitation Values adopted by the city as part of the CCVA (City of Cambridge, 2015)

Precipitation Changes	Baseline (1971-2000)
Annual Precipitation (in.)	45
Summer Precipitation (in.)	9.5
Winter Precipitation (in.)	11.4
# of days per year > 2 in. rain in 24 hours (days)	2
Max 5-day precipitation per year (in.)	6

The City of Cambridge's flood model, developed in ICM-2D, is a dynamic and integrated flood model that factors both riverine flooding in the Alewife Brook and Lower Charles River areas, as well as piped infrastructure flooding from stormwater (in separated areas) and combined sewer (in combined areas) across the city. The riverine flood model in the Alewife area was built upon and improved from the original 2010 FEMA HEC-RAS riverine hydraulic model for the Mystic River basin. The piped infrastructure flooding in the city has been developed by integrating pipes, manholes, catch basins, outfalls and other drainage/storage structures that already exist or are currently under construction in the city. The dynamic interaction between riverine flood levels, and piped infrastructure flooding, results in more realistic and accurate representation of actual flooding conditions. The city's flood model is also calibrated to available river stage and flow data at multiple locations in the Mystic River and the Charles River watersheds, and it is expected that the models will better simulate the flows and flooding in Cambridge for future precipitation scenarios, as well. The results of the city's flood model can be accessed here. The model results, in terms of maximum flood elevation at each parcel scale in the city for the different design storms under the present and future scenarios, as well as for FEMA 100- and 500-yr floods, are available to view at the city's FloodViewer website (last updated in 2022)

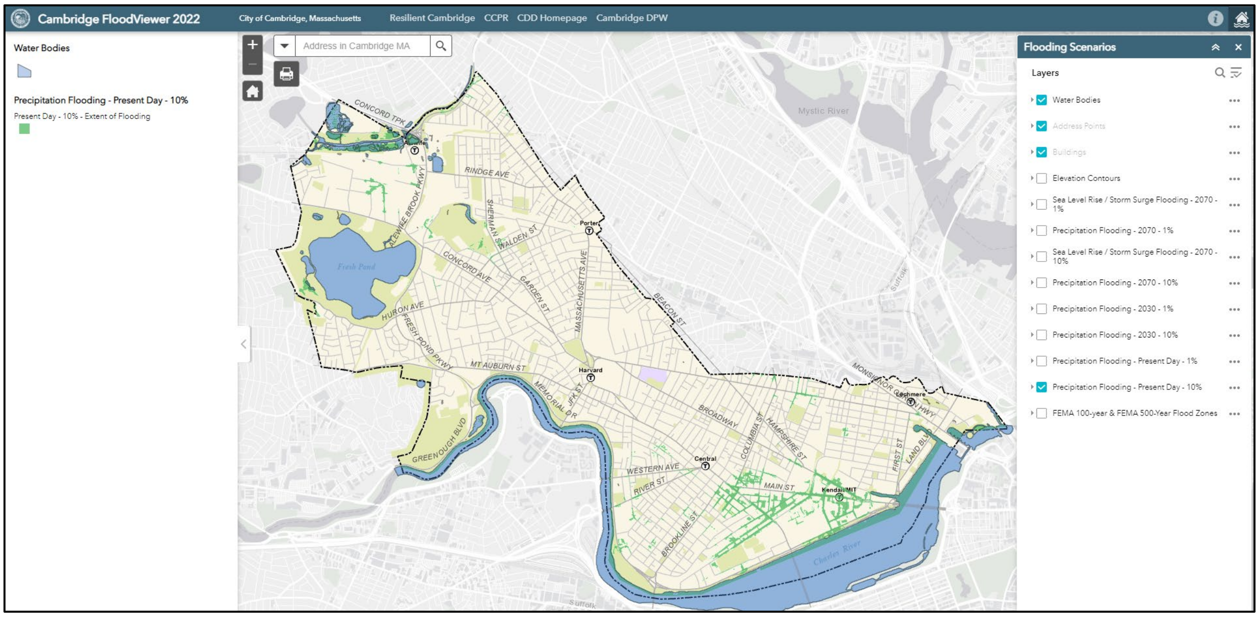


Figure 3-1. Cambridge Flood Viewer Present-day 10% Storm Event Flooding

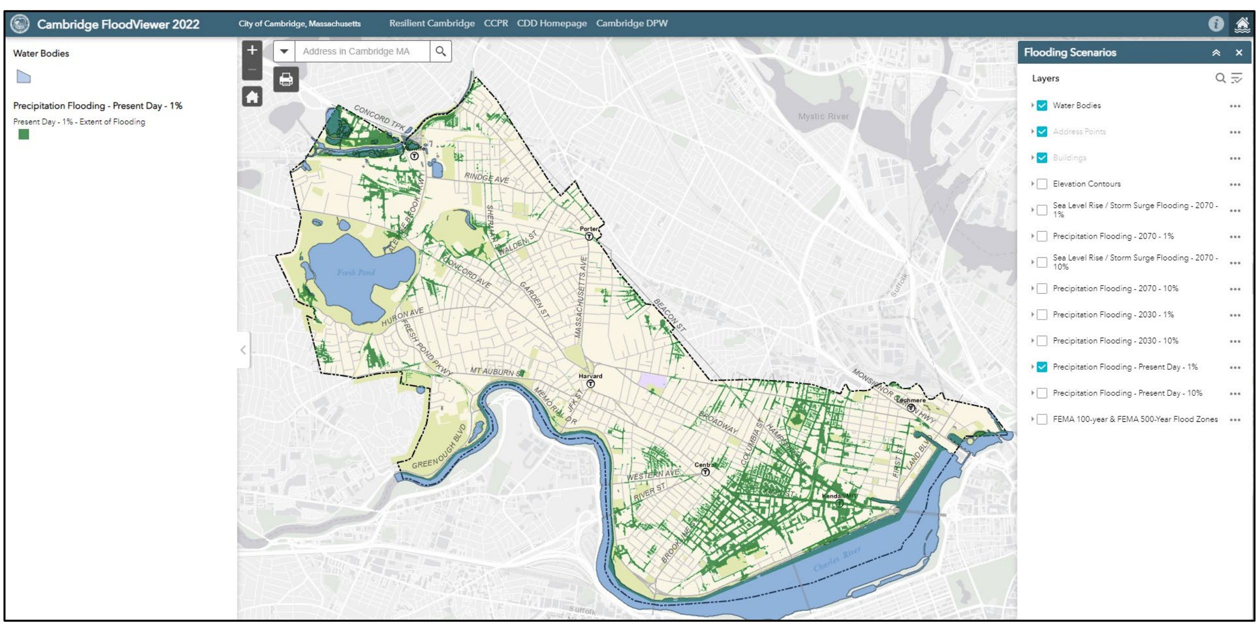


Figure 3-2. Cambridge Flood Viewer Present-day 1% Storm Event Flooding

Extent of flooding can further be measured by the population impacted by the flood events and the percent of land or properties flooded as a result of the event. Table 3.4 and Table 3.5 demonstrate the severity of flooding in the City of Cambridge through these metrics.

Table 3.4 is a summary table reporting extent of inland flooding impacts in the Alewife area from present 10-year and 100-year 24-hour design storms, as reported in the Climate Change Preparedness & Resiliency (CCPR) Alewife Plan (2017).

Table 3.4: Alewife Area Storm Event Flooding Impact

Year	Storm Event	% Flooded Land Area	% Flooded Properties
Present	10-year 24-hour precipitation event	3%	5%
	100-year 24-hour precipitation event	11%	18%

Table 3.5 is a summary table reporting extent of inland flooding impacts in The Port study area from flood events between 2013-2017, as reported in The Port Preparedness Plan (2019).

Table 3.5: Population at Risk in the Port Study Area

Population at Risk	Total Count	Impacted by Flooding
Children Aged 0-5	266	200
Seniors Aged 65+	359	280
Non-English Speakers	1,738	1,200
Residents below the Poverty Line	1.082	810

* The Port neighborhood area (approximately 191 acres) housed an average of 7,023 people between 2013-2017. The number of residents in The Port study area (approximately 153 acres) as considered in CCPR is approximately 4,780 because The Port study area is smaller than The Port neighborhood area. Assumptions were made for this population analysis because census tract data does not match The Port's study area boundaries. (Source: 2016 ACS data)

3.1.2.2. Frequency

The 2018 SHMCAP states that the frequency of substantial flood events in Massachusetts is once every 3 years. Described in Table 3.6, below, are the present day (baseline conditions) for design rainfall storm events of different frequencies for the city. These present day storm depths are based on extreme rainfall estimates provided by the Northeast Regional Climate Center (NRCC) intensity-duration-frequency (IDF) tables and curves.

Table 3.6: Baseline Storm Depths for 24-hr and 48-hr design storms (City of Cambridge, 2015)

Baseline (1971-2000)	
24-hr Design Storms	
10-yr	4.9 in
25-yr	6.2 in
100-yr	8.9 in
48-hr Design Storms	
10-yr	5.5 in
25-yr	7 in
100-yr	10 in

3.1.2.3. Location

As defined by FEMA, a repetitive loss property is any NFIP insured property which has been paid two or more flood claims of $1,000 or more in any given 10-year period (FEMA, 2020). Therefore, repetitive loss data does not represent all losses due to flooding and the number of buildings that experience losses due to flooding is likely higher. Uninsured properties do not received any aid from FEMA, with the exception of during a disaster declaration, when they may be able to receive a grant for individual assistance. Insured properties can apply for a mitigation grant while uninsured properties cannot.

The repetitive loss data below was provided by MEMA (MEMA, 2023). The identified repetitive loss properties have received an aggregated total building payment of $99,769 and contents payment of $83,900 from FEMA on three properties.

Table 3.7: Repetitive Loss Structures for the City of Cambridge, Massachusetts

Count of Repetitive Loss Properties	Count of Total Losses	Total Building Payments	Total Contents Payments
3	7	$99,768.39	$83,899.91

The city is bordered at the southern end by the Charles River and along the northwestern edge are the Fresh Pond and the Alewife Brook. The resultant Federal Emergency Management Agency (FEMA) flood hazard map is shown below in Figure 3.3. The FEMA National Flood Insurance Program's (NFIP) Flood Insurance Rate Maps (FIRMs) designate areas or Zones likely to experience flooding as high risk (Zones starting with A) or moderate- to low risk (Zones starting with B, C, or X) High risk properties with federally backed mortgages or those that have received federal disaster assistance are required to maintain flood insurance. Properties within moderate- to low- risk areas are not required, but are highly encouraged, to purchase flood insurance.

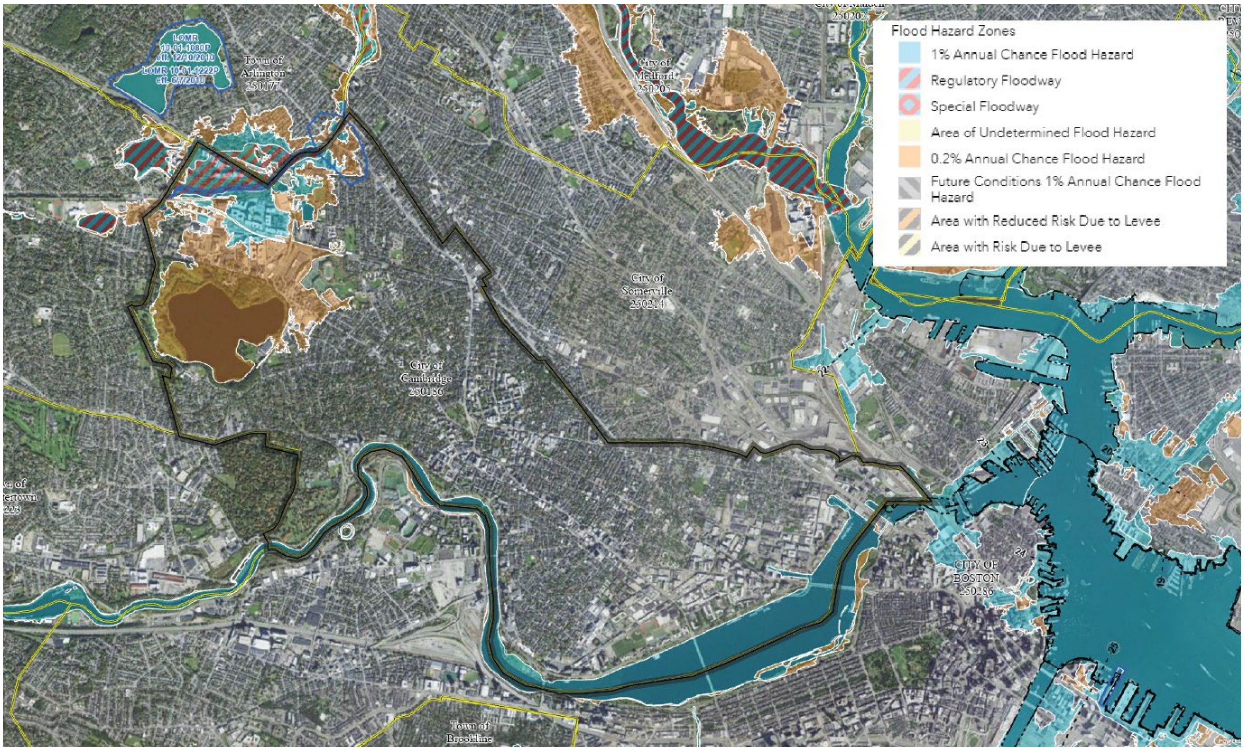


Figure 3-3: FEMA Flood Hazard Layers for the City of Cambridge

3.1.3 | Probability of Future Hazard Events due to Climate Change

3.1.3.1. Extent

Climate change projections indicate that extreme weather events are likely become more frequent and more intense in coming years. Compounding weather impacts may occur that can exacerbate the impacts of these events. Increases in temperature can lead to greater evaporation, thus increasing atmospheric moisture, and more intense precipitation events. High-intensity or heavy precipitation events can lead to flooding, landslides, infrastructure damage, and erosion.

The Fourth National Climate Assessment, Volume I ((Wuebbles, 2017), states that the observed changed in heavy precipitation has increased by 74% between 1901 and 2016 in the northeastern states. Long-term impacts of these changes may involve a change in floodplain boundaries, leaving areas once safe now vulnerable to flooding. Inland flooding intensity will increase as heavy rain falls in short periods of time, overloading soil absorption and riverbanks. These events can be particularly devastating in urban cities like Cambridge, where impervious surface and buildings can further prevent rainwater from absorbing in the soil. This added runoff may overwhelm stormwater systems, thus increasing the risk of flash flooding.

3.1.3.2. Probability

According to the latest published data from ResilientMA (MA EOEEA, 2021), the annual total precipitation in Cambridge area is projected to increase by ~11% with a projected 22% increase in maximum precipitation by the 2070 planning horizon. Winter precipitation (which includes rain, sleet, snow, and ice) will also be affected, with an estimated 16% increase in total winter precipitation by the 2070 planning horizon. The annual number of days with extreme precipitation is also estimated to increase in the future. Table 3.7 shows the estimated percentage increase in total precipitation and days with extreme precipitation from ResilientMA (MA EOEEA, 2021).

Table 3.8: Projected changes annual total precipitation in the Cambridge region (MA EOEEA, 2021)

Precipitation Parameter	Baseline	2030s	2050s	2070s	2090
Total precipitation: Annual (inches)	43.6	6.4	8.7	10.8	13.4
Total precipitation: Spring (inches)	11.2	8.2	9.5	14.5	16.6
Total precipitation: Summer (inches)	9.2	9.9	7.8	8	10.2
Total precipitation: Fall (inches)	11.6	1.2	4.8	4.2	5.6
Total precipitation: Winter (inches)	11.7	6.9	12.4	15.9	20.8
Number of Days >1" precipitation	6	1	1	2	2

These most recent projections from ResilientMA vary from the projections adopted by the city's 2015 Climate Change Vulnerability Assessment, shown in Table 3.8, and the city is considering updating its projections to be consistent with the latest and best available data from the State.

Table 3.9: Precipitation Changes for the City of Cambridge (City of Cambridge, 2015)

Precipitation Changes	Baseline	2030s (2015-2044)		2070s (2055-2084)	
	1971-2000	*Lower*	*Higher*	*Lower*	*Higher*
Annual Precipitation (in.)	45	48	48	51.5	54
Summer Precipitation (in.)	9.5	9.8	9.8	10.1	10.3
Winter Precipitation (in.)	11.4	12.6	12.7	14.1	15.4
# days per year > 2 in. rain in 24 hrs (days)	2	3	3	3	3
Max. 5-day precipitation per year (in.)	6	6.5	6.6	7	7.2
24-hr design storms					
10 yr	4.9	5.6		6.4	
20 yr	6.2	7.3		8.2	
100 yr	8.9	10.2		11.7	
48-hr design storms					
10 yr	5.5	6.4		7.2	
25 yr	7	8.6		9.8	
100 yr	10	13.2		15.7	

Changes in precipitation and temperature in Cambridge could lead to modifications in the current floodplain, putting areas that have not historically flooded at risk. Existing FEMA flood maps utilize historic flood data and do not provide future floodplains. Future flood data was developed for the city's model (Cambridge, 2022) and found that the floodplain expands geographically compared with FEMA floodplains. This could impact residents and businesses that are located in areas that have not experienced flooding in the past, which could result in significant economic and social costs.

Future projections show an increase in intensity and frequency of storm event. Design storms with higher return periods will become more frequent. Design storms are regularly used by engineers and planners to evaluate the performance of different systems and structures, such as drainage systems, flood control structures, and buildings, under extreme weather conditions. A 100-yr design storm has a 1% chance of occurrence in any given year and a 25-yr design storm has a 4% chance of occurrence in any given year.

Precipitation data projections developed for Cambridge (from MA EEA's Climate and Hydrologic Risk Project (Steinschneider, 2022)) indicate that the frequency of future extreme design storms will be higher in future. Future projected total precipitation depths over 24-hours were pulled from this data source and are indicated in Table 3.9. The projections are also plotted with NOAA Atlas 14 present day baselines, for a series of recurrence intervals, as shown in Figure 3.4. This figure shows the following relationships:

- Rainfall over a 24-hr period that historically had a 1-in-100 year frequency (8.2 inches) is likely to increase to a frequency of 1-in-10 by 2070.
- Rainfall over a 24-hr period that historically had a 1-in-25 year frequency (6.3 inches) is likely to increase to a frequency of 1-in-10 year by 2050.

Table 3.10: Future 24-hr design storm depth predictions (inches) in Cambridge

24-hr Design Storm Depth Predictions (inches)				
Recurrence Interval	**Present Day Baseline (NOAA Atlas14)**	**Cornell IDF Projection 2030**	**Cornell IDF Projection 2050**	**Cornell IDF Projection 2070**
1yr	2.6	3.0	3.2	3.6
2yr	3.3	3.7	4.0	4.4
5yr	4.3	4.9	5.3	5.8
10yr	5.2	5.9	6.4	7.0
25yr	6.3	7.3	7.8	8.6
50yr	7.2	8.3	8.8	9.8
100yr	8.2	9.3	10.0	11.1
200yr	9.3	10.7	11.4	12.7
500yr	11.2	12.8	13.7	15.1

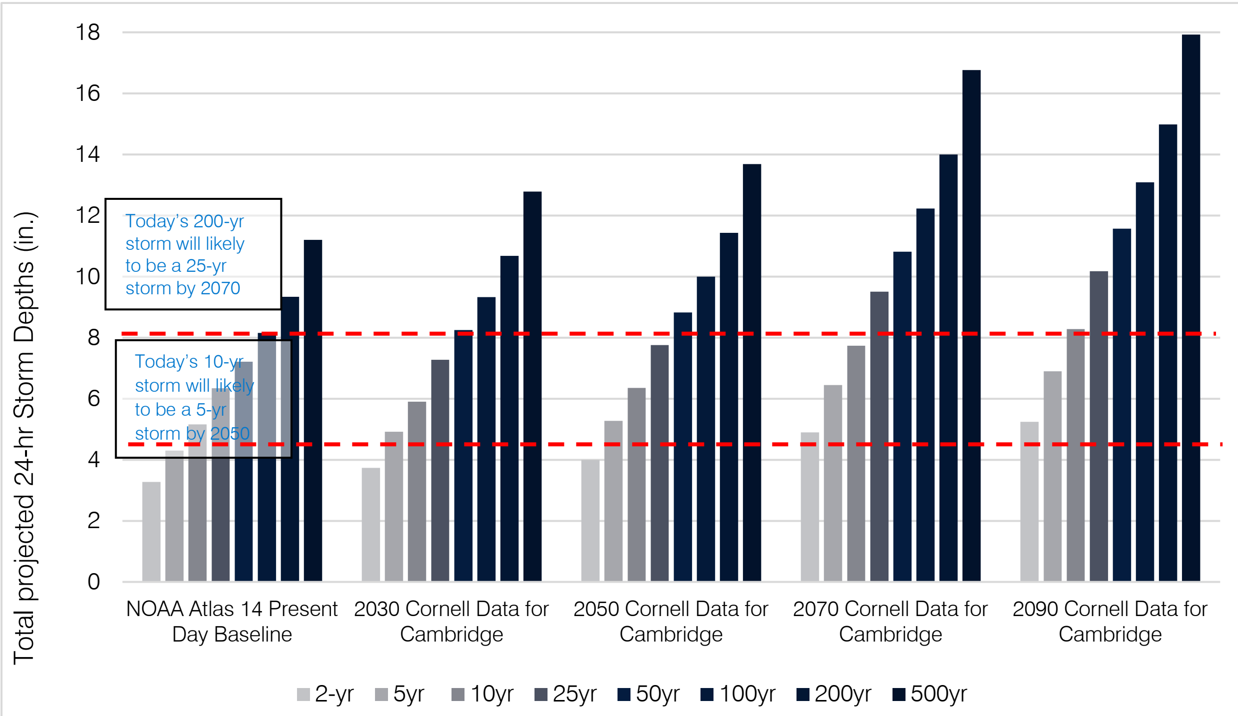


Figure 3-4: Future precipitation projections for 24-hr storm depths in Cambridge (Using Cornell University generated IDF projections as part of MA EEA's Climate and Hydrologic Risk Project)

3.1.3.3. Location

Figure 3.5 shows the impact of a 100-yr 24-hour duration storm by 2030 (left) and 2070 (right) in the city, as presented in the city's flood viewer (City of Cambridge, 2022). Low lying areas in Cambridge, particularly areas that are located close to the Charles River and Fresh Pond are more susceptible to inland flooding. The extent of floodplain will expand causing flooding in parcels that have not experienced flooding in the past.

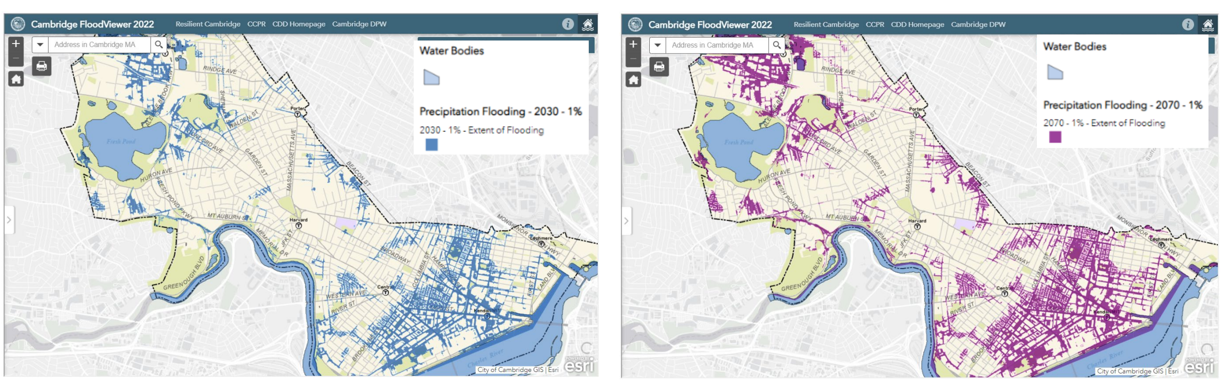


Figure 3-5: Potential flooding from a projected 100-year 24-hour storm with climate change (Left-2030, Right -2070) and an estimated rainfall of 11.7 inches over 24 hours (Source: Cambridge Flood Viewer)

3.2. Winter Storms and Nor'easters

3.2.1 | Description

Winter storms in Massachusetts can bring heavy snowfall and below-freezing temperatures. They can also include blizzards, ice storms, nor'easters, and other extreme forms of winter precipitation.

- Blizzards are characterized as snowstorms that reduce visibility to or below a quarter mile, while also being accompanied by wind gusts of 35 mph or greater (EEA & EOPSS, 2018).
- Ice storms can also be an issue during winter months, where liquid precipitation falls and freezes upon contact with the cold ground, creating ice buildups. These instances can create impaired walking and driving conditions and can also result in damage to power lines and trees (EEA & EOPSS, 2018).
- Nor'easters (which get their name from being a northeastern coastal storm) typically develop as a large counterclockwise wind circulation, around a low-pressure center. These storms include strong winds that blow in from the ocean, onto coastal areas. They are typically associated with heavy rains or snow and can cause storm surge of greater than 2 ft, coastal flooding, and coastal erosion (City of Cambridge & MAPC, 2015). Sustained winds of 20 to 40 mph are also common during nor'easters, even bringing wind gusts up to 50-60 mph.

3.2.2 | Previous Occurrences of Hazard Event(s)

The City of Cambridge has experienced a multitude of severe winter storm events since 1978. These hazard events are indicated in Table 3.10 below.

Table 3.11: Severe winter storm events since 1978, in the City of Cambridge, based on FEMA Disaster Declarations (FEMA, Declared Disasters, n.d.)

Date	Event
February 1978	Blizzard
March 1993	Blizzard
January 1996	Severe Snowstorm
March 2001	Severe Snowstorm
December 2003	Severe Snowstorm
January 2004	Severe Snowstorm
January 2005	Severe Snowstorm
April 2007	Severe Snowstorm

December 2010	Severe Snowstorm
February 2013	Blizzard
January 2015	Winter Storm Juno
March 2018	Back-to-back Nor-Easters
January 2022	Blizzard

3.2.2.1. Extent

The severity or extent of winter storm events is characterized by two scales: Northeast Snowfall Impact Scale (NESIS) and Regional Snowfall Index (RSI).

The NESIS was established by Paul Kocin (The Weather Channel) and Louis Uccellini (National Weather Service) and is used to classify "high impact northeast snowstorms with large areas of 10-inch snowfall accumulations and greater)" (EEA & EOPSS, 2018). The scale has five categories, which are categorized by impact to an area. The calculated NESIS value is a function of the area affected by the storm, quantity of snow that fell, and population living within the path of the storm (NOAA, 2023).

Table 3.12: Northeast Snowfall Impact Scale (NESIS)

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	10.0+	Extreme

More recently, however, the RSI has become more popular for use in quantifying the impact of a winter storm event for the eastern two-thirds of the U.S. While the NESIS is calibrated to the northeast, it has been used more nationally. Developed in 2005, the RSI is a more regional index that has come to replace the NESIS. The RSI calculates impact of storm based on the spatial extent, quantity of snow that fell, and population information, tied to societal impacts. It is cited as better able to "place snowstorms and their societal impacts into a historical perspective on a regional scale" (NOAA, 2023). Table 3.12 shows the classification of winter storms and nor'easters by their RSI and respective descriptions.

Table 3.13: Regional Snowfall Index (RSI)

Category	RSI	Description
1	1-3	Notable
2	3-6	Significant
3	6-10	Major
4	10-18	Crippling
5	18.0+	Extreme

3.2.2.2. Frequency

Notable winter storms and nor'easters often occur on an annual basis, if not more frequently. The SHMCAP describes the frequency of Nor'easters as one or two per year, with some years containing up to four of these hazard events (EEA & EOPSS, 2018). The Northeast generally experiences one or two major winter storms each year with varying degrees of severity (NESEC, 2017).

3.2.2.3. Location

Winter storms and nor'easters are citywide natural hazards. These events can create issues for residential, commercial, and emergency operations.

3.2.3 | Probability of Future Hazard Events due to Climate Change

3.2.3.1. Extent

Winter storms and Nor'easters are powerful storms that can cause significant damage and disruption to communities. Climate change is expected to cause an increase in precipitation in Massachusetts over the next 80 years, and the proportion of this precipitation that falls during extreme events is predicted to increase.

Although rising temperatures suggest that more precipitation will fall as rain than snow, historical data show that the frequency of extreme snowstorms in the U.S. doubled between the first and second half of the 20th century (EEA & EOPSS, 2018). With warmer air over the Atlantic Ocean, it will lead to more moisture laden air causing more intense blizzard events in the winter when they collide with cold air systems from the north in the NE US including cities like Boston and Cambridge (MA EOEEA, 2021).

Potential climate change impacts in Cambridge will likely include increased snowfall, sea level rise, storm surge, and more intense storm events. The projected sea level rise will exacerbate the impact of severe winter storms, particularly when they coincide with high tides creating higher coastal erosion and flooding. This could result in substantial damages from future nor'easters.

It is important for cities like Cambridge to prepare for the potential impacts of nor'easters, including cumulative impact of back-to-back storms. It is crucial that the city considers increasing its resilience to extreme weather events and investing in infrastructure and emergency management plans that can help mitigate the effects of these storms. As design wind speeds have increased in the last few years, it is crucial to consider the safety and stability of buildings and other structures in the face of stronger winds. By taking proactive steps to prepare for future winter storms, Cambridge can minimize the damage to their built infrastructure and protect the safety and well-being of their residents.

3.2.3.2. Probability

The probability of future winter storms and nor'easters are expected to increase in Cambridge potentially causing more damage to the city than present day. The future flooding impacts from winter storms and nor'easters combined with sea level rise and storm surge in the coastal areas are included in the Massachusetts Coast Flood Model (MC-FRM) that has been adopted by the City of Cambridge. The MC-FRM is a probabilistic based hydrodynamic flood model that provides future probabilities of flooding from nor'easters, tropical storms, hurricanes for the 2030, 2050 and 2070 planning horizons. The model also factors respective sea level rise projections for each of the future planning horizons. Based on the MC-FRM results, both the Amelia Earhart Dam and Charles River Dam are likely to be flanked and overtopped in the future from sea level rise and extreme storms, unless mitigation measures are implemented. Flooding may also stem from severe winter weather including winter storms and nor'easters. The probability of flooding maps from MC-FRM (final version as published by Woods Hole Group in September 2021) show that portions of western Cambridge in the Alewife Brook sub-watershed have a likelihood of 50 to 70% annual probability of flooding by 2070 and portions of eastern Cambridge in the lower Charles River sub-watershed have a likelihood of annual probability of flooding between 5 to 10% by 2070.

3.2.3.3. Location

The future flooding impacts from winter storms and nor'easters because of climate change, as discussed in the previous section, are likely to be citywide, with more frequent flooding expected to occur in the western portions of the city in the Alewife area. Citywide impacts from winter storms and nor'easters are also anticipated to cause damages to the built infrastructure.

3.3. Coastal Flooding as a Result of Dam Failure

3.3.1 | Description

Dams are built structures that serve as artificial barriers for the storage or control of water (EEA & EOPSS, 2018). The Massachusetts Department of Conservation & Recreation (DCR) defines dam failure as the "collapse of an impounding structure resulting in an uncontrolled release of impounded water from a dam" (DCR, 2017). Dam failure can occur in two primary ways; catastrophic failure (which includes rapid release of the impounded water) or dam overtopping ("caused by floods that exceed the capacity of the dam"). Dam overtopping is the cause for approximately 34% of all dam failures in the U.S. (EEA & EOPSS, 2018). Non-breach flood risks can also occur when downstream flooding occurs although the dam is functioning as designed and does not fail. One example of a non-breach risk is dam flanking, occurring when water proceeds to go beyond the dam by passing it on one or both sides.

The City of Cambridge currently relies on two dams for protection against coastal flood inundation: the Amelia Earhart Dam, located along the Mystic River, and the New Charles River Dam, situated at the head of the Charles River. While these two dams are both owned and operated by DCR, instead of the city, their proximity and functionality provide key protection to Cambridge. These two dams serve as vital infrastructure for the City of Cambridge to safeguard the community from the effects of present-day storm surge and coastal inundation. **Dam failure has not occurred at the Amelia Earhart or New Charles River Dam since their establishment in 1965 and 1978, respectively.** However, climate change projections of sea level rise and storm surge published by the city as part of its Climate Change Vulnerability Assessment (Cambridge, Climate Change Vulnerability Assessment, February 2017) project that both the dams are likely to be flanked and overtopped by 2070. Based on this report (Cambridge, Climate Change Vulnerability Assessment, February 2017), the Amelia Earhart Dam is likely to be flanked as soon as 2030-2035 by a 500-year water surface elevation and by 2045-2050 by a 100-year water surface elevation. The probability of complete failure of the Amelia Earhart Dam is unknown. As a low hazard potential dam, there isn't a Emergency Action Plan developed for the dam. Further analysis would need to be conducted on the dam in order to determine the probability of failure.

The Charles River Dam is likely to be flanked as soon as 2045 by a 500-year water surface elevation and by 2055-2060 by a 100-year water surface elevation. The Charles River Dam is likely to be overtopped by 2050 by a 500-year water surface elevation and by 2065 by a 100-year water surface elevation. With the more stringent sea level rise and storm surge projections adopted by the State (EEA & MEMA, 2023) as part of the Massachusetts Coast Flood Risk Model (MC-FRM), both these dams are likely to be flanked and overtopped sooner.

The salinity associated with these possible coastal flooding scenarios is cause for concern in regard to Cambridge's built infrastructure and natural resources (Cambridge, February 2017). If saltwater moves upstream into the Alewife Brook area, including into the Fresh Pond Reservoir, there could be significant impacts to the city's drinking water systems. Above-ground components of the water / stormwater system such as valves, hydrants, manhole covers, and pump stations would also be susceptible to corrosion if exposed to salt water for prolonged periods of time during flood events. Additionally, saline floodwaters may adversely affect the natural habitat and ecology in Cambridge's wetlands and natural areas.

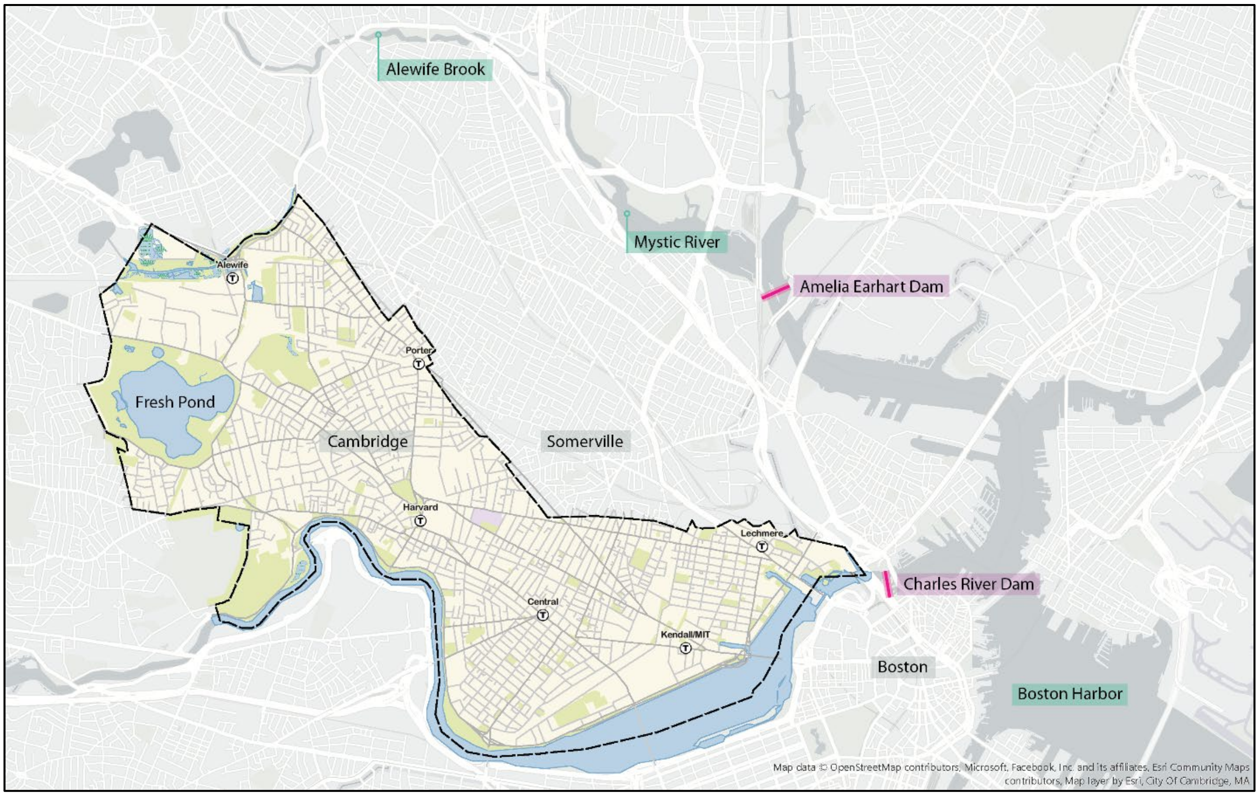


Figure 3-6. Locus map of Cambridge and the two dam locations.

3.3.1.1. Extent

The Cambridge CCVA (Cambridge, Climate Change Vulnerability Assessment, February 2017) states critical infrastructure systems – energy, roadways, public transit, telecommunications, critical service facilities, and water/wastewater systems – located in the Fresh Pond/Alewife area and in low-lying areas of the city linked to the Charles River are at increased risk from sea level rise/storm surge (SLR/SS) driven coastal flooding after 2030. The Fresh Pond-Alewife area is an area of particular concern due to the high probability of SLR/SS flooding and high depth of flooding that could significantly impact priority populations, critical infrastructure, and community resources. The stormwater and combined wastewater systems will likely be significantly impacted by SLR/SS flooding as there are additional areas that are likely to reach capacity and fail due to SLR/SS flooding compared to precipitation driven flooding alone.

The impacts of flooding from SLR/SS as a result of the flanking and overtopping of the dams have significant regional consequences, beyond the city, in terms of disruptions to energy distribution, transportation, and food services. Critical areas containing key infrastructure, such as the MBTA Red Line, Alewife Brook Parkway, and subsequent access to Route 2, as well as residential and vulnerable communities, can be highly impacted from the consequences of either or both of the dams being flanked and overtopped.

Flooding can cause physical damage to buildings and infrastructure, which could make areas inaccessible and create public safety hazards. Damages tend to increase with longer duration flooding, which could occur if the pumps at the Charles River Dam and Amelia Earhart Dam are not able to function properly during and after a storm. Analysis was done as part of CCVA Part II to estimate the duration of flooding in the city from flanking and overtopping of the Amelia Earhart

Dam using the BH-FRM data (Cambridge, 2017). Similar analysis using the MC-FRM has not yet been conducted to date. Saltwater flooding from SLR/SS also has the potential to cause long-term impacts to vulnerable local and regional infrastructure, such as the MBTA Red Line, due to its corrosive effects. Contamination from salt water or hazardous pollutants could also cause damage to water resources, such the Fresh Pond Reservoir.

3.3.1.2. Probability

The coastal flooding results from SLR/SS simulated using the MC-FRM for 2030 (Figure 3.7 through Figure 3.9) show that majority of the areas in the Alewife Brook watershed have a 0.5-1% annual probability of flooding by 2030, with areas north of the Alewife Brook can experience 1-2% annual probability of flooding by 2030. Areas adjacent to the Fresh Pond have a less than 0.1% annual probability of flooding by 2030. There is no coastal flooding in Eastern Cambridge around the Charles River by 2030. Some locations between the New and Old Charles River dams in the North Point area can experience less than 0.1% or between 0.1 to 0.2% annual probability of flooding, as well as at some locations along the Cambridge Somerville border, where there is a 1-2% annual probability of flooding by 2030.

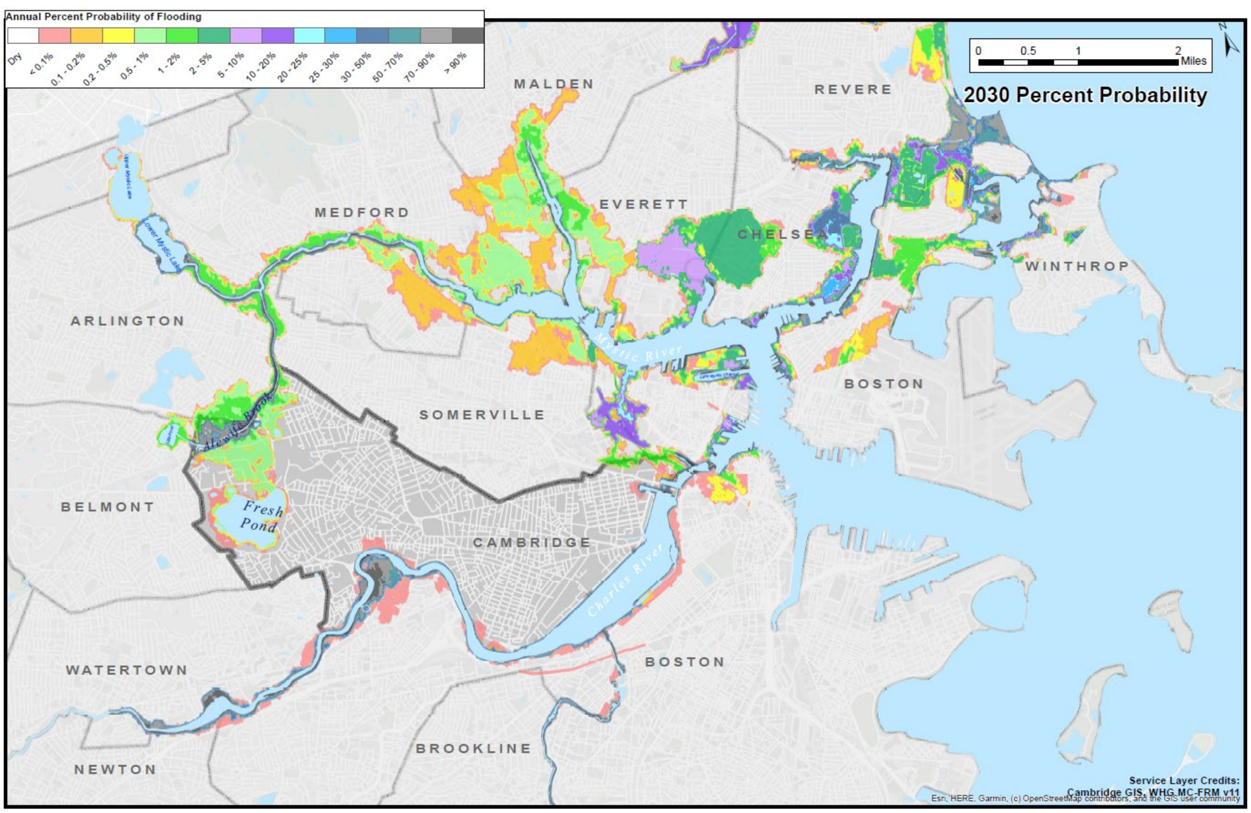


Figure 3-7: Probability and extent of coastal flooding by 2030, based on results from the Massachusetts Coast Flood Risk Model (2021)

MC-FRM results for 2050 (Figure 3.8) shows that majority of the areas in the Alewife Brook watershed have a 5-10% annual probability of flooding by 2050, with some areas north of the Alewife Brook can experience as high as 70-90% annual probability of flooding by 2050. Areas adjacent to the Fresh Pond have between 2-5% annual probability of flooding by 2050. The Charles River and areas adjacent to the Charles River have 0.1- 0.5% annual probabilities of flooding by 2050. Along the north bank of the Charles River in some locations and in the area between the New and Old Charles River dams in the North Point, the annual probabilities of flooding are as high as 2-5% by 2050.

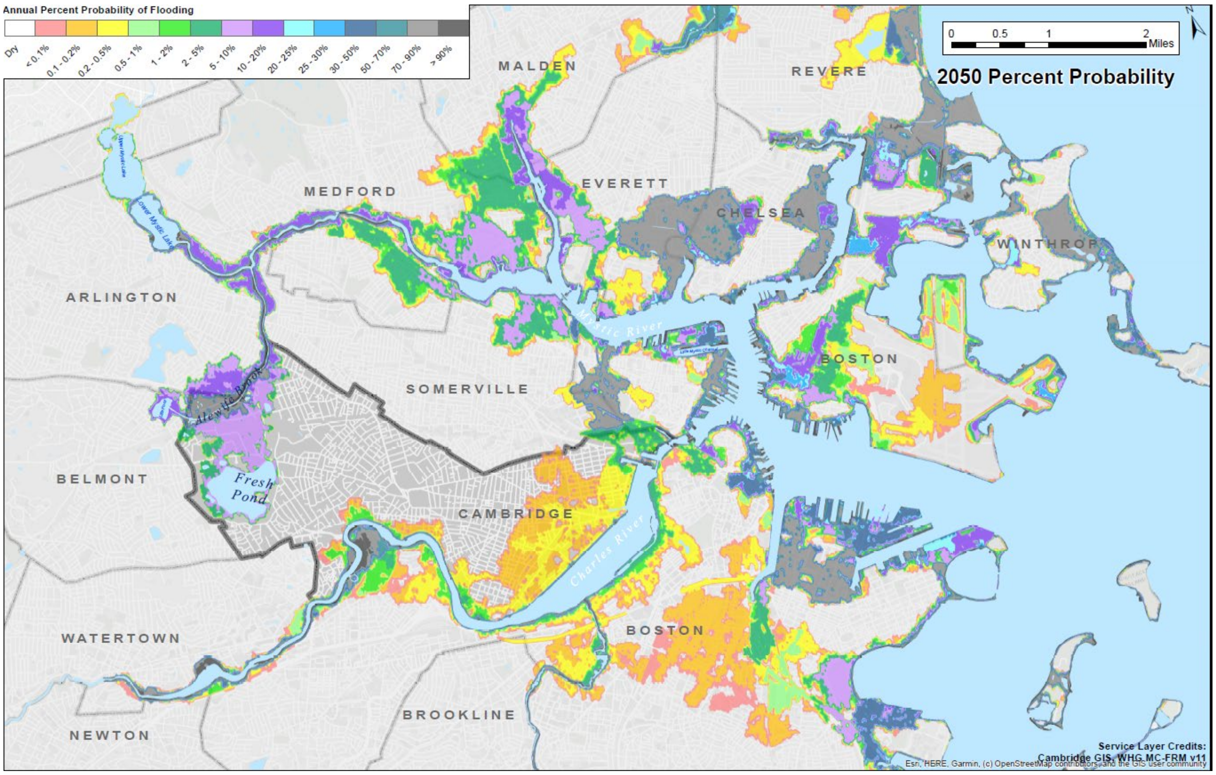


Figure 3-8: Probability and extent of coastal flooding by 2050, based on results from the Massachusetts Coast Flood Risk Model (2021)

MC-FRM results for 2070 (Figure 3.9) shows that majority of the areas adjacent to the Alewife Brook have a 50-70% annual probability of flooding by 2070, with some areas adjacent to the Alewife Brook likely to have 70-90% annual probability of flooding by 2070. The Charles River and areas adjacent to the Charles River have 5-10% annual probabilities of flooding by 2070. Along the north bank of the Charles River in locations between the New and Old Charles River dams in the North Point, the annual probabilities of flooding are as high as 70-90% by 2070.

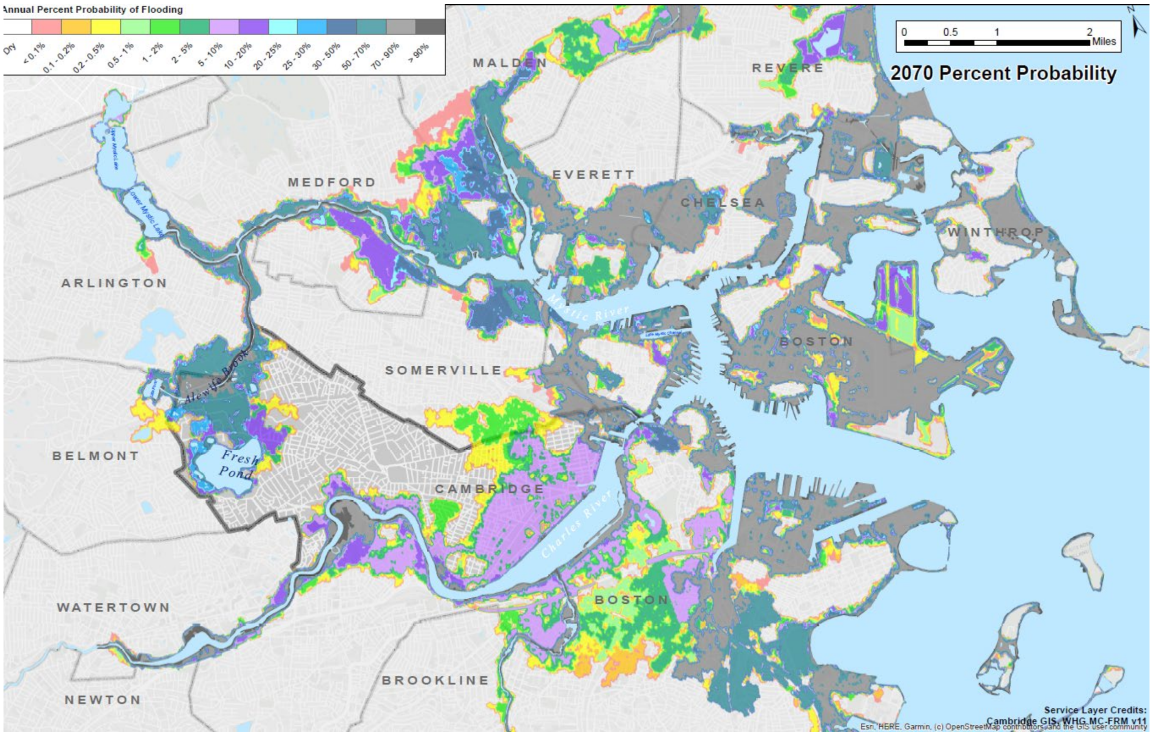


Figure 3-9: Probability and extent of coastal flooding by 2070, based on results from the Massachusetts Coast Flood Risk Model (2021)

3.3.1.3. Location

Figure 3.10 shows the geographic locations in the city that are likely to be flooded from sea level rise/storm surge from a 10% annual probability of flooding (left) and from a 1% annual probability of flooding (right) by 2070. Areas in the Alewife neighborhood are impacted from coastal flooding, with majority of the flooding from the Alewife Brook overtopping, as well as propagated coastal flooding through piped infrastructure in low-lying areas. Similarly, areas in Eastern Cambridge neighborhoods are impacted from coastal flooding, with a combination of flooding from the lower Charles River overtopping and propagated coastal flooding through piped infrastructure in low-lying areas. The extent of the floodplain will expand causing flooding in parcels that have not experienced flooding in the past.

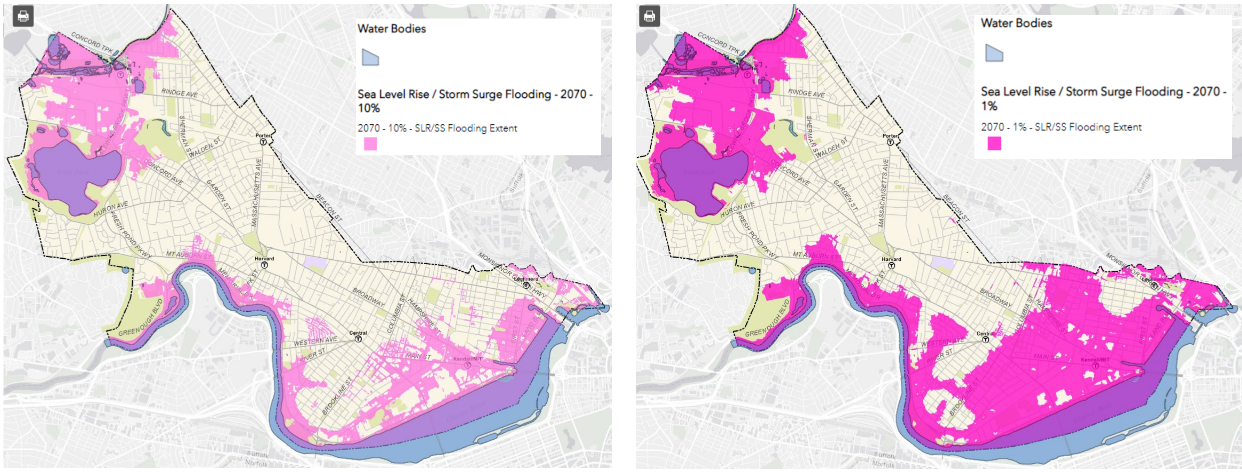


Figure 3-10: Potential flooding locations from projected coastal flooding by 2070 from climate change with sea level rise/storm surge (Left-10% annual probability, Right -1% annual probability) (Source: Cambridge Flood Viewer)

3.4. Hurricanes / Tropical Storms

3.4.1 | Description

Hurricanes originate from tropical storms, which form rotating cloud systems, developing over tropical or subtropical waters. There are four classifications of these types of storms (tropical cyclones) (National Hurricane Center, NOAA):

- **Tropical Depression:** A tropical cyclone with maximum sustained winds of 38 mph (33 knots) or less.
- **Tropical Storm:** A tropical cyclone with maximum sustained winds of 39 to 73 mph (34 to 63 knots).
- **Hurricane:** A tropical cyclone with maximum sustained winds of 74 mph (64 knots) or higher. In the western North Pacific, hurricanes are called typhoons; similar storms in the Indian Ocean and South Pacific Ocean are called cyclones.
- **Major Hurricane:** A tropical cyclone with maximum sustained winds of 111 mph (96 knots) or higher, corresponding to a Category 3, 4 or 5 on the Saffir-Simpson Hurricane Wind Scale.

3.4.2 | Previous Occurrences of Hazard Event(s)

There have been 57 hurricanes and tropical storms that have passed within 60 nautical miles of Cambridge between 1851 and 2021. At the time they passed by Cambridge, these storms ranged from extratropical storms, tropical depressions, and tropical storms, all the way to category 1 through category 3 hurricanes.

3.4.2.1. Extent

Table 3.14: Saffir-Simpson Hurricane Wind Scale (National Hurricane Center, NOAA)

Category	Sustained Winds	Types of Damage Due to Hurricane Winds
1	74 - 95 mph	**Very dangerous winds will produce some damage:** Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap, and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96 – 110 mph	**Extremely dangerous winds will cause extensive damage:** Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3	111 – 130 mph	**Devastating damage will occur:** Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4	131 – 155 mph	**Catastrophic damage will occur:** Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5	> 155 mph	**Catastrophic damage will occur:** A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

3.4.2.2. Frequency

According to NOAA's Historical Hurricane Tracks tool, which is a public interactive mapping application that displays Atlantic Basin and East-Central Pacific Basin tropical cyclone data, there are 57 storms (including Extratropical, tropical storms, tropical depression and hurricanes (Category 1 through 5) that have passed within 60 nautical miles of Cambridge between 1858 and 2021 (NOAA, 2023). The tracks of these storms are shown in Figure 3.11. While many of these storms have not been direct hits for the city, some of the worst hurricanes that have impacted the city include Hurricane Bob in 1991; "the twins" from 1954, Hurricanes Carol and Edna; and last but not least, the Great New England Hurricane of 1938 (CZM, 2023). In more recent years, Hurricanes Henri (2021), Hurricane Ida (2021) and Tropical Storm Elsa (2021) have caused significant damage to Cambridge and the surrounding area.

Figure 3-11: Historical Hurricane Tracks followed by storms within 60 nautical miles of Cambridge between 1851 and 2021 (NOAA, 2023)

3.4.2.3. Location

Hurricanes have the potential to impact the entire City of Cambridge. During August 2011, Irene's strong winds swept across Suffolk County, with frequent wind gusts of 35 to 55 mph, along with locally stronger wind gusts exceeding 60 mph. In the case of Hurricane Sandy, the timing meant the difference between millions of dollars of damage, as the storm passed by Boston 5 hours from high tide. A 100-year storm event hitting Boston during the high tide, combined with the 21 inches of sea level rise predicted for Boston by 2050, could result in $444 million in annual damages and could put up to 43,000 Bostonians at risk (City of Boston, 2016a). Since 2012, Massachusetts has experienced impacts from six tropical storms: Arthur, Hermine, Jose, Dorian, Andrea, and Fred.

The hurricane evacuation zone maps published by the Massachusetts Emergency Management Agency (MEMA) provide an indication of the locations of relative flood risk from hurricanes and tropical storms in MA. Figure 3.12 shows the hurricane evacuation zone map for the city of Cambridge. Parts of western Cambridge, including the Alewife area are in Zone A, which includes areas that, depending on predicted inundation, may flood first from storm surge during a tropical storm or hurricane. Parts of eastern Cambridge are in Zone B, which includes areas that would flood after areas in Zone A from storm surge during a tropical storm or hurricane. The cities of Boston and Cambridge have also designated a third zone, Zone C, which may flood depending on the track and intensity of the storm.

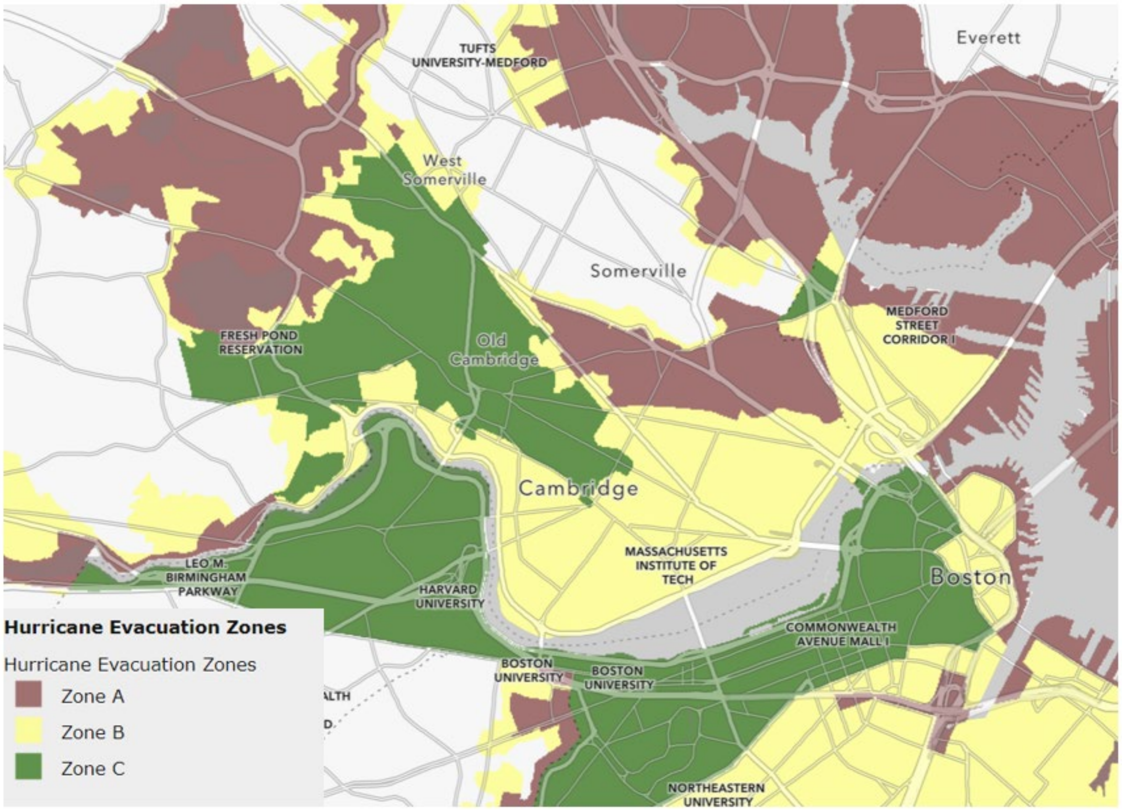


Figure 3-12: Hurricane evacuation zone map for the City of Cambridge (MEMA, mass.gov, 2023)

3.4.3 | Probability of Future Hazard Events due to Climate Change

3.4.3.1. Extent

Climate change will increase the intensity of tropical cyclones including hurricanes, leading to increased precipitation and storm surge in coastal communities (Ellen Douglas, 2022). The frequency of hurricanes is less certain, with some projections indicating a decrease in overall number but an increase in the proportion of the most intense category 4-5 hurricanes. The tracks of hurricanes may also shift northward, potentially making the Northeast more vulnerable to higher intensity storms that could cause a large amount of precipitation.

As a city located near the coast, Cambridge may be particularly vulnerable to the impacts of future hurricanes. Estimated SLR and higher intensity storms coupled with precipitation will likely result in damaging flood within the city during and after hurricanes especially if the rivers overflows their banks or the dams overtop. High winds associated with hurricanes could cause extensive damage to the city including downed trees and branches, structural damage, and power outages. Impacts such as these would leave the city vulnerable if emergency routes became blocked, public transportation was inaccessible, or cell service went down. Damage to infrastructure could leave much of the population with no housing or means of transportation.

To mitigate the potential impacts of future hurricanes, it will be important for the City of Cambridge to implement measures such as improving infrastructure, updating emergency response plans and evacuation routes. It will also be important for individuals and businesses to take steps to prepare for these events, such as developing evacuation plans and ensuring that homes and businesses are protected against flooding.

3.4.3.2. Probability

As cited in the 2022 Climate Change Impacts and Projections for the Greater Boston Area Report, while the overall frequency of hurricanes may remain the same or decrease, the impact of individual storms may increase due to SLR, increased storm surge, wind damage, and extreme precipitation (Ellen Douglas, 2022).

Future flooding impacts from hurricanes and tropical storms combined with sea level rise and storm surge in the coastal areas are included in the Massachusetts Coast Flood Model (MC-FRM) that has been adopted by the City of Cambridge. Based on MC-FRM, both the Amelia Earhart Dam and Charles River Dam are likely to be flanked and overtopped in the future from sea level rise and extreme storms, including hurricanes and tropical storms, which may result in portions of western Cambridge in the Alewife Brook sub-watershed to likely flood between 50 to 70% annual probability by 2070 and portions of eastern Cambridge in the lower Charles River sub-watershed to likely flood between 5 to 10% annual probability by 2070.

3.4.3.3. Location

Future hurricanes are anticipated to impact the entire City of Cambridge. While storm winds have the potential to damage the buildings and infrastructure across the city, flooding will impact primarily the low-lying areas of the city.

3.5. Tornadoes

3.5.1 | Description

Tornadoes are narrow, violently rotating columns of air that extend from the base of a thunderstorm to the ground. These windstorms develop when cool air overlays warm air, causing the warm air to rise rapidly. They are visible when dust and debris are collected in the rotating column.

Components that induce tornado formation include the following, (City of Cambridge & MAPC, 2015),

- 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

3.5.2 | Previous Occurrences of Hazard Event(s)

Table 3.15 indicates the number of tornado events in Middlesex County since 1955 (20 events), as well as their date, severity, direct deaths and injuries from the event, and property damage estimated.

Table 3.15: Tornado Events in Middlesex County, Massachusetts (NCEI NOAA, 2023)

Date	Severity*	Direct Deaths from the Event	Direct Injuries from the Event	Property Damage Estimated
October 24, 1955	EF1	0	0	2.50K
June 19, 1957	EF1	0	0	25.00K
June 19, 1957	EF1	0	0	0.25K
July 11, 1958	EF2	0	0	250.00K
August 25, 1958	EF2	0	0	2.50K
July 3, 1961	EF0	0	0	25.00K
July 18, 1963	EF1	0	0	25.00K
August 28, 1965	EF2	0	0	250.00K
July 11, 1970	EF1	0	0	25.00K
October 3, 1970	EF3	1	0	250.00K
July 1, 1971	EF1	0	1	25.00K
November 7, 1971	EF1	0	0	0.25K
July 21, 1972	EF2	0	4	2.500M
September 29, 1974	EF3	0	1	250.00K
July 18, 1983	EF0	0	0	0.25K
September 27, 1985	EF1	0	0	0.25K
August 7, 1986	EF1	0	0	250.00K
August 22, 2016**	EF1	0	0	1.000M

Date	Severity*	Direct Deaths from the Event	Direct Injuries from the Event	Property Damage Estimated
August 23, 2021	EF0	0	0	8.00K
August 23, 2021	EF0	0	0	2.00K

*Enhanced Fujita (EF) Severity Scale, described below.
**While there has yet to be a tornado that has touched down in Cambridge, the 2016 tornado in Middlesex County hit near the Cambridge Turnpike in Concord, MA, and headed northeast. This tornado caused roughly $1 million in property damages and one house suffered significant structural damage (NOAA NCEI, 2016).

3.5.2.1. Extent

The severity of tornadoes is rated by the National Weather Service (NWS, NOAA) based on 3-second wind gusts and subsequent damage created. Table 3.16 and Table 3.17 describe tornado severity and associated damages for each.

Table 3.16: Enhanced Fujita (EF) Scale for Tornado Damage, (NOAA, n.d.)

Fujita Scale			Derived EF Scale		Operational EF Scale	
F Number	Fastest 1/4-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

Table 3.17: Tornado Damage

Scale	Potential Damage
EF0	**Minor Damage** Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over.

Scale	Potential Damage
	Confirmed tornadoes with no reported damage (i.e., those that remain in open fields) are always: rated EFO.
EF1	**Moderate damage** Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	**Considerable damage** Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
EF3	**Severe damage** Entire stories of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations blown away some distance.
EF4	**Extreme damage to near-total destruction** Well-constructed houses and whole frame houses completely leveled; cars thrown and small missiles generated.
EF5	**Massive Damage** Strong frame houses leveled off foundations and swept away; steel-reinforced concrete structures critically damaged; high-rise buildings have severe structural deformation. Incredible phenomena will occur.

3.5.2.2. Frequency

Massachusetts has experienced approximately 190 tornadoes from 1950 to 2021, resulting in about 2.7 tornadoes ever year. However, there has been an average frequency of 2.1 events per year in the last 20 years (NCEI NOAA, 2023), and Middlesex County recorded 20 tornadoes between 1950 and 2023 (NCEI NOAA, 2023). Tornadoes most commonly occur in the summer months of June through August, forming in the afternoon or evening (City of Cambridge & MAPC, 2015).

This hazard is stated as having a 2-20% chance of occurrence per year, or a once in 5-50 years chance of occurrence (City of Cambridge & MAPC, 2015).

3.5.2.3. Location

Tornadoes are a potential citywide threat to Cambridge. This is a concern as most structures in Cambridge pre-date current building codes and could be subject to damages (City of Cambridge & MAPC, 2015).

3.5.3 | Probability of Future Hazard Events due to Climate Change

3.5.3.1. Extent

Climate change could lead to more frequent and intense tornadoes similar to the trends predicted with severe thunderstorms (EEA & EOPSS, 2018). Tornadoes are short-lived and relatively small-scale weather events, making it challenging to capture them accurately in global climate models. Additionally, tornadoes are influenced by many factors beyond just climate, including local weather patterns, geography, and atmospheric conditions. Therefore, it is difficult to make accurate predictions about the future frequency of tornadoes.

3.5.3.2. Probability

Based on currently available information, it is difficult to predict the probability of tornadoes in the future. However, climate change is expected to increase extreme weather events. Therefore, probability of tornadoes in Cambridge may increase in frequency and intensity under the influence of climate change.

3.5.3.3. Location

Like other severe storms, tornadoes could impact the whole city and its built infrastructure.

3.6. Earthquake

3.6.1 | Description

Earthquakes originate from a vibration in the Earth's surface, that results in a release of energy in the Earth's crust. This causes movement or trembling of the ground. Earthquakes generally occur along fault boundaries but can also be induced within interior portions of a plate. Massachusetts falls on the eastern edge of the North American plate, which is moving due to compressions and squeezing of global plates (EEA & EOPSS, 2018).

In addition to building collapse, earthquakes can cause structural damage to roadways, breakage of water and gas lines, and flooding and fires. Furthermore, landslides can be triggered by earthquakes.

3.6.2 | Previous Occurrences of Hazard Event(s)

Between 1963 and 2023, approximately 76 earthquakes have occurred in Massachusetts (USGS, 2023). Table 3.18 indicates the earthquakes that have occurred in Massachusetts since 1963, their depths (radius of impact), and their magnitudes (Richter Scale) (USGS, 2023). No earthquake has ever been recorded as originating within Cambridge's boundaries.

Table 3.18: Historical Occurrences of Earthquakes in Massachusetts (USGS, 2023).

Date	Magnitude	Location
1963-10-16	3.41	30 km SE of Gloucester, Massachusetts
1963-10-30	2.59	4 km NE of Ipswich, Massachusetts
1974-10-09	1.5	3 km SSE of Hopkinton, Massachusetts
1975-08-03	2.4	1 km SW of Ipswich, Massachusetts
1976-03-14	3	2 km SSW of Chatham, Massachusetts
1976-05-10	2.7	9 km SW of Bliss Corner, Massachusetts
1977-12-20	3.1	7 km NW of White Island Shores, Massachusetts
1978-09-01	2	2 km WSW of Acton, Massachusetts
1980-11-23	2.5	2 km NW of Chelmsford, Massachusetts
1981-09-12	2.1	1 km WNW of Teaticket, Massachusetts
1982-01-27	3	2 km WNW of North Lakeville, Massachusetts
1982-10-27	2.8	46 km E of Rockport, Massachusetts
1982-10-28	2.2	40 km ENE of Rockport, Massachusetts
1982-11-01	2.3	10 km ESE of Green Harbor-Cedar Crest, Massachusetts
1982-11-01	2.2	38 km ENE of Rockport, Massachusetts
1982-11-01	2.6	42 km E of Rockport, Massachusetts
1982-11-09	2.3	4 km N of Petersham, Massachusetts
1985-10-15	3	2 km E of Boxborough, Massachusetts
1989-08-24	3	2 km S of Fairhaven, Massachusetts
1990-01-23	2.5	3 km NNW of Boxborough, Massachusetts
1990-10-11	2.7	5 km NNE of The Pinehills, Massachusetts
1993-07-22	2.1	1 km E of Abington, Massachusetts
1993-07-28	2.3	3 km WNW of Chelmsford, Massachusetts
1994-10-02	3.3	1 km NW of Hardwick, Massachusetts
1994-10-02	3.7	6 km W of Hardwick, Massachusetts
1996-04-22	2.6	3 km NE of North Westport, Massachusetts
1999-10-13	2.7	2 km E of Littleton Common, Massachusetts
2000-06-16	3.3	5 km NE of Granville, Massachusetts
2002-06-07	2.5	3 km NNW of Hopedale, Massachusetts
2003-07-22	2.98	72 km NNE of Provincetown, Massachusetts
2004-02-24	2	8 km SSW of Bliss Corner, Massachusetts
2004-10-08	1.8	3 km SSE of Littleton Common, Massachusetts
2005-04-05	2.23	2 km NNE of Fairhaven, Massachusetts
2005-11-17	2.5	4 km S of Plymouth, Massachusetts
2007-10-08	1.8	2 km SSW of Merrimac, Massachusetts
2007-10-19	2.5	2 km WSW of Littleton Common, Massachusetts
2009-04-10	2.3	2 km ESE of Winthrop, Massachusetts
2011-05-16	2.1	16 km NW of Chilmark, Massachusetts

Date	Magnitude	Location
2012-09-16	2.11	69 km ENE of Rockport, Massachusetts
2012-11-06	1.94	3 km N of Northampton, Massachusetts
2013-02-20	2.3	6 km ESE of Newburyport, Massachusetts
2014-01-09	2.03	2 km SW of Mattapoisett, Massachusetts
2014-02-11	2.23	4 km SW of Mattapoisett, Massachusetts
2014-05-03	1.38	4 km SW of Mattapoisett, Massachusetts
2014-08-18	2	28 km SE of Gloucester, Massachusetts
2015-04-21	1.8	1 km N of Plympton, Massachusetts
2015-11-18	1.5	2 km ESE of Holliston, Massachusetts
2016-02-22	1.3	3 km WNW of Acton, Massachusetts
2016-06-01	2.2	50 km ENE of Rockport, Massachusetts
2017-09-06	1.7	1 km SW of Athol, Massachusetts
2017-10-01	1.6	1 km N of Fairhaven, Massachusetts
2017-11-28	1.6	1 km SW of Boxborough, Massachusetts
2018-06-25	1.4	2 km ENE of Franklin, Massachusetts
2018-12-21	1.4	3 km WNW of Gardner, Massachusetts
2018-12-21	2.1	3 km NNE of Templeton, Massachusetts
2018-12-23	2.2	2 km W of Gardner, Massachusetts
2019-01-26	0.9	2 km S of Boxborough, Massachusetts
2019-01-28	1.6	3 km ESE of Baldwinville, Massachusetts
2019-02-08	1.4	7 km E of Nahant, Massachusetts
2019-02-18	1.1	3 km ESE of Boxborough, Massachusetts
2019-04-22	1.7	19 km SSE of Gloucester, Massachusetts
2019-04-27	2.1	27 km NE of Rockport, Massachusetts
2019-07-01	1.5	27 km SE of Gloucester, Massachusetts
2019-08-21	1.7	0 km S of Onset, Massachusetts
2019-10-26	1.3	4 km ESE of Essex, Massachusetts
2019-12-03	2.1	1 km W of North Plymouth, Massachusetts
2020-07-24	2.1	16 km ENE of Edgartown, Massachusetts
2020-11-08	3.6	10 km S of Bliss Corner, Massachusetts
2020-11-22	2	9 km SSW of Bliss Corner, Massachusetts
2021-07-25	1.4	2 km N of South Peabody, Massachusetts
2021-08-04	1.2	1 km NE of Peabody, Massachusetts
2021-08-18	1.3	0 km ESE of Peabody, Massachusetts
2022-01-01	2	15 km N of Rockport, Massachusetts
2022-03-04	2.2	2 km SSE of Erving, Massachusetts
2022-09-24	1.8	1 km S of Boxborough, Massachusetts
2022-11-05	2.1	5 km NNW of Nantucket, Massachusetts

3.6.2.1. Extent

To measure the magnitude and intensity of an earthquake, the Richter Magnitude Scale and the Modified Mercalli Intensity scale are used (refer to Table 3.19 and 3.20).

Table 3.19: Richter Magnitude Scale & Subsequent Effects (City of Cambridge & MAPC, 2015).

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

Table 3.20: Modified Mercalli Intensity Scale (USGS, n.d.)

Intensity	Shaking	Description/Damage
I	Not Felt	Not felt except by very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings.
FIV	Light	Felt indoors by many, outdoors by few during the day. At night some awakened. Dishes, windows, doors disturbed, walls make cracking sounds.
V	Moderate	Felt by nearly everyone, many awakened. Unstable objects overturned.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved. Damage slight.

Intensity	Shaking	Description/Damage
VII	Very Strong	Damage negligible in buildings of good design and construction, slight to moderate in well-built structures, considerable damage in poorly built.
VIII	Severe	Damage slight in specially designed structures, considerable damage and partial collapse in standard buildings. Damage great in poorly built structures
IX	Violent	Damage considerable in specially designed structures. Damage great in substantial buildings with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed, most masonry and frame structures destroyed with foundations. Rails bent.

3.6.2.2. Frequency

The 2018 State Hazard Mitigation and Climate Adaptation Plan states that there is about a 10-15% chance, over a ten-year period, that a magnitude 5.0 or greater earthquake could occur somewhere in New England (EEA & EOPSS, 2018). The 2018 State Hazard Mitigation and Climate Adaptation Plan further states that earthquake events occur with a 1-2% chance of occurrence per year, or once in 50-100 years.

Based on the USGS 2014 Massachusetts Seismic Hazard map (Figure 3.13), Cambridge is also stated to have an earthquake peak ground acceleration (PGA) that has a 2% chance of being exceeded in 50 years, has a value between 14-20 %g (%g: percent of gravity (or, percentage of the force we experience from gravity) (USGS, n.d.).

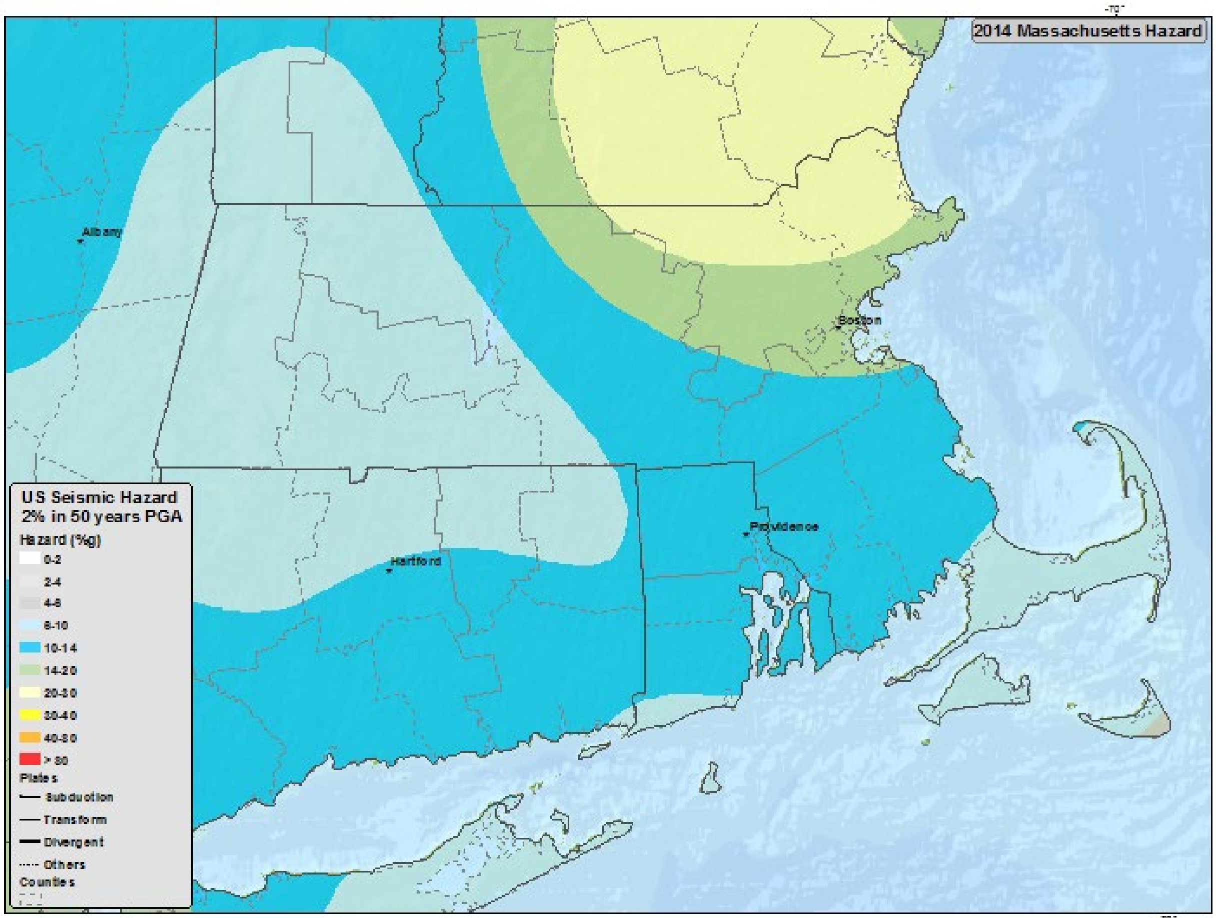


Figure 3-13. 2014 Massachusetts Seismic Hazard, (USGS, n.d.)

3.6.2.3. Location

Earthquakes are expected to be a citywide hazard event for Cambridge. However, certain areas of the city are more susceptible to damages and liquefaction than others. Liquefaction is when loosely packed, water-logged sediments lose strength and shift in large masses. Portions of Cambridge, particularly the southern end along the Charles River, were built on non-engineered artificial fill. Other sections of the city subsist on glacial outwash or glacial till. Both these soil types are highly susceptible to liquefaction, which can be triggered with an earthquake magnitude of 5.0 or greater. Figure 3.13 and Figure 3.14 depict the current geology and liquefaction potential.

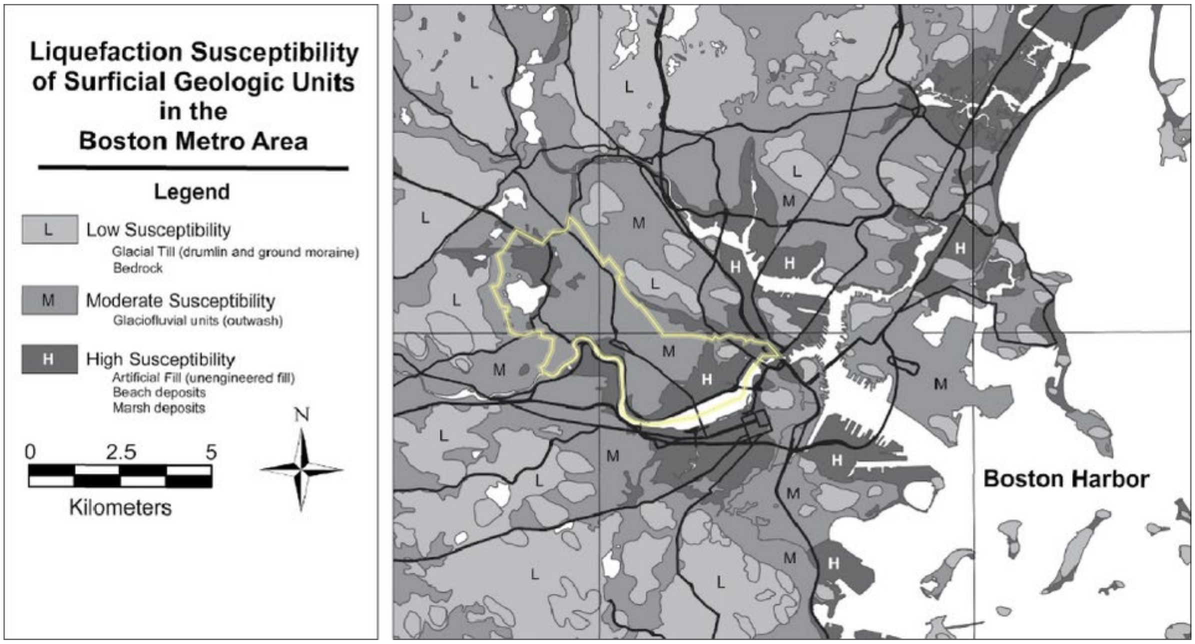


Figure 3-14. Boston Study Region Liquefaction Potential (City of Cambridge & MAPC, 2015)

3.6.3 | Probability of Future Hazard Events due to Climate Change

3.6.3.1. Extent

Earthquakes are natural hazards that can occur at any time and without warning. While it is not possible to predict exactly when and where an earthquake will occur, scientists can estimate the probability of earthquake occurrences based on historical data and geological studies. According to (NASA, 2019), "induced seismicity" can occur as a result of human water usage, which causes changes in water levels at fault lines. This phenomenon has been observed in the vicinity of dams in the United States, particularly when there are rapid fluctuations in the water level behind the dam.

3.6.3.2. Probability

Although earthquakes cannot be predicted, the USGS 2014 Seismic Hazard Map helps identifying areas that are more likely to experience earthquakes. For Cambridge, the map predicts moderate peak gravity acceleration of 14 to 20 percent (Figure 3.13).

3.6.3.3. Location

Earthquakes will impact the entire city . Areas with soft soils or loose sediments and buildings with weak foundation and poor seismic design are more vulnerable to earthquake damage due to their tendency to amplify seismic waves.

3.7. Landslides

3.7.1 | Description

The U.S. Geological Survey describes landslides as including, “a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows.” While gravity is a primary instigator for a steepened slope becoming a landslide, other contributing factors exist. When sloped material is subject to heavy rainfall or over-saturates in another way, debris or mud may flow. The resultant flow can be dangerous to trees, houses, cars, and built infrastructure. This effect can be exacerbated when erosion from rivers, glaciers, or waves create over steepened slopes.

3.7.2 | Previous Occurrences of Hazard Event(s)

There are no documented previous occurrences of landslides in Cambridge.

3.7.2.1. Extent

Landslides are measured in terms of intensity and velocity. Factors of landslide vulnerability include location, type of human activity, use, and frequency of landslides. Hazards can be reduced by avoiding construction on steep slopes and in locations of existing or known landslides, or by first stabilizing these slopes. Refer to the table below for a description of the resultant volume of moving land from the two qualitative measurements. This table can clarify the consequential destructiveness of a landslide based on the aforementioned characteristics.

Table 3.21: Landslide Measurement of Volume and Velocity (Cardinali et al., 2002)

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

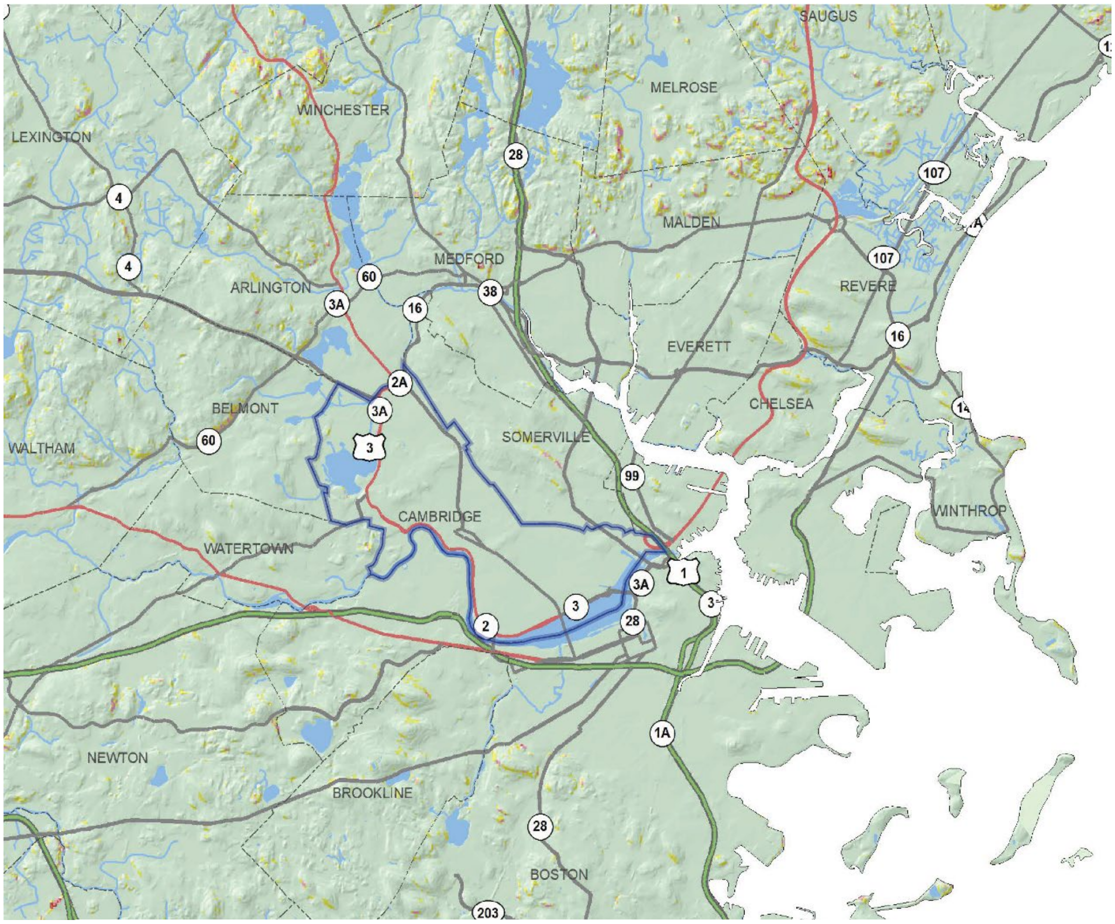
Estimated Volume (m^3)	Expected Landslide Velocity		
	Fast Moving (Rock Fall)	Rapid Moving (Debris Flow)	Slow Moving (Slide)
>500,000	-	Very High Intensity	High Intensity
>>500,000	-	-	Very High Intensity

3.7.2.2. Frequency

Due to the lack of previous occurrences in Cambridge, landslides have a very low frequency of occurrence. It is estimated that these events can occur less than 1% per year.

3.7.2.3. Location

Landslides have the potential to be a citywide hazard event, although the overall flat topography of the city is generally not conducive for a landslide to occur. It is likely that if a landslide were to occur in Cambridge, it would occur as a slow-moving slide rather than a fast moving rock fall. As evident in Figure 3.15 below, the City of Cambridge is classified as the green, stable area, with a very low relative slide ranking.



Map Color Code	Predicted Stability Zone	Relative Slide Ranking[1]	Stability Index Range[2]	Factor of Safety (FS)[3]	Probability of Instability[4]	Predicted Stability With Parameter Ranges Used in Analysis	Possible Influence of Stabilizing or Destabilizing Factors[5]
	Unstable	High	0	Maximum FS<1	100%	Range cannot model stability	Stabilizing factors required for stability
	Upper Threshold of Instability		0 - 0.5	>50% of FS1	>50%	Optimistic half of range required for stability	Stabilizing factors may be responsible for stability
	Lower Threshold of Instability	Moderate	0.5 - 1	≥50% of FS>1	<50%	Pessimistic half of range required for instability	Destabilizing factors are not required for instability
	Nominally Stable	Low	1 - 1.25	Minimum FS=1	_	Cannot model instability with most conservative parameters specified	Minor destabilizing factors could lead to instability
	Moderately Stable		1.25 - 1.5	Minimum FS=1.25	_	Cannot model instability with most conservative parameters specified	Moderate destabilizing factors are required for instability
	Stable	Very Low	>1.5	Minimum FS=1.5	_	Cannot model instability with most conservative parameters specified	Significant destabilizing factors are required for instability

Figure 3-15. Slope Stability Map and Legend of Northeastern Massachusetts, Focusing on Cambridge (Massachusetts Geological Survey, UMass Amherst, 2013)

[1]Relative Slide Ranking - This column designates the relative hazard ranking for the initiation of shallow slides on unmodified slopes.

[2]Stability Index Range - The stability index is a numerical representation of the relative hazard for shallow translational slope movement initiation based on the factors of safety computed at each point on a 9 meter (~30 foot) digital elevation model grid derived from the National Elevation Dataset. The stability index is a dimensionless number based

on factors of safety generated by SINMAP that indicates the probability that a location is stable considering the most and least favorable parameters for stability input into the model. The breaks in the ranges of values for the stability index categories are the default values recommended by the program developers.

[3]Factors of Safety - The factor of safety is a dimensionless number computed by SINMAP using a modified version of the infinite slope equation that represents the ratio of the stabilizing forces that resist slope movement to destabilizing forces that drive slope movement (Pack et al., 2001). A FS>1 indicates a stable slope, a FS<1 indicates an unstable slope, and a FS=1 indicates the marginally stable situation where the resisting forces and driving forces are in balance.

[4]Probability of Instability - This column shows the likelihood that the factor of safety computed within this map unit is less than one (FS<1, i.e., unstable) given the range of parameters used in the analysis. For example, a <50% probability of instability means that a location is more likely to be stable than unstable given the range of parameters used in the analysis.

[5]Possible Influence of Stabilizing and Destabilizing Factors - Stabilizing factors include increased soil strength, root strength, or improved drainage. Destabilizing factors include increased wetness or loading, or loss of root strength.

3.7.3 | Probability of Future Hazard Events due to Climate Change

3.7.3.1. Extent

Climate change may lead to an increase in the frequency and severity of rainfall events, which could cause soil saturation and erosion, potentially triggering landslide events (Gariano, 2016). Furthermore, rapid snow melt and rain-on-snow events can also increase the risk of landslides.

3.7.3.2. Probability

Although Cambridge has a low frequency of landslides occurrence, climate change may increase the likelihood of landslides in the area due to more frequent and intense storms, reduced vegetation cover resulting from increased drought events, or increased urbanization.

3.7.3.3. Location

Landslides will be a citywide phenomenon particularly areas with low vegetation will likely to be most affected by potential landslides. As can be seen in Figure 3.16 above, all of Cambridge has a very low risk for landslides.

3.8. Tsunami

3.8.1 | Description

A tsunami is a devastating onshore surge of water or a string of waves created by the displacement of a large volume of water (EEA & EOPSS, 2018). A tsunami may form following an earthquake or volcanic activity occurring below or near the ocean floor, but can also be caused by landslides, glacier calving, and meteorite impacts. Tsunamis can move hundreds of miles per hour (mph) in the open ocean and can come ashore with waves as high as 100 feet or more (EEA & EOPSS, 2018). As they approach shallower water and land, tsunamis are often no more than 10 ft in height, and slow to speeds of 20 to 30 mph (NOAA, 2018).

The previous Cambridge Hazard Mitigation Plan 2015 Update did not include mention of tsunamis, likely due to the rarity of occurrence for the city, as the city is located inland of direct coastal exposure.

3.8.2 | Previous Occurrences of Hazard Event(s)

Research conducted by NOAA and USGS, for the United States and Territories National Tsunami Hazard Assessment, Historical Record and Sources for Waves – Update, indicates that there have been two occurrences of a tsunami in Massachusetts: one of an undetermined height and one with wave runup between 0.01 and 0.3 meters. The report indicates the runup event was earthquake-triggered (NOAA & USGS, 2015). There is no documentation that these events affected the City of Cambridge.

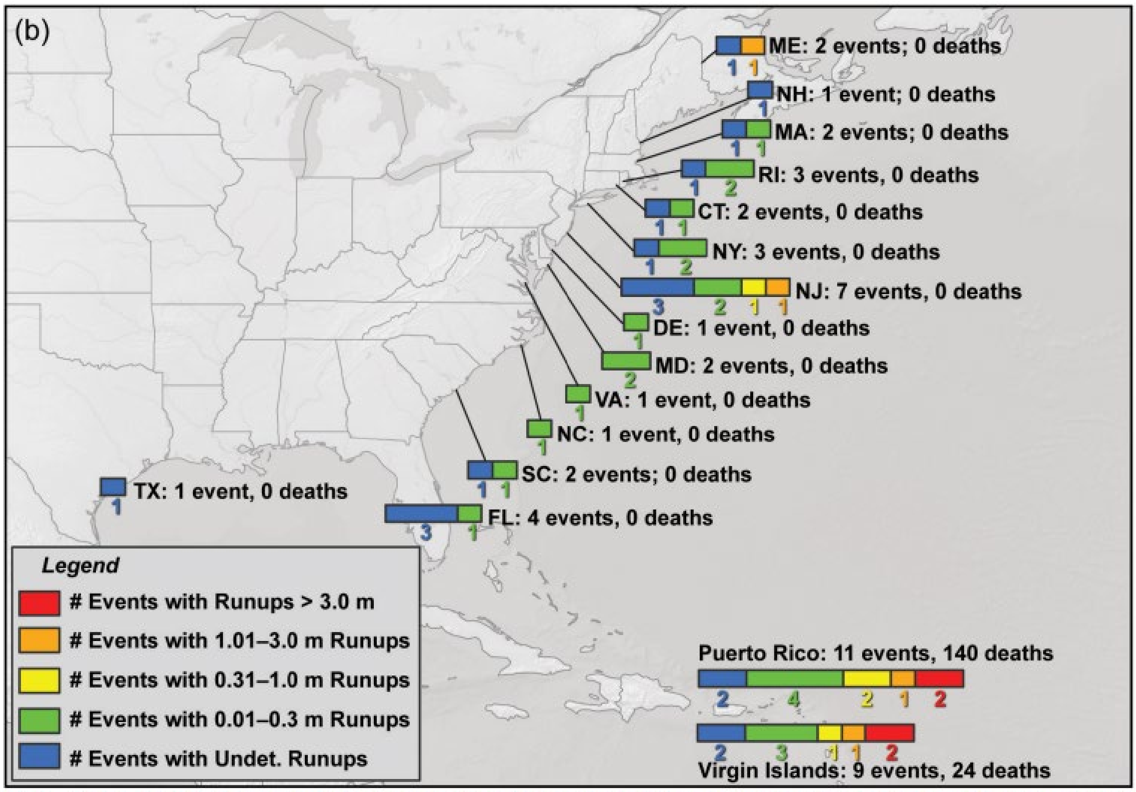


Figure 2-4. Maps showing total number of tsunami events, total number of events causing runup heights from 0.01 m to >3.0 m, and total deaths due to tsunamis for U.S. states and territories in the (a) Pacific Ocean and (b) Atlantic Ocean. (Note: Bar scales in (a) and (b) are not the same.)

Figure 3-16: Runup events along the East Coast of the U.S. (NOAA & USGS, 2015)

3.8.2.1. Extent

The severity of these two occurrences in Massachusetts were minimal, with no reported deaths or damages (NOAA & USGS, 2015). There has been no threat of a significant tsunami for the coast of Massachusetts in recent history (EEA & EOPSS, 2018).

3.8.2.2. Frequency

The frequency of occurrence of a tsunami in Massachusetts is 1 event every 39 years (EEA & EOPSS, 2018), with 0.01 total events per year and all tsunami runups of less than 1.0 m (NOAA & USGS, 2015).

3.8.2.3. Location

If a tsunami were to occur, the geographic location of the tsunami could potentially result in an impact to a significant part of the city, depending on the runup (NOAA & USGS, 2015). It is more likely that locations within Cambridge likely to experience coastal flooding will be the area impacted.

3.8.3 | Probability of Future Hazard Events due to Climate Change

3.8.3.1. Extent

Natural disasters such as earthquakes, volcanic activity, and landslides can trigger tsunamis. As a result of melting ice and collapsing glaciers, earthquakes, landslides, and submarine landslides are expected to increase, potentially leading to more frequent or stronger tsunamis. Additionally, isotonic rebound and glacier earthquakes caused by a warmer climate could trigger additional tsunamis in the future (EEA & EOPSS, 2018). Currently, there is no information available about the likelihood of a destructive tsunami occurring along the Massachusetts coastline. The existence of two dams may protect Cambridge from some coastal impacts, including the potential to lessen damage from a tsunami. However, the extent of damage would be dependent on the magnitude of the tsunami.

3.8.3.2. Probability

Given the infrequency of tsunami occurrences along the East Coast, the probability of tsunamis affecting Cambridge is very low.

3.8.3.3. Location

Depending on the magnitude of a tsunami, it could have the potential to impact all of Cambridge, or locations within Cambridge likely to experience coastal flooding.

3.9. Extreme Temperatures

3.9.1 | Description

Temperatures are considered extreme when they extend outside of the typical range of average conditions for acute or prolonged periods of time. Extremes can vary seasonally and occur in the form of either extreme cold or extreme heat. These temperature extremes can affect everyday life for the city and its residents. Hazard events can trigger issues for public and environmental health, economic activities, electrical grids, and reliable transportation. While Massachusetts has a climate of four well-defined seasons with varying temperature averages, extremes outside of these seasonal fluctuations can cause major problems for the city.

3.9.2 | Previous Occurrences of Hazard Event(s)

3.9.2.1. Extreme Heat

Table 3.22 below summarizes some of the annual average and extreme heat parameters for the City of Cambridge.

Table 3.22: Annual Temperatures for the City of Cambridge (City of Cambridge, 2015)

Temperature Changes	Baseline (1971-2000)
Annual Temperature (°F)	50
Summer Temperature (°F)	70.6
Days > 90°F (days/year)	11
Days > 100°F (days/year)	<1
Heat Index (°F)	85

The NWS issues a Heat Advisory when the maximum heat index temperature is expected to be 100° or higher for at least 2 days, and night time air temperatures will not drop below 75°. The NWS issues an Excessive Heat Warning when the maximum heat index temperature is expected to be 105° or higher for at least 2 days and night time air temperatures will not drop below 75°. According to the NOAA Storm Events Database (NOAA, Storms Event Database, 2023), there have been 22 heat events reported between 2016 and 2022, and 10 excessive heat events reported in the same time period.

3.9.2.2. Extreme Cold

Table 3.23 below summarizes the annual average and extreme cold parameters for the City of Cambridge.

Table 3.23: Annual Temperatures for the City of Cambridge (City of Cambridge, 2015)

Temperature Changes	Baseline (1971-2000)
Annual Temperature (°F)	50
Winter Temperature (°F)	29.8
Days < 32°F (days/year)	145
Days < 0°F (days/year)	6
Heat Index (°F)	85

An average of 1.5 extreme cold weather events per year have occurred over the last two decades. Between 1994 and 2018, there were 33 cold weather events within the Commonwealth.

3.9.2.3. Extent

Extreme Heat

Relative humidity can worsen human health effects as temperatures increase. The extent of extreme heat temperatures is generally measured through the NWS Heat Index, which is based both on temperature and relative humidity, and describes a temperature equivalent to what a person would feel at a baseline humidity level. Figure 3.19 presents the heat index chart as published by NOAA National Weather Service. Understanding this relationship is helpful for measuring or predicting the impact of high temperatures and humidity on human health. Often coined the "feels like" temperature, the heat index is an indicator of heat stress on the human body.

NWS Heat Index — Temperature (°F)

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

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Classification	Heat Index	Effect on the body
Caution	80°F - 90°F	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution	90°F - 103°F	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
Danger	103°F - 124°F	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger	125°F or higher	Heat stroke highly likely

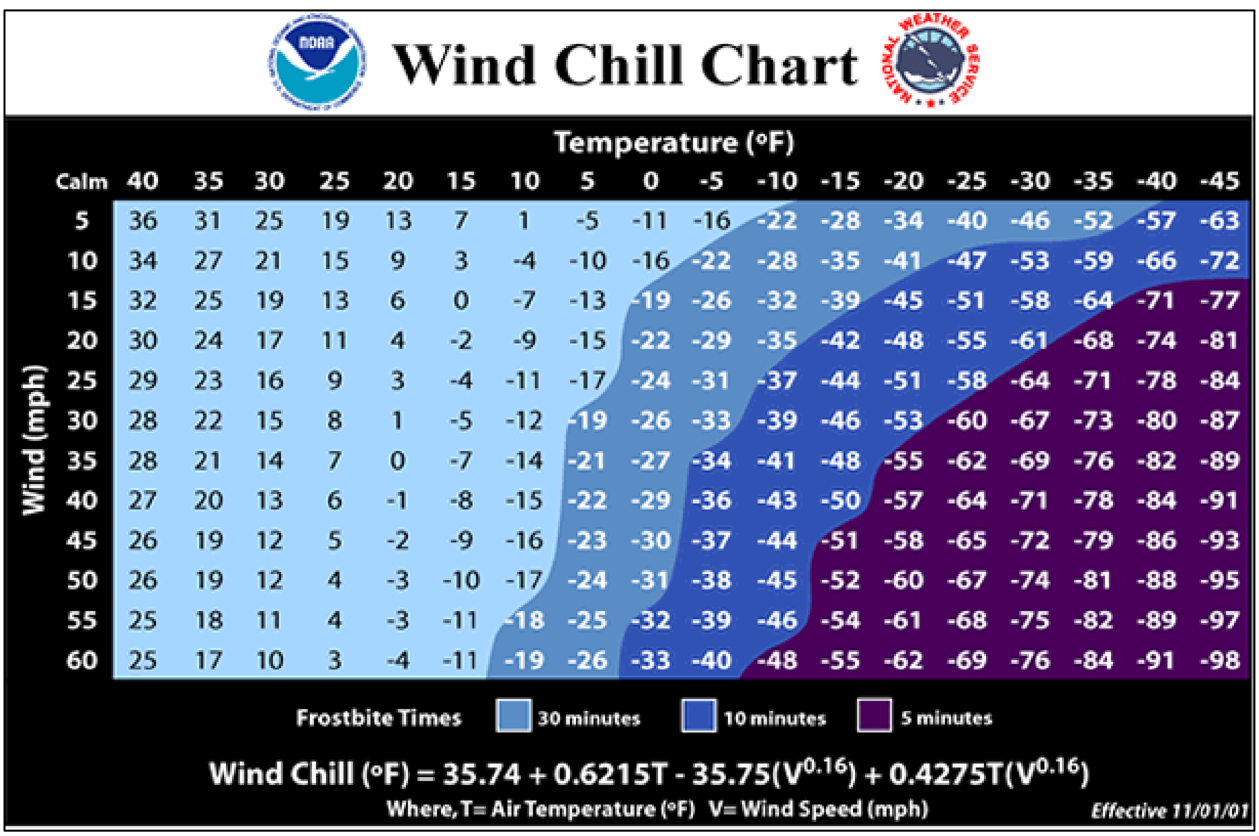
Figure 3-17. National Weather Service Heat Index (NWS NOAA)

Heat wave is an extreme heat phenomenon that affects the city. Heat waves are identifiable as 3 or more consecutive days when maximum temperatures greater than 90°F occur. This implies that there is an extended period of unusually high temperatures, causing stress on everyday operations and physical health (EEA & EOPSS, 2018).

Another extreme heat phenomenon that is relevant for the City of Cambridge is the urban heat island (UHI) effect. The term "heat island" describes built-up areas that are hotter than nearby rural or shaded areas. An urban environment like the city also exacerbate the effects of extreme heat through the presence of impervious surfaces. Increased tree canopy and other engineered green infrastructure solutions, such as bioretention basins, rain gardens, green roofs, and highly reflective surfaces, as well as built shade structures have the potential to reduce the UHI effect in Cambridge. The city's UHI provides additional detail.

Extreme Cold

Extreme cold temperatures can be exacerbated by factors such as wind and relative humidity. The extent of extreme cold temperatures is generally measured through the Wind Chill Temperature Index, and Figure 3.18 shows the Wind Chill Temperature Index. As evident from the figure, temperatures can feel colder and cause more damage to human health as wind speeds increase. Wind Chill Temperature is the temperature that people and animals feel when they are outside, and it is based on the rate of heat loss from exposed skin by the effects of wind and cold. As wind increases, the body loses heat at a faster rate, causing the skin's temperature to drop. The NWS issues a Wind Chill Advisory if the Wind Chill Index is forecast to dip to –15°F to – 24°F for at least 3 hours, based on sustained winds (not gusts). For example, frostbite can occur in 30 minutes at warmer than usual temperatures if wind speeds are greater.



Wind Chill Chart

Temperature (°F)

Wind (mph) / Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes | 10 minutes | 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Figure 3-18: National Weather Service Wind Chill Chart (NWS NOAA, 2001)

3.9.2.4. Frequency

Extreme Heat

The 2018 SHMCAP states that two extreme hot weather events have occurred annually in Massachusetts (EEA & EOPSS, 2018). Additionally, from 1971 to 2000, there have historically been an average of 11 days per year over 90^{O} F, and only one day over 100^{O} F every seven years or so (City of Cambridge and ATMOS, 2015). In 2022, the hottest 30 day stretch on record was recorded in the Boston metro area with over 26 days of temperatures over the 80^{O} F (Epstein, 2022).

Extreme Cold

The 2018 SHMCAP states that 1.5 extreme cold weather events have occurred annually in Massachusetts (EEA & EOPSS, 2018).

3.9.2.5. Location

Extreme Heat

Extreme heat is often more extreme in concentrated parts of the city that have less tree canopy, more pavement, and dark surfaces such a roofs that absorb more heat, as evident in Figure 3.20 and Figure 3.21.

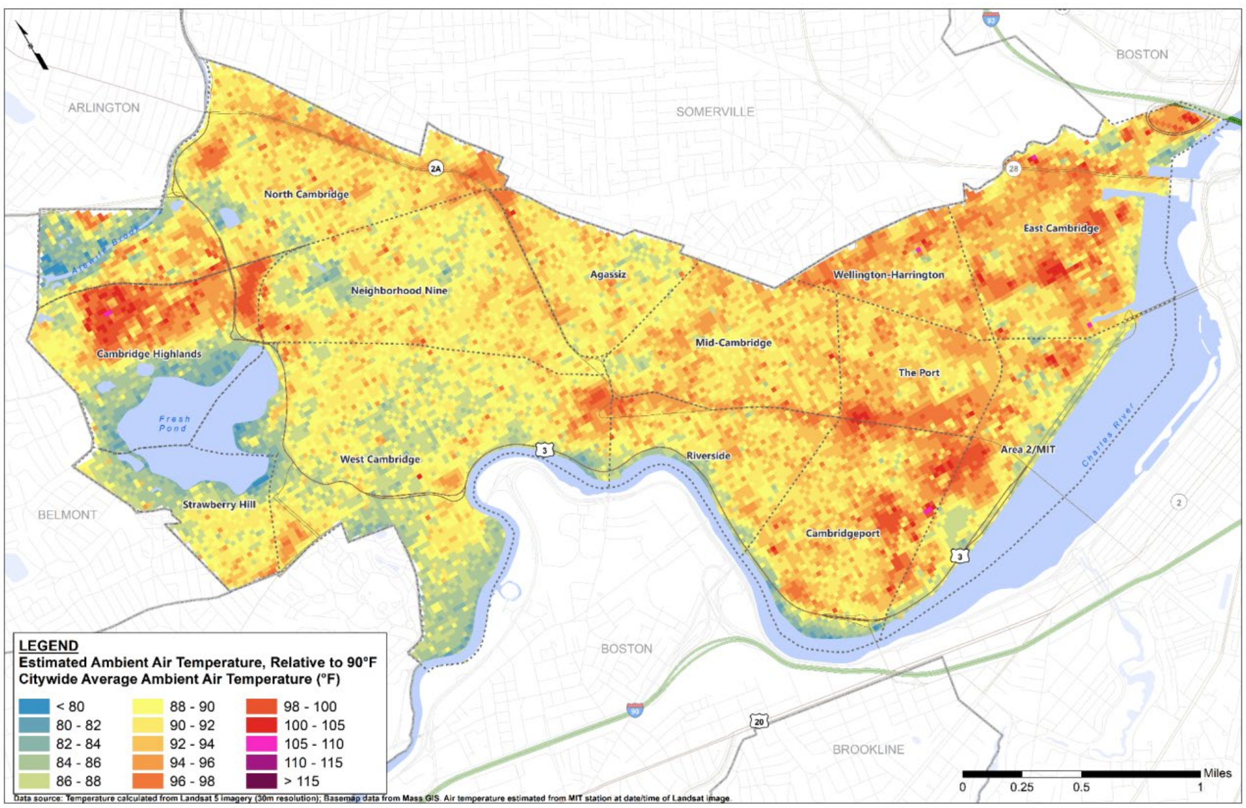


Figure 3-19. Estimated Ambient Air Temperature Relative to 90 °F under 2018 canopy, impervious surface and cool roof conditions (City of Cambridge, 2022)

A critical measure for temperature is the heat index, which combines ambient air temperature and relative humidity to determine the "feels-like" or the human-perceived temperature. Heat index is a key indicator for reporting public health concerns since heat index exceeding 91°F is considered to be in the "extreme caution" zone from prolonged exposure to heat or strenuous activity.

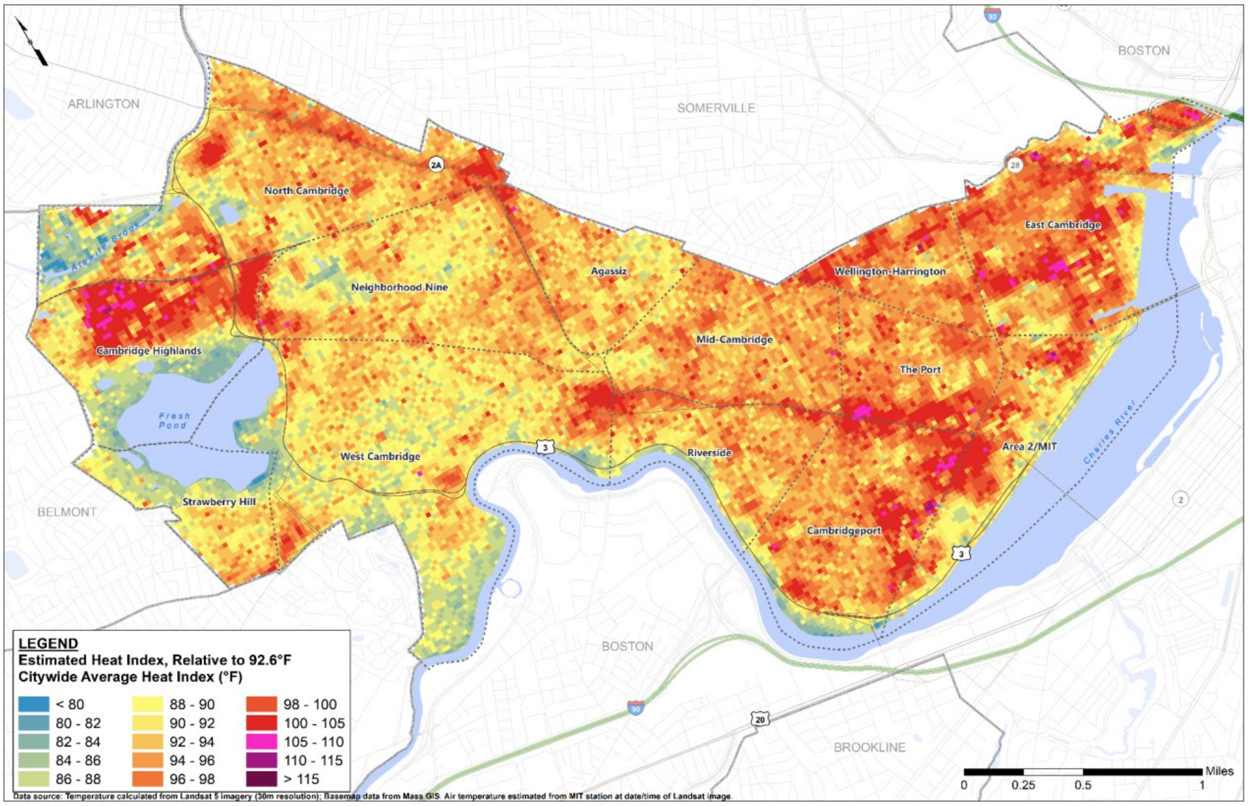


Figure 3-20. Estimated Heat Index Relative to 93°F under 2018 canopy, impervious surface and cool roof conditions (City of Cambridge, 2022)

Extreme Cold

Extreme cold can occur city-wide. Extreme cold can disproportionately affect priority community members through the city, especially for people without shelter, those who are stranded, and those who live in home that are poorly insulated or without heat.

3.9.3 | Probability of Future Hazard Events due to Climate Change

3.9.3.1. Extent

Extreme Heat

Based on all the recently published reports (IPCC, MA Climate Assessment, GBRAG) temperatures will continue to increase through the 21st century. Summers are expected to get hotter with a higher number of days with maximum temperature above 90°F and above 100°F.

The following figure (Figure 3.22) shows the future warming scenarios from Cambridge CCVA (City of Cambridge and ATMOS, 2015). As shown in the report, annual average temperatures and winter temperature are projected to increase by 8°F, whereas summer temperature is estimated to increase up to 10°F by 2070 under high emission scenarios. Both the number of days above 90°F and 100°F are estimated to increase considerably by 2070. Summer temperature is estimated to increase up to 10°F by 2070 under high emission scenarios. The graphic from CCVA report (Figure 3.22) shows the relative changes in high heat days over the three-month summer period (June, July, August) in the future. As depicted in the figure, if the warmest days of the year only occurred during the summer months of June through August, it is possible that temperatures in Cambridge could surpass 90°F for majority of the summer.

Figure 31 shows baseline and projected temperature of Cambridge (City of Cambridge and ATMOS, 2015).

Temperature Changes	**Baseline**	**2030s (2015-2044)**		**2070s (2055-2084)**	
	1971-2000	**Lower**	**Higher**	**Lower**	**Higher**
Annual Temperature (°F)	50	53.3	53.5	55.8	58.7
Summer Temperature (°F)	70.6	74.5	74.8	77.4	80.6
Winter Temperature (°F)	29.8	32.2	33	34.6	38
Days > 90°F (days/year)	11	29	31	47	68
Days > 100°F (days/year)	<1	2	2	6	16
Heat Index (°F)	85	94.75	96	101	115.5

Figure 3-21: Baseline and projected temperature of Cambridge

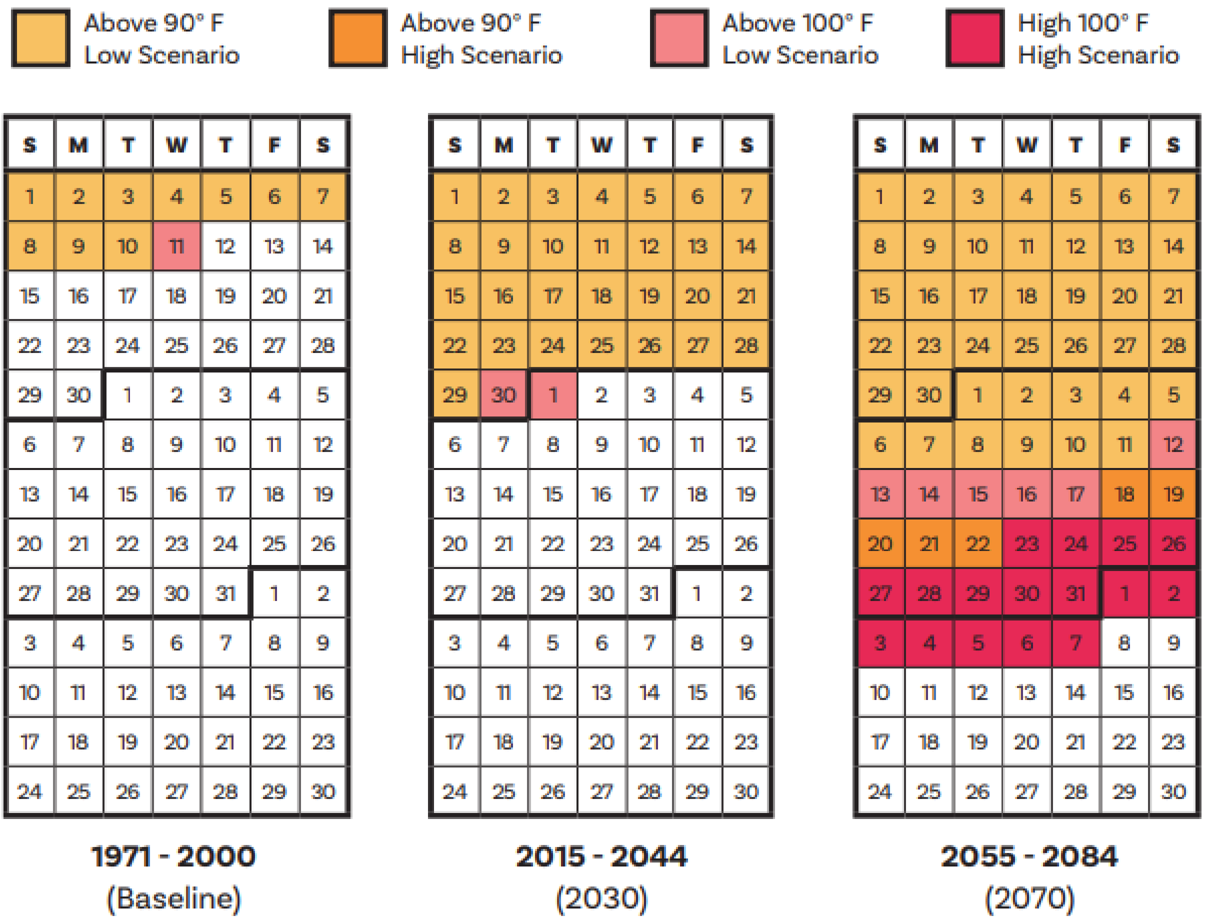


Figure 3-22: Relative increase in projected days above 90F and 100F over a three-month period as shown in Cambridge CCVA (City of Cambridge and ATMOS, 2015)

The state has recently published updated climate projections in ResilientMA ((MA EOEEA, 2021) from MA EEA's Climate and Hydrologic Risk Project (Phase 1). The projections in ResilientMA are based on higher emission scenario (RCP8.5) and the data is available at the HUC-8 basin scale. The updated numbers are reported in Table 3.23 for heat related climate parameters for the Charles River Basin. The inference from the data still remains the same as the CCVA report namely that the annual, summer, and winter average temperatures are estimated to increase by the end of the century. Summer is anticipated to be hotter by up to 39 more number of days above 90°F by 2070.

Additionally, updated viewer also provide data of heat stress events which is defined as a number of instances when a 3-day moving average of temperature is above 86 °F (MA EOEEA, 2021). Heat stress event is an indicator of extreme heat events that cause heat-related illnesses (Department of Health, New York State, 2020). Number of heat stress events is projected to increase up to 6 events per year by 2070 and 11 events per year by 2090. The impact of heat stress will be more pronounced in cities like Cambridge where built infrastructure dominates the landscape and lower amounts of shade is available.

Table 3.24: Projected changes in temperature parameters from baseline as reported in ResilientMA

Heat Parameters	**Baseline** (1971-2000)	**2030** (2020-2049)	**2050** (2040-2069)	**2070** (2060-2089)	**2090** (2080-2099)
	Higher Emission Scenario (RCP8.5)				
Annual Average Temperature (°F)	50.4	3.6	5.4	8.1	9.9
Summer Average Temperature (°F)	69.6	3.6	5.4	8.1	9.9
Winter Average Temperature (°F)	30.6	3.6	6.3	8.1	9.9
Days above 90°F (days/year)	8	12	21	39	52
Days above 95°F (days/year)	1	4	8	17	25
Days above 100°F (days/year)	0	0	1	4	8
Days below 32°F (days/year)	120	-28	-41	-57	-65
Number of heat stress events (events/year)	0	1	2	6	11

Extreme Cold

In Massachusetts, the winters are projected to get warmer with a smaller number of sub-zero days. As shown in Figure 3.22 above, annual average temperatures and winter temperatures are projected to increase by 8°F. The winter is estimated to become warmer, and we may see up to 57 fewer days below sub-zero.

3.9.3.2. Probability

Extreme Heat

Extreme heat is highly probable to impact the city in the future. The urban environment of Cambridge with higher impervious surfaces and lower canopy coverage and shade structures is particularly responsible for high heat impacts.

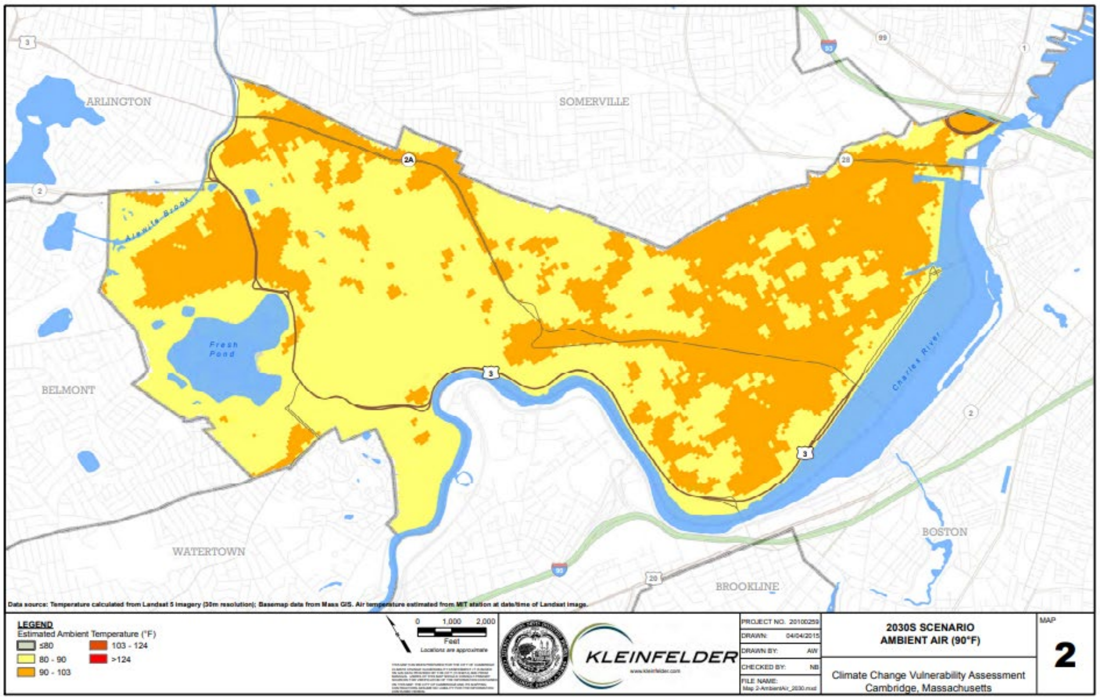
Extreme Cold

Although extreme cold weather events are predicted to decrease in frequency, the city should remained prepared to respond to these events.

3.9.3.3. Location

Extreme Heat

Although high heat is anticipated to impact the entire City of Cambridge, parts of the city are more vulnerable than others. Figure 3.23 (top) shows the urban heat island (UHI) variability in the city when the average temperature for that day is 95ºF, which is a scenario that is likely to occur more frequently by 2030 and 2050. Figure 3.23 (bottom) also shows the UHI variability in the city when the average temperature for that day is 100ºF, which is a scenario that is likely to occur more frequently by 2070 and 2090 (City of Cambridge, 2015). As illustrated in the figures, the heat impacts will be more concentrated in the NW and SE corners of the city.



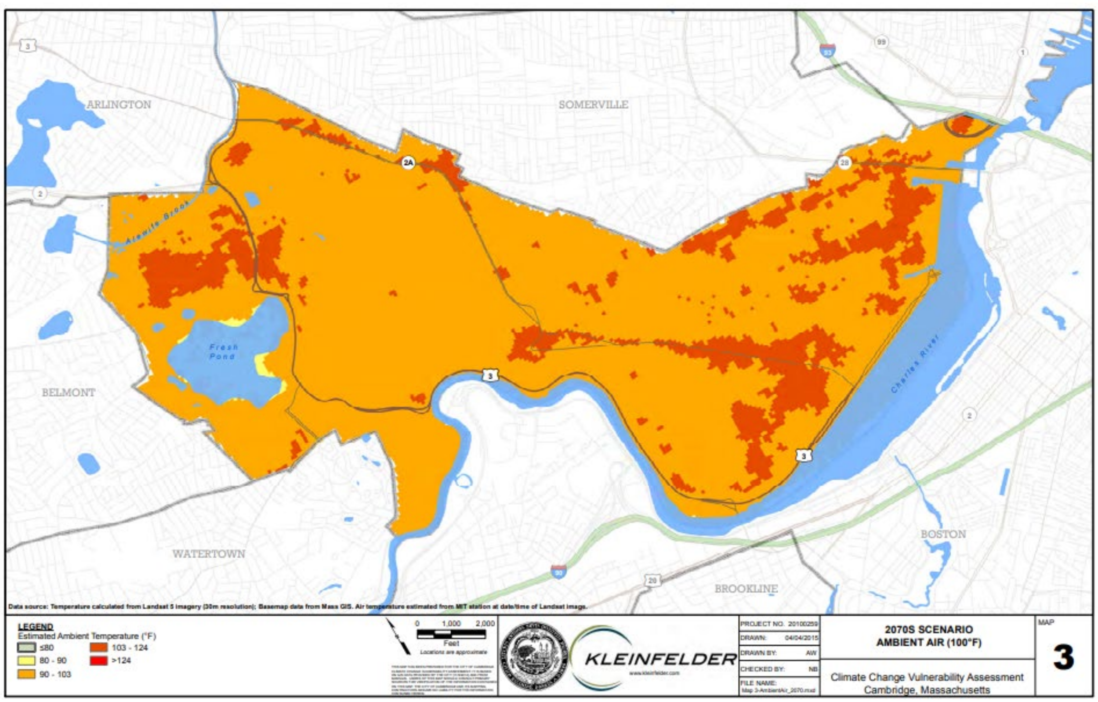


Figure 3-23: Projected future ambient temperature by 2030 (at 90°F) and by 2070 (at 100°F) (City of Cambridge, 2015)

Extreme Cold

Extreme cold weather events are predicted to impact Cambridge city-wide when they occur in the future. Those unable to find shelter, with inadequate or no heating sources, and additional priority populations are located all over the city and are all highly vulnerable to impacts of extreme cold.

3.10. Drought

3.10.1 | Description

Drought is an extended duration of time characterized by below normal levels of precipitation. The duration of drought can vary widely and can occur in virtually all climatic zones, with different conditions based on the region-specific precipitation normals. Drought differs from aridity, in which a region experiences low precipitation as a typical or permanent characteristic of the climate (i.e., a desert).

Drought is classified in Massachusetts by the Secretary of Energy and Environmental Affairs (EEA), through recommendations provided by the Drought Management Task Force (DMTF). The DMTF is comprised of members of EEA and the Massachusetts Emergency Management Agency (MEMA). The DMTF gathers information about current drought conditions, makes recommendations to governing officials, and manages responses. To aid in understanding and disseminating information about drought across the State, the Massachusetts Drought Management Plan (MA DMP) was adopted in September 2019. The plan states that its goal is to "minimize drought impacts to the Commonwealth by improving agency coordination; enhancing monitoring and early drought warning capabilities; and outlining preparedness, response, and recovery activities for state agencies, local communities, and other entities affected by drought" (EEA & MEMA, 2019).

3.10.2 | Previous Occurrences of Hazard Event(s)

3.10.2.1. Extent

The MA DMP classifies drought into five levels, based on six drought indices.

FIVE DROUGHT LEVELS	SIX DROUGHT INDICES
LEVEL 0: Normal	1. Precipitation
LEVEL 1: Mild Drought (formerly Advisory)	2. Groundwater
LEVEL 2: Significant Drought (formerly Watch)	3. Streamflow
LEVEL 3: Critical Drought (formerly Warning)	4. Lakes and Impoundments
LEVEL 4: Emergency Drought	5. Evapotranspiration (crop moisture)
	6. Fire Danger

Frequency

The US Drought Monitor (USDM) defines the frequency of occurrence of a drought event in percentiles, "relative to all historical measured events… to gage the severity of a measurement at individual stations and to gage the severity of overall drought" (EEA & MEMA, 2019). Percentile ranges are therefore assigned for each drought level, allowing for the comparison of data across locations. Described in Table 3.24 are the percentile ranges, as classified by the MA DMP and USDM. Table 3.25 and Table 3.26 indicate the drought status for Massachusetts since 1929.

Table 3.25: Comparison of Percentile Ranges between the Massachusetts DMP and USDM.

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

Table 3.26: Historical Occurrences of Drought in MA from 1929-2019 (EEA & MEMA, 2019)

Date	Area Affected	Recurrence Interval (years)	Remarks
1929-32	Statewide	10 to >50	Water-supply sources altered in 13 communities. Multistate.
1939-44	Statewide	15 to >50	More severe in eastern and extreme western Massachusetts. Multistate.
1957-59	Statewide	5 to 25	Record low water levels in observation wells, northeastern Massachusetts.
1961-69	Statewide	35 to >50	Water-supply shortages common. Record drought. Multistate.
1980-83	Statewide	10 to 30	Most severe in Ipswich and Taunton River basins; minimal effect in Nashua River basin. Multistate.
1985-88	Housatonic River Basin	25	Duration and severity as yet unknown. Streamflow showed mixed trends elsewhere.
1995	-	-	Based on statewide average precipitation
1998-99	-	-	Based on statewide average precipitation
Dec 2001 – Jan 2003	Statewide	-	Level 2 drought (out of 4 levels) was reached statewide for several months
Oct 2007 – Mar 2008	Statewide except West and Cape & Islands regions	-	Level 1 drought (out of 4 levels)
Aug 2010 – Nov 2010	Connecticut River Valley, Central and Northeast regions	-	Level 1 drought (out of 4 levels)
Oct 2014 – Nov 2014	Southeast and Cape & Islands regions	-	Level 1 drought (out of 4 levels)
Jul 2016- Apr 2017	Statewide	-	Level 3 drought (out of 4 levels)

Table 3.27: Drought Status from 2018-2022 for Northeastern MA (EEA & MEMA, 2023).

Year	Month	Northeastern MA Drought Status
2020	May	Significant
	June	Mild
	July	Significant
	August	Significant
	September	Significant *(Charles Basin – Critical)*
	October	Mild
	November	Mild
2021	March	Mild
2022	May	Significant
	June	Significant
	July	Critical
	August	Critical
	September	Significant
	October	Mild
	November	Significant
	December	Mild

3.10.2.2. Location

Drought is classified by the Drought Management Task Force of the EEA Water Resources Commission. The Drought Management Plan (EEA & MEMA, 2019) divides the state into seven regions: Western, Central, Connecticut River Valley, Northeast, Southeast, Cape, and Islands. The City of Cambridge is located within Middlesex County, and therefore, the Northeast Drought Region. The city's drinking water supply sources including the Hobbs Brook Reservoir Subbasin and the Stony Brook Reservoir Subbasin are located outside of the city in Lexington, Lincoln, Weston, and Waltham, which are also part of the Northeast Drought Region. In addition, the city has the ability to pivot between city sources and the Massachusetts Water Resources Authority (MWRA) water supply as a source, of which many reservoirs are outside of the Northeast Region, and therefore drought status may be different than the status within Cambridge.

Demonstrated in Figure 3.24 is a Massachusetts Drought Status Map, effective for January 13, 2023. This map shows how drought statuses can be declared at the regional level.

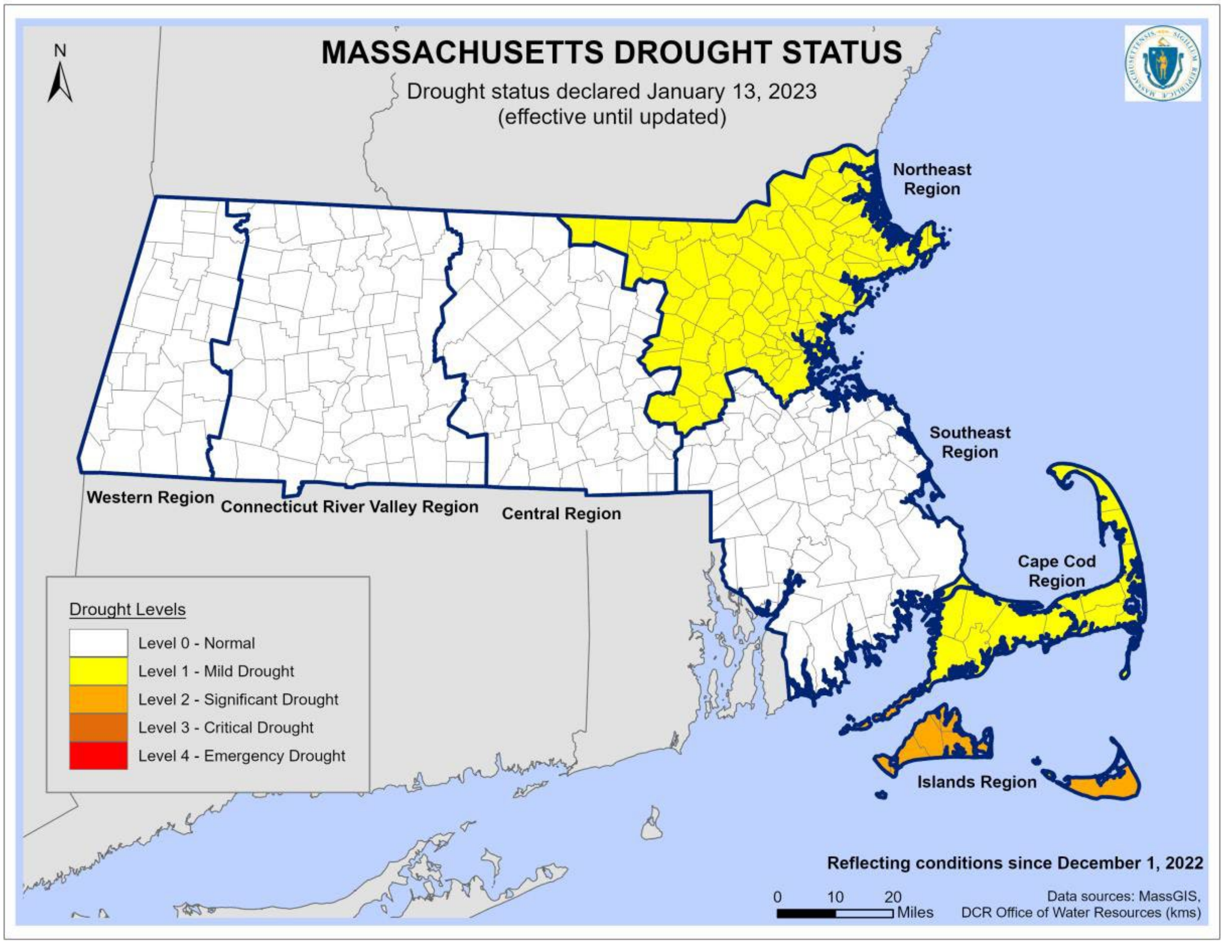


Figure 3-24: Massachusetts Drought Status Map, effective for January 13, 2023, (EEA & MEMA, 2023)

3.10.3 | Probability of Future Hazard Events due to Climate Change

3.10.3.1. Extent

Climate change is anticipated to intensify drought conditions due to rising air temperatures and changes in precipitation patterns. Although overall precipitation is predicted to increase, the frequency of rain events is expected to decrease, leading to prolonged dry periods that elevate the likelihood of drought conditions (EEA & EOPSS, 2018).

2022 Massachusetts Climate Change Assessment uses projected number of events of consecutive dry days and projected annual total number of days without rain as the two primary indicators for future drought predictions. The following table (Table 3.27) shows the projected change in these two parameters over time (MA EOEEA, 2021). Both parameters indicate that number of dry days (annual and consecutive) will increase by three to six percent (3-6%).

Table 3.28: Drought Indicators as Mentioned in 2022 MA Climate Assessment

Drought Indicators (Boston Harbor Basin)	Baseline	2030s	2050s	2070s	2090
Consecutive dry day events: Annual	31	31	32	32	33
Annual number of days without rain **(days per year)**	182	185	192	194	198

3.10.3.2. Probability

Predicting the probability of drought in the future can be complex and uncertain, as it depends on a variety of factors, including the climate conditions, land use practices, and geographic location. However, with climate change resulting in a higher number of dry days, the probability of drought is projected to increase. The likelihood of droughts lasting one to three months could increase by up to 75% by the end of the century in Northeastern States under a high emissions scenario (EEA & EOPSS, 2018).

3.10.3.3. Location

Cambridge will continue to be impacted by drought on a citywide scale. In addition the public water supply for Cambridge is located outside jurisdictional boundaries and has the potential to be impacted by drought.

3.11. Wildfire / Brush Fire

3.11.1 | Description

A brushfire is considered an uncontrolled fire in vegetative wildland areas primarily burning underbrush, such as grass, shrub, leaf litter, and downed limbs.

Wildfires, or expansive fires burning large swathes of forested land, are considered an indirect hazard to Cambridge. A wildfire is not likely to occur within Cambridge, but impacts from wildfires including air quality decreases, have been experienced in recent years.

Note that Cambridge is also susceptible to urban conflagrations, which are large building to building fires that spread over a relatively large urban area. This type of fire is not considered a natural hazard but can be ignited by a natural hazard event.

3.11.2 | Previous Occurrences of Hazard Event(s)

3.11.2.1. Extent

Wildfire and brushfire data for Cambridge was collected from the LANDFIRE program, which provides information on vegetation, wildland fuel, and fire regimes across the United States (LANDFIRE, 2020). This dataset represents different types of fuel sources for wildfires and is based on 13 Anderson Fire Behavior Fuel (FBF) Models, with each value representing a different type of fuel. The FBFM 3, 11, 12, and 13 values represent fuel for rapidly spreading, high-intensity fires, while FBFM 4, 7, and 10 represent fuel for moderate to quickly spreading intense fires, and FBFM 2, 6, and 9 represent fuel for low flame, moderately paced spreading fires. The values of FBFM 1, 5, and 8 represent fuel for very low-intensity fires that are not easily spread.

Table 3.29: Landfire Fuel Sources Categories

#	Display attribute, fire behavior 13 fuel model
FBFM1	Surface fires that burn fine herbaceous fuels, cured and curing fuels, little shrub or timber present, primarily grasslands and savanna
FBFM2	Burns fine, herbaceous fuels, stand is curing or dead, may produce fire brands on oak or pine stands
FBFM3	Most intense fire of grass group, spreads quickly with wind, one third of stand dead or cured, stands average 3 ft tall
FBFM4	Fast spreading fire, continuous overstory, flammable foliage and dead woody material, deep litter layer can inhibit suppression
FBFM5	Low intensity fires, young, green shrubs with little dead material, fuels consist of litter from understory
FBFM6	Broad range of shrubs, fire requires moderate winds to maintain flame at shrub height, or will drop to the ground with low winds
FBFM7	Foliage highly flammable, allowing fire to reach shrub strata levels, shrubs generally 2 to 6 feet high
FBFM8	Slow, ground burning fires, closed canopy stands with short needle conifers or hardwoods, litter consist mainly of needles and leaves, with little undergrowth, occasional flares with concentrated fuels
FBFM9	Longer flames, quicker surface fires, closed canopy stands of long-needles or hardwoods, rolling leaves in fall can cause spotting, dead-down material can cause occasional crowning
FBFM10	Surface and ground fire more intense, dead-down fuels more abundant, frequent crowning and spotting causing fire control to be more difficult

#	Display attribute, fire behavior 13 fuel model
FBFM11	Fairly active fire, fuels consist of slash and herbaceous materials, slash originates from light partial cuts or thinning projects, fire is limited by spacing of fuel load and shade from overstory
FBFM12	Rapid spreading and high intensity fires, dominated by slash resulting from heavy thinning projects and clearcuts, slash is mostly 3 inches or less
FBFM13	Fire spreads quickly through smaller material and intensity builds slowly as large material ignites, continuous layer of slash larger than 3 inches in diameter predominates, resulting from clearcuts and heavy partial cuts, active flames sustained for long periods of time, fire is susceptible to spotting and weather conditions

3.11.2.2. Frequency

The Fire Department responds to a limited number of brush fires of varying sizes annually.

Table 3.30: Wildfires reported in Cambridge

Year	# of Incidents	# of Acres Burned (Fire Module)	# of Wildland Acres Burned	Total Acres Burned
2017	26	1	0	1
2018	18	0	103	103
2019	8	0	1	1
2020	31	0	4	4
2021	9	1	0	1
2022	17	1	0	1
Total	83	1	108	109

3.11.2.3. Location

Most of Cambridge is not exposed to landfire, with FBF 1, 2, and 8 types being the most common types of fire in the city (Figure 3.25). The data shows that the areas along the bank of the Charles River, Alewife Brook, and Fresh Pond Reservation are more prone to fire than the rest of the city. The marshy land in the Alewife brook area is prone to FBF 3, 8, and 10 fires, while Fresh Pond Reservation is prone to FBF 1 fires. The Cambridge Cemetery is also prone to FBF 1 fires, while Danehy Park is prone to FBF 2 fires. Harvard University Law School and surrounding areas are prone to FBF 3 fires, and the MIT campus area is prone to FBF 2 fires.

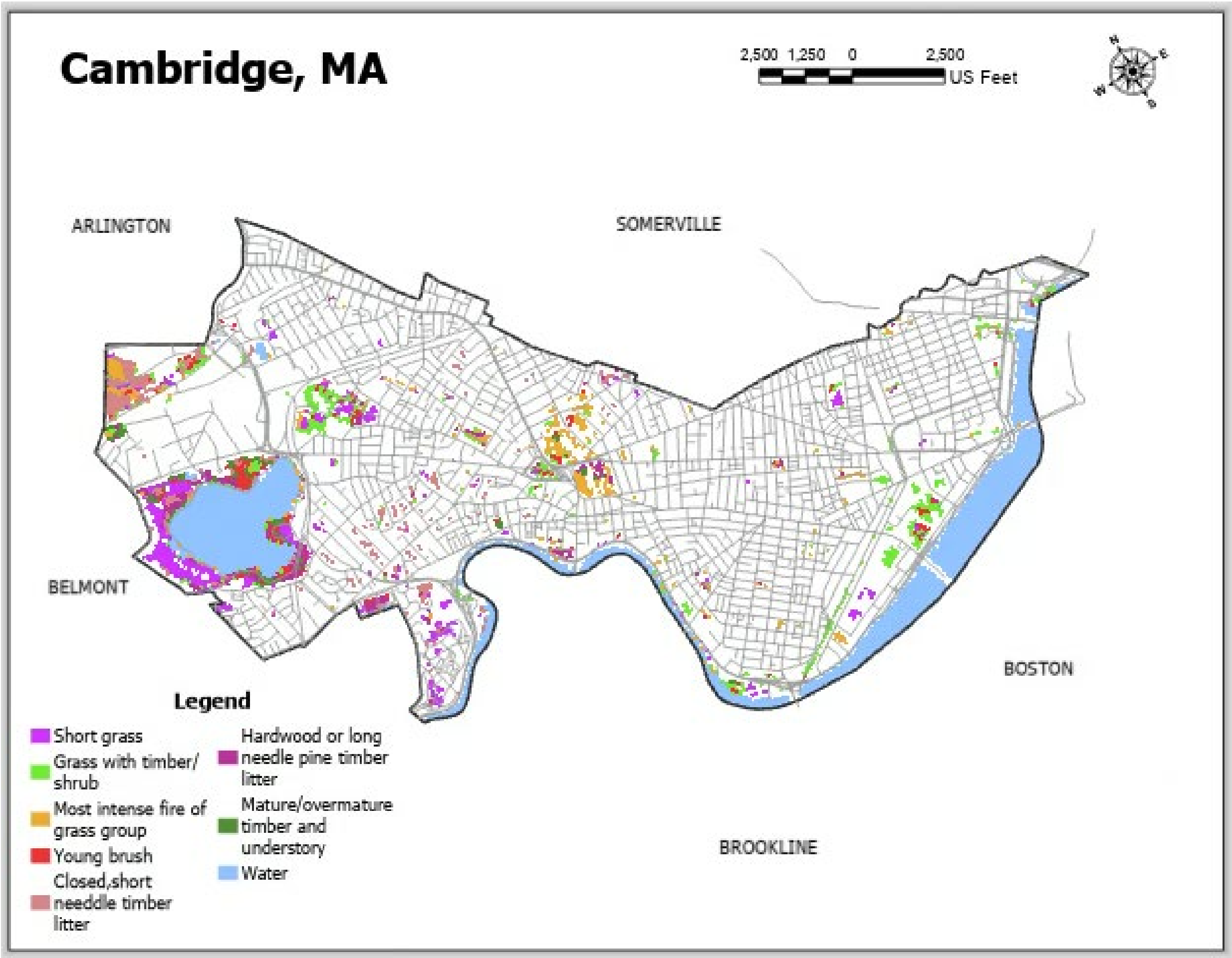


Figure 3-25: Landfire Distribution in the City of Cambridge based on Fuel Type

3.11.3 | Probability of Future Hazard Events due to Climate Change

3.11.3.1. Extent

As has already been seen in the western United States and Canada, increased temperatures coupled with longer periods of drought causes larger and more destructive wildfires. Increased temperatures due to climate change can create drier conditions, promoting evaporation of moisture from vegetation and soils. This can result in more frequent and intense wildfires and the fuel becomes more susceptible to ignition. An increase in fuel, including dried brush and dead vegetation, will allow for fire to spread more rapidly. As discussed previously, climate change can alter precipitation patterns, leading to more prolonged droughts. Drought reduces water supply, which may impact firefighters' ability to respond to fires. Increased hot temperatures in summer months will cause the power system to become overloaded and more likely to start a fire, while other changes in atmospheric circulation patterns have the potential to spread wildfires more quickly due to higher wind speed (EPA, 2022).

3.11.3.2. Probability

The probability of land fires is anticipated to increase due to climate change. As described in the SHMCAP, rising temperatures and changes in precipitation may lead to increased risk of seasonal drought during summer and fall in the Northeast. In addition, higher temperatures lead to greater evaporation and earlier winter and spring snowmelt. Drought and warmer temperatures will increase the risk of wildfire and brush fire, by causing vegetated areas to dry out and become more flammable. Research has found that frequency of lightning strikes could increase 12 percent for every degree of Celsius of warming, further increasing the probability of brush fire due to a lightning strike. (EEA & EOPSS, 2018)

3.11.3.3. Location

The location of potential landfires within the City of Cambridge is only anticipated to change if extent of the city's urban forest, parks, gardens, and natural areas, change, as these are the areas likely to be impacted by the increased potential for brush fire.

3.12. Pests and Invasive Species

3.12.1 | Description

The term invasive species can apply to both flora and fauna. This section will focus on plants and insects (referred to as pests) specifically. The Massachusetts Invasive Plant Advisory Group (MIPAG) was founded in 1995 by the Executive Office of Energy and Environmental Affairs to inform the Commonwealth about the presence and management of invasive species. MIPAG defines invasive species as meeting the following four base criteria (MIPAG, 2022):

- non-indigenous to Massachusetts,
- demonstrates the potential for rapid and widespread dispersion and establishment,
- has the potential to disperse over spatial gaps,
- exists in high numbers in natural habitats.

Often invasive species cause harm to local ecosystems, as they develop self-sustaining populations that become dominant and disruptive to native species. Invasive species often do not have natural predators and therefore are not restricted in their new habitat – monopolizing natural communities and causing economic and environmental damages (EEA & EOPSS, 2018).

Pests exacerbate the problems that invasive plant species pose. Pests often prey on native plant species, causing pre-mature death and creating gaps in the eco-system for invasive species to fill. Certain pests, while not necessarily detrimental to the environment, can pose a threat to public health.

3.12.2 | Previous Occurrences of Hazard Event(s)

There are numerous plants, insects, and fungi species that persist in Massachusetts as invasive. The following tables indicate the species that threaten Massachusetts and more specifically the Fresh Pond Reservation and surrounding areas in Cambridge.

Table 3.31: Massachusetts "Invasive" Flora Species (MIPAG, 2022) and (City of Cambridge, 2023)

Species	Common Name
Acer platanoides*	Norway maple
Acer pseudoplatanus	Sycamore maple
Aegopodium podagraria	Bishop's goutweed, bishop's weed; goutweed
Ailanthus altissima*	Tree of heaven
Alliaria petiolata*	Garlic mustard
Ambrosia artemisiifolia*	Common ragweed
Arctium minus*	Common burdock
Artemisia vulgaris*	Mugwort
Berberis thunbergii*	Japanese Barberry
Cabomba caroliniana	Carolina fanwort; fanwort
Celastrus orbiculatus*	Asiatic bittersweet
Centaurea maculosa*	Spotted knapweed
Chelidonium arvense*	Celandine
Cirsium arvense*	Canada thistle
Cirsium vulgare*	Bull thistle
Commelina communis*	Asiatic dayflower
Convallaria majalis*	European lily of the valley
Convolvulus arvensis*	Hedge bindweed
Cynanchum louiseae	Black swallow-wort; Louise's swallow-wort

Species	Common Name
Elaeagnus umbellata	Autumn olive
Eragrostis curvula	Weeping lovegrass
Euonymus alatus	Winged euonymus, burning bush
Euphorbia esula	Leafy spurge; wolf's milk
Glaucium flavum	Sea or horned poppy, yellow hornpoppy
Hesperis matronalis	Dame's rocket
Iris pseudacorus*	Yellow iris
Lepidium latifolium	Broad-leaved pepperweed, tall pepperweed
Ligustrum vulgare*	Common privet
Lonicera japonica*	Japanese honeysuckle
Lonicera morrowii	Morrow's honeysuckle
Lonicera x bella [morrowii x tatarica]	Bell's honeysuckle
Lysimachia nummularia	Creeping jenny, moneywort
Lythrum salicaria*	Purple loostrife
Myriophyllum heterophyllum	Variable water-milfoil; two-leaved water-milfoil
Myriophyllum spicatum	Eurasian or European water-milfoil; spike water- milfoil
Phalaris arundinacea	Reed canary-grass
Phragmites australis	Common reed
Phragmitesaustralis*	Phragmites
Phytolacca americana*	Pokeweed
Polygonum cuspidatum*	Japanese knotweed
Polygonum perfoliatum	Mile-a-minute vine or weed; Asiatic tearthumb
Potamogeton crispus	Crisped pondweed, curly pondweed
Ranunculus ficaria/Ficaria verna	Lesser celandine; fig buttercup

Species	Common Name
Rhamnus cathartica*	Common buckthorn
Rhamnus frangula*	Glossy buckthorn
Rhodotypos scandens*	White kerria jetbead
Robinia pseudoacacia*	Black locust
Rosa multiflora*	Multiflora rose
Salix atrocinerea/Salix cinerea	Rusty Willow/Large Gray Willow complex
Solanum dulcamara*	Bittersweet nightshade
Trapa natans	Water-chestnut
Vicia cracca*	Cow vetch
Vincetozicum nigrium*	Black swallow-wort
Xanthium strumarium*	Cocklebur

* Invasive Species Commonly Found at Fresh Pond Reservation and Surrounding Areas

Table 3.32: Invasive Terrestrial Fauna and Fungi Species in Massachusetts (EEA & EOPSS, 2018)

Species	Common Names
Lymantria dispar	Spongy / Gypsy moth (insect)
Ophiostoma ulmi, Ophiostoma himalulmi, Ophiostoma novo-ulmi	Dutch elm disease (fungus)
Adelges tsugae	Hemlock woolly adelgid (insect)
Cryphonectria parasitica	Chestnut blight (fungus)
Anoplophora glabripennis	Asian long-horned beetle (insect)
Cronartium ribicola	White pine blister rust (fungus)
Lycorma delicatula	Spotted Lantern Fly (insect)
Operophtera brumata	Winter Moth (insect)

The City of Cambridge completed a citywide urban forest master planning effort in 2019 that reviewed existing species composition and diversity and examined potential changes to the canopy over time as a result of various climatic factors including heat, drought, and introduction of new pests (CUFMP, 2019). This plan provides specific species composition recommendations for future plantings to help achieve species diversity goals in the city through minimizing the potential impacts of pests. It also outlines pest management strategies for both plants and insects, with the ultimate goal of eradicating many invasive species from Cambridge's ecosystem.

Ticks and mosquitos are not generally harmful to the environment, but instead pose a risk to human health. Rather than eradicate these pests entirely, close monitoring and public awareness campaigns can be an effective protection strategy for the public.

Deer ticks, dog ticks, and Lonestar ticks are species of ticks found in Massachusetts that attach to animals or people that come into direct contact with them (MA DPH, 2023). Deer ticks are responsible for spreading Lyme disease, babesiosis, anaplasmosis, *Borrelia miyamotoi*, and Powassan virus. Dog ticks are responsible for spreading Rocky Mountain spotted fever and certain types of tularemia. Lone star ticks are not a significant source of human illness in Massachusetts at this time but are capable of spreading tularemia, ehrlichiosis and southern tick-associated rash illness. One of the most important forms of prevention is checking for ticks once a day on your body.

Mosquitos can spread diseases to humans, including West Nile virus (WNV) and eastern equine encephalitis (EEE) in Massachusetts (MA DPH, 2023). Only a small number of mosquitoes are infected at any given time, so being bitten by a mosquito does not mean you will get sick. However, the best way to avoid both of these illnesses is to prevent mosquito bites using insect repellent, wearing full coverage clothing, and removing standing water from areas around your home. The Massachusetts Department of Public Health has released a Risk Map and Reporting form for EEE and WNV that residents can use to live track positive samples over time (MA DPH, 2023). Several counties in Massachusetts show Low or Moderate Risk for both diseases. Additionally, the CDC has identified malaria cases in Florida and Texas (CDC, 2023). While no malaria cases have presently been identified in Massachusetts, potential spreading of the disease is being closely monitored by CDC.

3.12.2.1. Extent

The damage rendered by pests and invasive species can be significant. Invasive species can trigger a wide-ranging cascade of lost ecosystem services and can reduce the resilience of ecosystems to future hazards by placing a constant stress on the system. (EEA & EOPSS, 2018). Increased spread of disease through ticks and mosquitos can also be a significant detriment to public health across the city, particularly if residents are discouraged from being active outdoors.

3.12.2.2. Frequency

It is difficult to quantify the frequency of invasive species occurring because their presence is ongoing rather than a series of discrete events. Invasive species have the ability to travel long distances (either via natural mechanisms or accidental human interference), which allows these species to propagate rapidly and therefore has increased the frequency of threat over the years. (EEA & EOPSS, 2018) In water systems, invasive species can quickly spread once introduced, as there are generally no physical barriers to prevent establishment, outside of physiological tolerances, and there are many opportunities for transport to new locations. (EEA & EOPSS, 2018)

3.12.2.3. Location

Invasive species are a widespread problem throughout Massachusetts and are a citywide issue for Cambridge. The geographic extent of invasive species varies greatly depending on the species in question and other factors, including habitat and the range of the species. (EEA & EOPSS, 2018).

3.12.3 | Probability of Future Hazard Events due to Climate Change

3.12.3.1. Extent

Invasive species distribution and migration will be impacted by climate change. Climate change may increase the growing season and growth during spring and fall, which typically favors invasive species and generalists over native species, reducing biodiversity. In urban areas like Cambridge, invasive species could cause damage to infrastructure and impact human health by outcompeting native species for resources. The warming climate may also accelerate the movement, consumption, dispersion, and generation time of pests, pathogens, and invasive species, benefiting their proliferation (Dukes, 2009). Global trade and travel have created pathways for exotic species to spread, and non-native species accustomed to warmer climates may proliferate northward as the climate warms.

Changing climatic conditions could shift suitable habitats for native species, increase the risk of new species introductions, create competition from established invaders, and lengthen the peak periods for tick and mosquito activity, potentially resulting in losses in native biodiversity and culturally important species as well as increasing risk to public health. Increased presence of pests, invasive species and land use change may also harm native aquatic species and ecosystems, alter water quality, and impact recreational activities.

3.12.3.2. Probability

Estimated increase in atmospheric CO_2 concentrations may impede the recovery of ecosystems after significant disruptions, increasing the likelihood of successful establishment or expansion of invasive species (EEA & EOPSS, 2018). As a result, probability of damage caused by pests and invasive species is likely to increase in the future.

3.12.3.3. Location

Pests and invasive species will continue to be a citywide issue for Cambridge. The citywide urban forest, parks, gardens, natural areas, and waterbodies are particularly likely to be impacted by the increased populations of pests and invasive species due to climate change.

Chapter 4:

Inventory of Community Assets

4. Inventory of Community Assets

This section provides an inventory of the community assets that are important to the City of Cambridge and paints a picture of a vibrant community with diverse people, buildings, structures, systems, and important resources which make Cambridge unique. Reducing the vulnerability of these assets to natural hazards is critical to the city's neighborhoods, businesses, operations, and economy, and to ensure its longevity. Assets discussed in this chapter are further assessed for their vulnerability to natural hazards in Chapter 5. Actions the City intends to take to mitigate the impacts from natural hazards are discussed in Chapter 7.

4.1. Categories of Community Assets

Assets are defined broadly as anything that is important to the character and function of a community (FEMA, 2023). These can be built, natural, or non-physical elements. They range from emergency facilities and critical infrastructure to community events that help shape collective identity and social cohesion. Below are asset categories, community lifelines, and the list of assets. This analysis is the first step in identifying who or what is vulnerable and developing a plan for future resilience.

4.1.1 | Overarching Categories

Assets are organized into the following categories which represent the wide variety of perspectives, purposes, and goals that asset categories can include and are based on the categories outlined in FEMA's Hazard Mitigation Handbook.

Critical Facilities	These facilities are critical for life safety and the economy. The operation of these facilities during and after a disaster is crucial. Their ability to keep functioning affects both the severity of the impacts and the speed of recovery.
People	Assets that serve populations that are more vulnerable to disaster (e.g., elderly, children, visiting populations) and/or serve densely populated areas. Areas with greater population density, or populations less able to respond and/or recover during a natural hazard. This includes priority populations, such as people of color, tribal and Indigenous communities, women, members of the LGBTQ+ community, people experiencing homelessness, the elderly, underserved communities, or those without access to transportation. In Cambridge, this category includes many of the aforementioned groups, in addition to a large and transient student population. Cambridge is also mindful of those with disabilities, those with limited proficiency in English, those living below the poverty line, and those with low educational attainment (Cambridge, Resilient Cambridge, 2021; Cambridge, Resilient Cambridge, Resilient People, 2021).

Structures	New and existing buildings, as well as built facilities that provide community lifeline services which help the community respond to and recover from natural hazards. Consider the type of building (residential, commercial, industrial, etc.) as well as the age and construction type of the structure. In Cambridge, important structures include the hospitals, fire stations, police stations, schools, and universities.
Systems	A collection of components that perform a critical service for the community. These are networks and capabilities of the community. The loss or breakdown of these components due to a natural hazard could increase community vulnerability and damage. Common systems include roadways or transportation systems such as subways or bus routes. In Cambridge, important systems include the MBTA, drinking water, stormwater, and wastewater systems.
Natural, Historic, and Cultural Resources	Features that add value to the community through education, community connection, sense of belonging, connection to nature, and community protection through natural systems. These assets enhance the quality of life in a community. They also help the local economy through agriculture, tourism, and recreation. They support ecosystem services and build the economy. These assets include places of worship, places of recreation, public art, and open space areas. In Cambridge, examples of these include Harvard Square and the Memorial Church of Harvard University.
Economy	After a disaster, economic resiliency is one of the major drivers of a speedy recovery. Economic assets can have direct or indirect losses. For example, building or inventory damage is a direct loss. Functional downtime and loss of wages are indirect losses. Economic assets are defined as entities that produce a financial benefit for the community.
Activities that have value to the community	Assets in place that benefit the community by increasing community morale and well-being. In Cambridge, these include community events, such as the Cambridge Arts Council Dance Party and the River Festival, the Cambridge Jazz Festival, Harvard Square's May Fair, Danehy Park Day, and the Boston Hong Kong Dragon Boat Festival. These also include long-standing traditions such as the Head of the Charles and other activities such as the City of Cambridge Farmers Markets or Community Garden Program.

4.1.2 | FEMA's "Community Lifelines"

"Community Lifelines" is FEMA's term for assets that the community cannot survive without. "A lifeline enables the continuous operation of critical government and business functions and is essential to human health and safety or economic security" (FEMA, 2020).

For the purposes of hazard mitigation planning and the asset inventory developed for this plan, community lifelines are used to categorize all assets in terms of these critical functions. Not all assets are community lifelines.

A subset of the City of Cambridge's Assets falls into one of eight lifelines that have been classified and described as follows (FEMA, 2019)

Law enforcement and government services, as well as the associated assets that maintain communal security, provide search and rescue, evacuations, and firefighting capabilities, and promote responder safety.

Support systems that enable the sustainment of life, such as water treatment, transmission, and distribution systems; food retail and distribution networks; and wastewater collection and treatment systems.

Infrastructure and service providers for medical care, public health, patient movement, fatality management, behavioral health, veterinary support, and health or medical supply chains.

Service providers for electric power infrastructure, composed of generation, transmission, and distribution systems, as well as gas and liquid fuel processing, transportation, and delivery systems. Disruptions can have a limiting effect on the functionality of other community lifelines.

Infrastructure owners and operators of broadband internet, cellular networks, landlines, cable services, satellite communications services, and broadcast networks (radio and television). Communications systems encompass a large set of diverse modes of delivery and technologies (e.g., translations and meeting accessibility standards, etc.), often intertwined but operating independently. Services include elements such as alerts, warnings, and messages, as well as 911 and dispatch. Also includes accessibility of financial services.

Multiple modes of transportation often serve complementary functions and create redundancy, adding to the inherent resilience in overall transportation networks. Transportation infrastructure includes highways/roadways, mass transit, railway, aviation, maritime, and intermodal systems.

Systems that mitigate threats to public health/welfare and the environment. This includes assessment of facilities that use, generate, and store hazardous substances, as well as specialized conveyance assets and efforts to identify, contain, and remove incident debris, pollution, contaminants, oil, or other hazardous substances.

Systems for Potable Water and Wastewater Management. This includes potable water intake, treatment, storage, and distribution. It also includes wastewater collection, storage, treatment, and discharge (EPA, 2023).

4.2. City of Cambridge Assets

Community assets were identified for the City of Cambridge using the city's most recent geographic information system mapping available publicly on the City's website, assets identified in the Climate Change Vulnerability Assessment work completed in 2015 and 2017, assets identified as critical for continuous power needs, and the latest U.S. Census. Appendix E includes maps showing city assets.

Critical Facilities	32
People	697
Structures	266
Natural, Cultural, and Historic Resources	919
Systems	255
Activities	78
Total Assets	2,215
% of Assets that are Community Lifelines	35%

4.2.1 | Critical Facilities in Cambridge

There is a list of critical facilities within the City of Cambridge to which Eversource prioritizes providing electrical power. This prioritization of service includes restoring access to the grid as fast as possible and, when delays are considered too significant, providing emergency on-site backup power in the form of mobile generators. The list of critical facilities may adjust from year to year but as of 2023, includes 32 locations that consist of:

- Major transportation facilities and structures.
- Utility facilities related to gas and telecommunications.

- City buildings such as City Hall, emergency response buildings for police and fire and emergency operations, including public works.
- Public health facilities such as hospitals, assisted living, and rehabilitation.
- Emergency shelter locations.
- Public water supply facilities and structures.

All these assets are considered community lifelines.

4.2.2 | "People" Assets

"People" assets include be populations in that may be less able to prepare, respond and/or recover before, during and after a disaster, and the facilities that serve populations that are more vulnerable to disaster (e.g., elderly, children, visiting populations) and/or serve densely populated areas. Section 4.2.2.1 discusses the populations in Cambridge that are considered "people" assets. Section 4.2.2.2 discusses the physical facilities that serve these populations.

4.2.2.1. Populations

According to the latest U.S. Census, the City of Cambridge has a population of just over 118,000 people, which is a 12.5% increase since the year 2010. The 2020 Census recorded 49,564 occupied housing units, with an average household size of approximately 2.1 persons. Cambridge has a population density of over 18,500 people per square mile and 7,500 housing units per square mile. According to the 2017-21 American Community Survey, as of 2021, Cambridge is the tenth most densely populated city in the United States.

Priority populations are more vulnerable to natural hazards due to factors such as mobility restrictions, emergency communications language barrier, and existing health conditions. It is also more challenging for priority populations to recover from disastrous scenarios due to economic limitations. Examples of priority populations in Cambridge include (United States Census Bureau, 2023):

- Youth (just over 4% of the population is under 5 and just over 12% of the population is under 18, per the 2020 U.S. Census)
- Persons 65 years and older (just over 11 percent of the city's population falls into this category)
- Veterans (approximately 1,500 veterans in the city)
- Foreign born (almost 30% of the population)
- Those who speak a language other than English at home (approximately 35% of the population over 5 years old)
- Renters (almost 2/3 of the population rent)
- Those who do not have a computer (4% of households) and those who do not have an internet subscription (almost 10%)
- Persons in poverty (just over 12%)
- Persons with a disability, under the age of 65 (almost 5%)

The Resilient Cambridge plan included a study of some of the priority population characteristics per neighborhood of the city (Cambridge, 2021). Neighborhoods are shown in Figure 4.1. Table 4.1 summarizes the percentage of the population with a specific population characteristic for each city neighborhood based on the American Community Survey 5-Year Estimates for 2018.

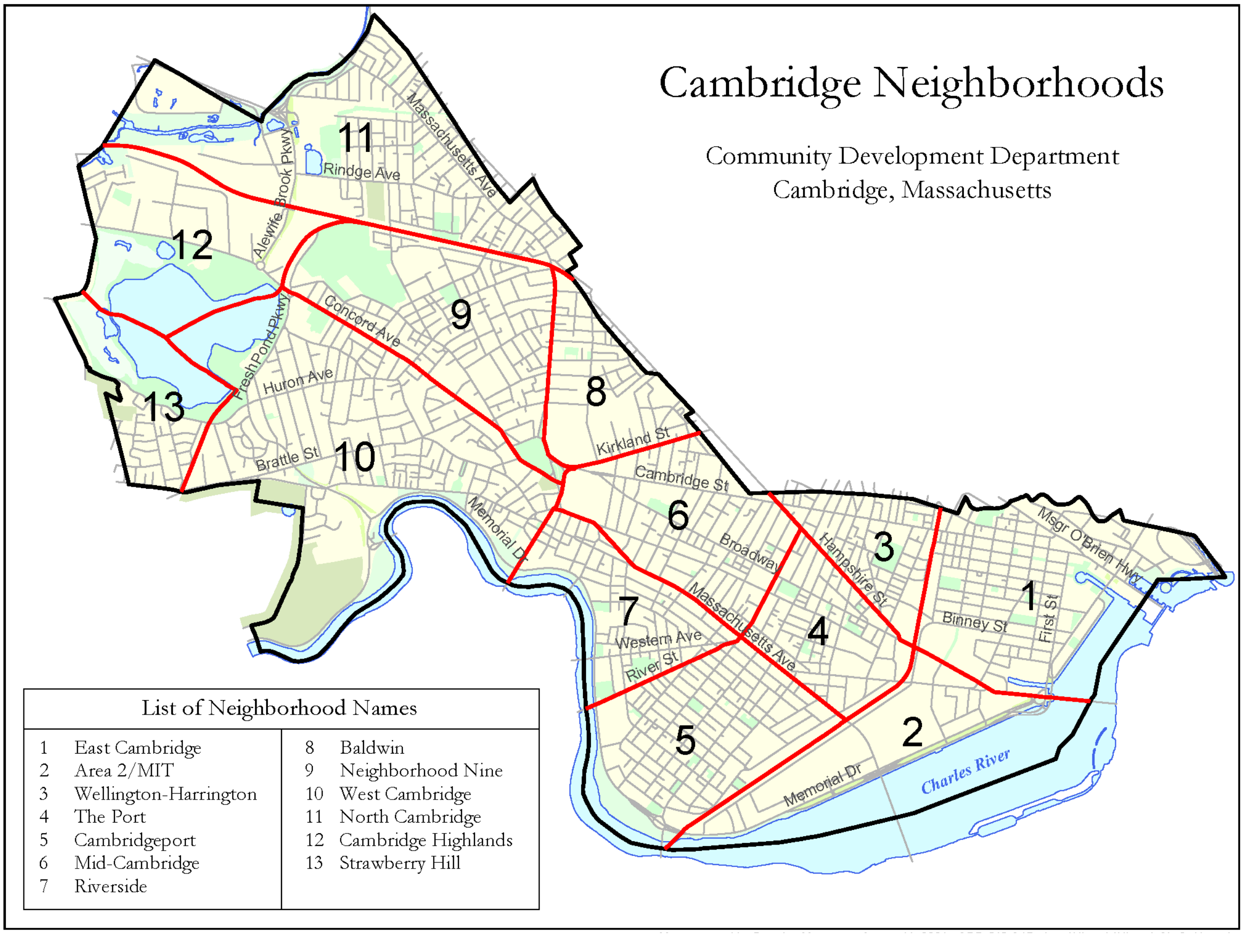


Figure 4-1: Map of Cambridge neighborhoods, by Cambridge CDD

These populations might not be able to recover from one hazard, or might just barely recover from one when there's another, setting them back again, with follow on impacts for ability to remain or be secure in retirement, afford healthcare, age in place, etc.

Table 4.1: Priority Population Characteristics (% of Population) per Neighborhood in Cambridge.

Neighborhood	Percent Renters	Percentage Below the Poverty Line	Percentage without a HS Degree or GED	Percentage with Limited English Capabilities	Percentage with Self-Identified Disability	Percentage Under 5	Percentage Single (Not Married)	Percentage Over 65, Single
East Cambridge	56.6	16.3	6.6	6.1	10.1	5.2	44.0	11.3
Area 2/MIT	75.6	22.5	0.0	7.3	3.5	0.8	36.8	0.0
Wellington-Harrington	66.5	15.5	13.8	9.3	6.0	4.8	31.9	5.7
The Port	60.6	16.8	8.0	3.1	6.7	5.1	26.3	6.2
Cambridgeport	58.7	12.9	4.6	4.1	5.3	4.1	37.3	6.9
Mid-Cambridge	53.9	14.6	3.6	2.7	4.2	3.4	43.5	8.2
Riverside	67.7	15.5	5.4	2.7	4.4	3.1	37.5	4.7
Baldwin	59.3	6.9	1.2	2.1	3.2	2.4	35.0	5.9
Neighborhood Nine	51.0	11.5	1.8	2.6	5.4	3.5	44.3	12.4
West Cambridge	35.0	5.0	1.7	1.2	6.0	5.1	34.1	12.6
North Cambridge	63.9	16.4	7.6	8.4	8.1	4.6	31.8	8.5
Cambridge Highlands	56.0	5.3	5.4	1.6	2.0	3.9	36.5	6.9
Strawberry Hill	56.7	9.7	9.1	4.0	8.0	8.6	48.2	15.4

Legend

	0-10%	Low Percentage of Priority Populations
	11%-20%	Moderate Percentage of Priority Populations

	21%-30%	High Percentage of Priority Populations
	31%-100%	Very High Percentage of Priority Populations

**Table 4.1 does not reflect additional priority populations such as*

- *the unhoused and unstably housed populations in Cambridge*
- *those who are economically insecure, more broadly defined than percentage below the poverty line; and*
- *those above the poverty line but economically insecure in Cambridge's housing and cost of living environment.*

4.2.2.2. Facilities that Serve these Populations

Table 4.2 shows the current facilities that serve people assets in Cambridge by type and number. In addition, the relevant community lifeline, previously described in Section 4.1.2, is noted. Appendix E includes maps showing city assets.

Table 4.2: Number of Assets in the People Category

Sub-type of Asset	Count of Asset	Community Lifeline
Arts and Culture (e.g., language and multicultural arts centers)	7	Should this and other empty categories either have a category or read "N/A"?
Child and Youth Services (e.g., after school programs, guidance, Boys and Girls Club, youth centers, etc.)	10	
Community Resources and Community Centers (e.g., Community legal services, counseling, adult education, community center, American Legion, Veterans of Foreign Wars, Salvation Army, YWCA etc.)	7	
Daycare Facilities	76	
Elderly Facilities (e.g., apartments and housing, rehabilitation centers, senior centers, nursing facilities, etc.)	18	Food, Hydration, Shelter
Health Centers	13	Health and Medical
Health-Related Service	20	Health and Medical

Sub-type of Asset	Count of Asset	Community Lifeline
Hospitals	3	Health and Medical
Housing (includes public and private, inclusionary housing, etc.)	139	Food, Hydration, Shelter
Housing-Related Service (veterans affairs and Cambridge Housing Authority)	2	Food, Hydration, Shelter
Nonprofit, Transitional Housing/Shelters	254	Food, Hydration, Shelter
Playgrounds	60	
Private Schools	34	Food, Hydration, Shelter
Public Schools	18	Food, Hydration, Shelter
Shelter	6	Food, Hydration, Shelter
Waterplay (e.g., parks, schools, and fields with access to natural or manufactured water features)	30	
TOTAL	**697**	

4.2.3 | "Structure" Assets

"Structure" assets are built facilities including residential, commercial, and industrial facilities that may be in harm's way during a hazard event. Many of these structures provide community lifeline services. Cambridge is a highly urbanized and densely developed community where much of the land area is occupied by existing residential neighborhoods, commercial corridors, and districts, open space, and recreational spaces. Some land is protected as conservation land and undevelopable wetlands. Development occurring now and in the future in the city is largely infill development and redevelopment (City of Cambridge & MAPC, 2015). Appendix E includes maps showing city assets.

4.2.3.1. Development Since Previous Hazard Mitigation Plan

While the city is built out, there has been some development since completion of the previous Hazard Mitigation Plan in 2015. Development is tracked for the City of Cambridge to identify buildout trends and determine where new development is feasible, which was identified during the City's planning process called Envision Cambridge, which provides a guide for sustainable development in the city. The Metropolitan Area Planning Council tracks development statistics using its Massbuilds database. Since the end of 2014, 191 buildings were completed across the city. Over 6,100 housing units and nearly 9.5 million square feet of commercial square footage have been built in that time period.

Table 4.3: Recently Completed Development in Cambridge (2015 – Present Day)

Year of Completion	Total Number of Projects[a]	Total Number of Housing Units[b]	Total Commercial Square Footage
2015	15	1,616	1,147,972
2016	12	360	1,300,729
2017	7	319	830,207
2018	8	854	446,062
2018	18	321	2,011,373
2020	13	803	1,000,299
2021	12	524	943,797
2022	13	1,329	1,796,599

Source: (MassBuilds, 2023)

Notes:
(a) Housing units include the combined total of single-family, small multi-family, and large multi-family housing units.
(b) Commercial square footage includes, but is not limited to, general commercial, retail, industrial, hotel, research and development, office space.

In addition to housing, the development of the commercial and retail sector has grown. Neighborhoods such as Kendall Square have experienced a tremendous amount of technology and R&D growth during the last few years. However, small businesses in Cambridge and the region were deeply impacted by the COVID-19 global pandemic. In neighborhoods such as the Port, there are food deserts with limited eating options and no grocery stores aside from small corner shops. Other areas are more saturated with food options. In addition, the two largest food stores are Whole Foods, which is not affordable for many residents. The city's Food Action Plan provides additional detail.

4.2.3.2. Existing Structural Assets

Table 4.4 shows current structural assets in Cambridge by type and number. In addition, the relevant community lifeline, previously described in Section 4.1.2, is noted. Appendix E includes maps showing city assets.

Table 4.4: Number of Assets in the Structures Category

Sub-type of Asset	Count of Asset	Community Lifeline
Dams	4	Water Systems
Emergency Operations Center	1	Safety & Security
Emergency Shelters (includes schools and other locations that function as emergency shelters)	17	Food, Hydration, Shelter
Fire Stations	8	Safety & Security
Food-Related Services (e.g., food pantry, meal programs, etc.)	22	Food, Hydration, Shelter
Gas Stations	12	Energy
Grocery Stores (includes corner stores, gas stations, bodegas, small markets, etc.)	89	Food, Hydration, Shelter
Hazardous Materials Storage	38	Hazardous Materials
Bridges and Underpasses	3	Transportation
Municipal Buildings	21	Safety & Security
Municipal Parking Lots	10	
Pharmacies	15	Health and Medical
Police Stations	5	Safety & Security
Post Offices	7	
Professional Ambulance Service	1	Health and Medical
Public Libraries	7	
Public Pools	3	
Snow Emergency – Parking Only (e.g., Galleria Mall, One Kendall Square Garage, First Street Garage, 52 Oxford Garage, 65 Waverly Street Lot)	5	

Sub-type of Asset	Count of Asset	Community Lifeline
Snow Emergency – Snow Storage	1	
Tunnels	1	Transportation
University Police Departments	2	Safety & Security
TOTAL	**266**	

4.2.3.3. Dams

Critical infrastructure like dams and levees provide recreation, water supply, floodplain management, energy, and other essential functions. Dam owners and operators can be private, non-profit, or public. These structures and their owners are a vital component of local hazard mitigation.

The Hazard Potential Classification System for Dams provides an indication of the consequences of failure of a dam in the United States. This system contains three classes I – Low, II – Significant, and III – High, each representing the degree of potential damage to downstream life and property (FEMA, 2004).

The Amelia Earhart dam and the New Charles River Dam have the potential to impact the City of Cambridge in the event of a breach or overtopping. These dams are not owned or operated by the City of Cambridge.

- The Amelia Earhart (NID# MA01088) is classified as a Low Hazard Potential Dam (Class III). This dam was last inspected in March of 2017 (USACE). Low Hazard Potential Dam classification signifies that no loss of human life is expected with failure, and there is low or limited economic, environmental, and lifeline losses probable (FEMA, 2004). The top of the Amelia Earhart Dam is 11.76 ft-NAVD88.

- The New Charles River Dam (NID# MA01092) is classified as a Significant Hazard Potential Dam, which was last inspected in February of 2022 (USACE). Significant Hazard Potential classification indicates possible loss of life due to dam failure. Furthermore, dam failure may cause damage to homes, industrial or commercial facilities, secondary highways or railroads, and potential interruption of relatively critical facilities (MA DCR, 2017).

For these two dams, Cambridge staff are in ongoing communications with the dam owners and the region related to planning for potential flanking and overtopping under future climate conditions, as well as potential upgrades and enhancements to minimize impacts due to coastal flooding. Section 3.3.1 of the Natural Hazard Profiles discusses coastal flooding because of dam failure.

The City of Cambridge owns and operates two dams, both located outside of the city limits. These include the Stony Brook Reservoir Dam and the Cambridge Reservoir Dam, both of which create reservoirs for the city's water supply.

- The Stony Brook Reservoir Dam (NID# MA00293) is classified as a High Hazard Potential Dam. This dam is in Weston. This earthen dam is 32 feet tall and over 1,200 feet long. The dam is inspected every two years in compliance with state requirements and as of the last inspection was in satisfactory condition.

- The Cambridge Reservoir Dam (NID# MA00750) is classified as a High Hazard Potential Dam. This dam is in Waltham. This earthen dam is 31 feet tall and over 1,600 feet long. The dam is inspected every two years in compliance with state requirements and as of the last inspection was in satisfactory condition.

Both dams are assigned the high hazard potential classification, which means failure or mis-operation will cause loss of human life.

4.2.3.4. Potential Future Development

The City of Cambridge's Community Development Department (CDD) tracks larger-scale residential and commercial developments. Its Current Development Log database is updated on a quarterly basis and provides detailed information on each of the developments and overall trends. As of October 2023, Cambridge currently has 77 projects anticipated for future development. These projects are at various stages in the development process, including projected, planned, and already under construction. These projects total more than 16 million square feet and provide an additional 5217 residential units. Most projects are in East Cambridge and consist mainly of office and research and development. However, overall in Cambridge, residential development is slightly more prevalent than office/R&D with approximately 39% of projects being primarily residential and 25% categorized as office/R&D (Cambridge, 2023).

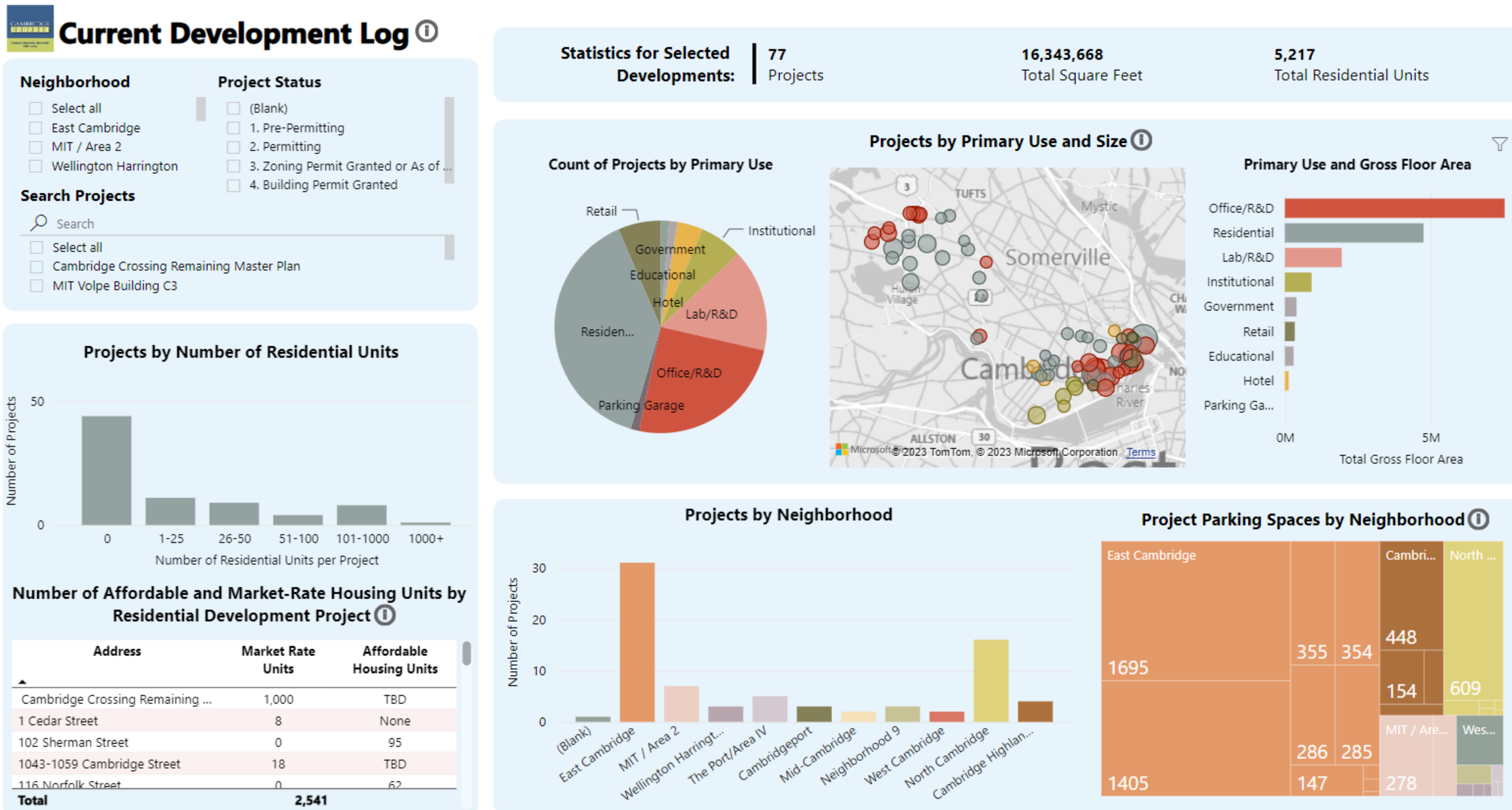


Figure 4-2: Image of the Current Development Log as of October 2023

4.2.4 | "Systems" Assets

"System" assets are defined as a collection of components that perform a critical service for the community. Systems are linear type assets. Systems may include horizontal assets associated with linear type assets. Table 4.5 shows the current systems assets in Cambridge by type and number. In addition, the relevant community lifeline, previously described in Section 4.1.2, is noted. Appendix E includes maps showing city assets.

Table 4.5: Number of Assets in the Systems Category

Sub-type of Asset	Count of Asset	Community Lifeline
Antenna Towers (FCC Registered Private Individual)	3	Communications
Backup Electric Generators	50	Energy
Cell Towers (e.g., Verizon wireless, T-Mobile Northeast)	3	Communications
Data Hub, Colocation Center	2	Communications
Emergency Communications Center	1	Communications
Energy Steam Line	1	Energy
Energy System Power Plant	6	Energy
Gas Distribution System	16	Energy
Major Roads	47	Transportation
Natural Gas Station	2	Energy
NSTAR Electric Substation	20	Energy
Sewer System (separate)	Portions of city	Water Infrastructure
Sewer system (combined)	Portions of city	Water Infrastructure
Sewer & Stormwater Pump Stations	70	Water Infrastructure
Steam Generating Facilities	1	Energy

Sub-type of Asset	Count of Asset	Community Lifeline
Stormwater Pump Station	8	Water Infrastructure
Stormwater system	City-wide	Water Infrastructure
Subway Station	10	Transportation
Telephone Office, Switch	1	Communications
Train Lines (e.g., MBTA Red Line, MBTA Green Line, MBTA Commuter Rail)	3	Transportation
Transmission Line	1	Communications
Utility Facilities	5	Communications, Energy, Food, Hydration, Shelter
Water System	City-wide	Water Infrastructure
Water System Reservoirs (e.g., Hobbs Brook (upper and lower, Stony Brook, Fresh Pond, and Payson Park Reservoir)	5	Water Infrastructure
TOTAL	**255**	

4.2.5 | Natural, Cultural, and Historic Resources Assets

Natural Resources are areas that provide protective function to reduce magnitude of hazard impact and increase resiliency, areas of sensitive habitat that are vulnerable to hazard events, and /or protection of areas that are important to community objectives, such as the protection of sensitive habitat, provide socio-economic benefits, etc.

Historical and Cultural Resources are assets that possess historical, cultural, archaeological, or paleontological significance, including sites, contextual information, structures, districts, and objects significantly associated with or representative of earlier people, cultures, maritime heritage, and human activities and events.

Table 4.6 shows the current natural, cultural, and historic resources assets in Cambridge by type and number. In addition, the relevant community lifeline, previously described in Section 4.1.2, is noted. Appendix E includes maps showing city assets.

Table 4.6: Assets in the NCHR Category

Sub-type of Asset	Count of Asset	Community Lifeline
Community Assets (defined by city CDD GIS, e.g., museums, galleries, theater, dance facilities, CCTV, music schools, arts associations, etc.)	51	
Community Gardens	14	
Historic Districts (e.g., Fort Washington and Old Cambridge)	2	
Historic Landmarks and Easements	117	
National Reg of Historic Places	226	
Open Space Parcels	221	
Places of Worship	80	
Public Art Installations	206	
Tree Canopy	City-wide	
Water Bodies (e.g., Alewife Brook, Charles River)	2	
TOTAL	**919**	

4.2.6 | Economic

Economic assets are defined as entities that produce a financial benefit for the community.

As described in the Envision Cambridge Economy Plan, the city envisions a more equitable city, where all people, regardless of their background or identity, have access to opportunities. This Plan outlines strategies and actions to create a more inclusive labor market and regulate development to create an environment that will serve the city's economic goals. The city has been working towards the goals of:

1. Shared Community Prosperity: Ensure access to job opportunities and living wages, as well as access to robust education, training, and support services.
2. Equity: Eliminate racial, gender, and other disparities in economic opportunity.
3. Global Economic Center: Maintain Cambridge's centrality in the global knowledge economy.

4. Employment Diversity: Diversify employment opportunities beyond high-skill work in a few industries.
5. Business Diversity: Ensure local businesses of diverse types, sizes, and growth stages are able to start, grow, and remain in Cambridge.
6. Great Commercial Districts: Preserve and enhance the distinctive character of Cambridge's commercial districts, especially its major squares and mixed-use corridors.

The City of Cambridge has twelve vibrant commercial and development districts that offer a healthy retail and services mix to residents, workers, and visitors. These districts provide diverse amenities, commercial spaces, and employment opportunities that play a key role in the city's economic performance and its success. Cambridge's compact geography and population density allow businesses to thrive. Central Square, Alewife/Fresh Pond, East Cambridge, Harvard Square, Huron Village/Observatory Hill, Inman Square, Kendall Square, Lower Massachusetts Avenue, North Point, Osborn Triangle, and Porter Square/North Massachusetts Avenue are the 12 commercial districts in the city (CDD, 2023) – some create arts and cultural hubs and provide diverse nightlife, while others consist of innovation spaces with a mix of small and large retail and service businesses. All these commercial districts bring vibrancy to surrounding neighborhoods. Figure 4-3 shows these districts.

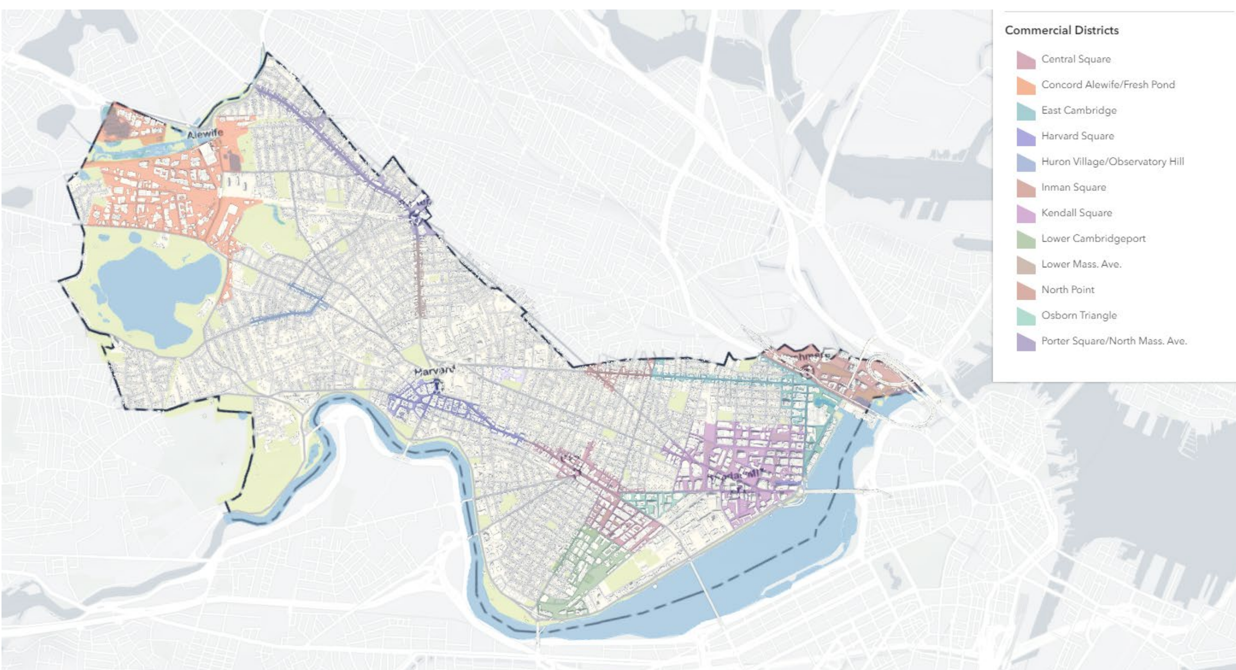


Figure 4-3: Image Cambridge's Commercial Districts (GIS, 2023)

The Cambridge Top 25 employers list provides insight into the overall economic climate in Cambridge. Since the mid-1980s, the Community Development Department (CDD) has collected employment data annually. According to the CDD, Table 4.7 lists the top employers in 2022 (City of Cambridge, 2023).

Table 4.7: Top Employers in Cambridge in 2022

Company	Employees	Type
Harvard University	12,553	Higher Education
Massachusetts Institute of Technology	9,043	Higher Education
Takeda Pharmaceuticals	3,634	Biotechnology
Cambridge Innovation Center	3,499	Start Up Incubator
City of Cambridge	3,480	Government
Novartis Institute for Biomedical Research	2,254	Biotechnology
Sanofi	2,200	Biotechnology
Broad Institute	2,119	Research & Development
Google	2,100	Technology
Phillips North America	2,000	Electronics & Health Technology

4.2.7 | Community Assets

Community assets are activities that benefit the community by increasing community morale and well-being. Activities may include education and knowledge transfer. Table 4.8 shows the current community assets in Cambridge by activity/event, location, organization, and expected guests. Appendix E includes maps showing city assets.

Table 4.8: Assets that have Value to the Community

Activity or Event	Location	Organization	Guests Expected
2023 Dance Party Event	Massachusetts Ave. from Clinton St. to Prospect St.	Cambridge Arts Council	10,000
2023 Susan G. Komen New England 3-Day	Walking Route near BU Bridge	The Susan G. Komen Breast Cancer Foundation, Inc.	800
ADWA Commemoration Parade	Danehy Park to Cambridge Commons	Massachusetts Ethiopian Support Association, Inc.	200

Activity or Event	Location	Organization	Guests Expected
Annual BBN Circus	10 Buckingham St.	Buckingham Browne & Nichols School	700
Annual Juneteenth Celebration Parade	Massachusetts Ave, Western Ave, Riverside	Paragon Society	100
Asian Task Force Against Domestic Violence (ATASK) Lantern Festival	Danehy Park Grounds	Asian Task Force Against Domestic Violence (ATASK)	500
Battle of The Bridge	Hoyt Field	Friday Night Hype / Ink Elite Classic	300
Berklee x Passim Summer in the City Series	Palmer St Alley	Passim	50
Bionic 5K	41 Church St.	Bionic Project, Inc.	750
Birthday celebration of poet Rabindranath Tagore	Harvard Square	Swaralipi	30
Boston Hong Kong Dragon Boat Festival	Charles River	Boston Hong Kong Dragon Boat Festival	20,000
Boston PHA O2Breathe Walk	Cambridge Commons	Boston PHA O2Breathe Walk	100
Broad Institute: Annual BBQ	Timothy Toomey Park	The Broad Institute	750
Cambridge Jazz Festival	Danehy Park	Cambridge Jazz Foundation	8000
Cambridge Montessori School Moving Up Ceremony	St Peter Field	Cambridge Montessori School	350
Cambridge Science Festival	MIT Museum	MIT Museum	Unknown
Cambridge-Somerville Asian Festival	The Foundry	Cambridge Families of Asian Decent	300
Central Square Dumpling Festival	Sidney St. between Green St. and Pacific St.	Central Square BID	4000
Central Square Food Truck Festival	Sydney St. between Green St. and Pacific St.	Central Square BID	4000
Children's Brotherhood Holy Ghost Feast	Saint Anthony Parish	Children's Brotherhood	400
Chinese New Year Celebration	Fitzgerald Theatre, Cambridge Rindge & Latin School	Chinese American Association of Cambridge	100
Chinese/Lunar New Year Rolling Parade	City Hall Lawn	Chinese American Association of Cambridge	100
Community Iftar	Cambridge Street Upper School	Office of Mayor Siddiqui	800
CRLS Graduation Ceremony	Russell Field	Cambridge Public Schools/Cambridge Rindge and Latin School	3500

Activity or Event	Location	Organization	Guests Expected
Danehy Park Day	Danehy Park	Cambridge Recreation	5000
Danehy Summer Concert Series	Danehy Park	Cambridge Recreation	100
Ethiopian American Family Day and Ethiopian New Year Festival	Danehy Park	Massachusetts Ethiopian Support Association	150
Fair Housing for All	Cambridge Public Library on Broadway	Community Development Department (CDD) and housed in Cambridge	100 - 200
Fall Classic 5K	64 Sidney St.	Clark E Promotions	2000
Family Fun Day BBQ	Squirrel Brand Park, corner of Broadway and Boardman	Just A Start Corporation	300
Farmers markets	Varies	Varies	Varies
Festa Junina	Saint Anthony Parish	Saint Anthony Parish Brazilian Apostolate	500
Fresh Pond Day	Fesh Pond	Cambridge Water Dept.	400 - 600
Friday Night Hype	Donelly Field	Friday Night Hype	100
Fusion	State St. between Massachusetts Ave. and Osborne St. Cross Street is Windsor St.	Subcentral & Infra	800
George's Anchor Of Kindness	Central Square. Magazine St. and Green St. Corner of Massachusetts Ave.	Anchor Of Kindness	30
Greek festivals	Saint Constantine & Helen Greek Orthodox Church	Greek Boston	2000
Harvard Square MayFair	Harvard Square	Harvard Square Business Association	50,000
Harvard Wellbeing Week Human & Pet Parent Fun Day	Cambridge Commons	Harvard Student Wellbeing Council	100
Hasty Pudding Woman of the Year Parade	Massachusetts Ave.	Hasty Pudding Theatricals	1,000
Head of the Charles	Charles River	Head of the Charles	400,000
Holy Ghost Feast of the Portuguese-American Civic League of Camb. & Som.	Springfield St. and Cambridge St.	Holy Ghost Feast of the Portuguese-American Civic League of Camb. & Som.	150
HONK! Festival	Varies	HONK! Festival	Unknown
Hoops 'N' Health	Hoyt Field	Men's Health League, Public Health Dept.	Unknown

Activity or Event	Location	Organization	Guests Expected
Inaugural Folk Collective Event	Palmer St. Alley	Passim	50
Inman East & Crafts	Inman Square	East Cambridge Business Association	300
Juneteenth Tournament	Saint Mary Park	Cambridge Youth and Families Connect, Equity Roadmap, Families of Color Coalition	200
Le Grand Prix Elmendorf du Pain	8th St. and Cambridge St.	East Cambridge Business Association	1,000
Loving Day Celebration	Joan Lorentz Park	Citizens Civic Unity Committee	200
Mass Mutual and Boston Red Sox Opening Day Drone Show	Cambridgeside Galleria Parking	EventsPermits LLC	0
Memorial Day	1500 Massachusetts Ave	Veteran Services	200
Mexican Street Food Festival	Sidney St. between Green St. and Pacific St.	Central Square BID	4,000
MLK Day of Service Community Walk	Riverside/Cambridgeport	Many Helping Hands 365	250
MSYEP parties and events	Varies	Mayor's Summer of Youth Employment Program (MSYEP)	Varies
New England Open Market	Church St	Harvard Square Business Association / New England Open Markets	500
Old Time Classic	St. Peters Field	Cambridge Recreation	500
Paddy's Annual Cambridge Classic 5K	260 Walden St.	Paddy's Lunch	600
Patriots Day Celebration	1500 Massachusetts Ave	Veteran Services	200
Play Streets and Block Parties	Varies – Induvial Streets	Community Development Department (CDD)	Varies
Port Arts Fest/Mural Masters	Port Neighborhood	Community Arts Center, Inc.	350
Port Pride Day	Clement Morgan Park	The Margaret Fuller Neighborhood House	Unknown
Pride Brunch	City Hall	Office of the Mayor and Cambridge LGBTQ+ Commission	100 - 300
River Festival	Cambridge Waterfront	Cambridge Arts Council	175,000

Activity or Event	Location	Organization	Guests Expected
Run To Home Base	Massachusetts Ave. from Memorial Drive to Vassar St. and Memorial Drive between Longfellow Bridge and Vassar Street	DMSE SPORTS	2,000
Saint Anthony Feast	400 Cardinal Medeiros Ave.	Saint Anthony Parish	400
Santo Cristo Feast	Saint Anthony Parish	Saint Anthony Parish	500
SerbFest	41 Alewife Brook Parkway	St. Sava Cathedral	1,000
Spring Classic 5K	64 Sidney St.	Clark E. Promotions	2,000
St. John's Brotherhood	Saint Anthony Parish	Saint John's Holy Ghost Brotherhood	400
Summer Boston Celtic Music Festival - Day Event	Palmer St. Alleyway in front of Club Passim	Club Passim	100
Summer Classic 5K	64 Sidney St.	Clark E. Promotions	2,000
Summer Soul Slide Skatepark Series	Lynch Family Skatepark	Right Here Recordings	300
Super Sunday	Kendall Square	RACE Cancer Foundation	1,000
The Encouragement Program, Inc.	St Peter Park	The Encouragement Program, Inc.	25
The Port Park Party	Inside Clement Morgan Park	DPW	100
Wild Rabbit Community Moto Show	Naco Taco, State St, Village State, Windsor St.	Central Square BID	3,000
Wills David Moore youth center annual 7-8th grade basketball tournament	Hoyt Field Basketball Courts	Kevin Moore	60
Winter Classic 5K	64 Sidney St.	Clark E Promotions	2,800
TOTAL	**78**		**Over 720,000**

4.3. Assessing Vulnerability of Community Assets and Identifying Impacts

The vulnerability of the community assets, identified in this chapter, to the natural hazards described in Chapter 3, are presented in Chapter 5.

Chapter 5:

Vulnerability & Impacts Assessment

5. Vulnerability & Impacts Assessment

5.1. Introduction & Overview

In hazard mitigation planning, risk is the potential for damage or loss when natural hazards described in Chapter 3 interact with assets described in Chapter 4. For Cambridge, assets include people, structures, systems, natural, historic, and cultural resources, the economy, and valued activities. The risk assessment looks at two key factors: vulnerability and impact.

- **Vulnerability** is a description of which assets within locations identified to be hazard prone are at risk from the effects of the identified hazard(s) (FEMA, 2022).
- **Impacts** are the consequences or effects of each hazard on the city's assets identified in the vulnerability assessment (FEMA, 2022).

For each natural hazard described in Chapter 3, this chapter presents an overview of which assets are most at risk from the effects of that hazard and describes the consequences of that vulnerability.

Starting in 2015, Cambridge undertook a detailed climate change vulnerability assessment which evaluated the city's critical assets and infrastructure for the present day and anticipated future climate risks. The vulnerability assessment included inland/riverine flooding, sea level rise, extreme heat, and provided a robust economic analysis. Following the vulnerability assessment, Cambridge developed the Resilient Cambridge Plan which identified broad resilience strategies and actions for neighborhoods, buildings, infrastructure, and overall creating a greener city. The vulnerability assessment in this plan builds upon Cambridge's previously released reports.

5.2. Methodology

5.2.1 | Vulnerability Assessment Overview

Natural hazard profiles presented in Chapter 3 were used to determine which assets identified in Chapter 4 are located within hazard prone areas, presently or in the future. For inland flooding and coastal flooding, GIS mapping of assets and of areas of flooding were utilized as further described in Sections 5.3.1 and 5.3.3. For all other hazards, the identified hazard is not mapped or cannot be mapped and therefore a qualitative analysis that relies on local knowledge and rational decision making was used to identify vulnerability. Because Cambridge has a considerable number of assets that are present city-wide, vulnerability discussions focus on specific assets that are most important and most susceptible to damage or loss from hazards.

5.2.2 | Identification of Potential Impacts

There are three ways to analyze impacts:

- **Historical Analysis:** Historical analysis uses data on the impacts and losses of previous hazard events to predict the anticipated impacts and losses for a similar future event.

- **Exposure Analysis:** An exposure analysis identifies the existing and future assets in known hazard areas. GIS is often used for this analysis and to make maps to visualize the risk. An exposure analysis can quantify the number, type and value of structures, community lifelines and other assets in areas of identified hazards. It can identify any assets exposed to multiple hazards. Exposure analysis can also help a community understand areas that may be vulnerable if and when buildings, infrastructure and community lifelines are built in hazard-prone areas. For Cambridge, an exposure analysis was used for inland and coastal flooding.

- **Scenario analysis:** A scenario analysis asks "what if" a certain event occurs. This kind of analysis uses a hypothetical situation to think through potential impacts and losses. A scenario analysis can be completed narratively by walking through a scenario with the planning team and documenting what could happen. It can also be completed using modeling. FEMA's Hazus program is one of the most common scenario analysis tools for hazard mitigation. For Cambridge, FEMA's Hazus-MH Version 2.2 SP1 was used to estimate potential losses from earthquakes and hurricanes.

Table 5.1, below, discusses general impacts that can be the result of natural hazards affecting Cambridge's assets. These impacts are discussed throughout this chapter.

Table 5.1 Types of Impacts due to Occurrence of Natural Hazards

(Types of impacts are not particularly ranked by severity)

Impact	Examples
Loss of Life	Death
Physical Injuries	Cuts, bruises, broken bones, or amputations.
Public Health	Spread of disease or vector-borne illnesses Respiratory problems arising from air pollution
Property Damage	Damage to physical structures Damage to contents within homes and buildings Damage to vehicles
Economic Impacts	Lost wages

Impact	Examples
	Closure of or interruption to businesses Increased insurance premiums Increased costs for repairs/rebuilding Decreased property values Disruption of industry and the transport of goods and services Decreased tourism revenues
Displacement	Forced abandonment of the home due to unsafe living conditions, either permanently or temporarily
Environmental Impacts- Contamination	Air pollution from dust and debris Transport of toxic chemicals by floodwaters Release of hazardous materials into soil and water Decreased water quality Sewage release into waterways
Environmental Impacts- Ecological	Loss of wildlife Loss or destruction of habitat Disruption to migratory patterns Loss of biodiversity
Environmental Impacts- Geological	Landslides Erosion Removal of topsoil Debris deposit Altered nutrient balance
Psychological Impacts	Trauma Anxiety Stress PTSD
Building Damage	Structural damage to roofs, walls, or foundations Collapse or destruction
Utility Infrastructure Damage	Damage to power lines, communications towers, and water and gas mains resulting in power outages, loss of water or gas, and loss of communication, radio signal, or internet
Transportation Infrastructure Damage	Damage to or debris build-up on roads, bridges, railways, or airports that render them impassable or unsafe to use

Impact	Examples
Disruption to Lifelines	Medical facilities, emergency services, or transportation networks are unable to provide essential services due to damage or debris
Impacts to Daily Life	Cancellation or postponement of sporting or other events that are important to the community. Damage to parks, community centers, or public pools inhibits recreation. Destruction of historic or cultural landmarks Interruption of education Limitations to home care providers maintaining service to those in need

Approximately one third of households in Cambridge do not own cars and rely on public transportation. The city has one of the highest walkability scores in the region. It is important to identify support services and assets within reasonable walking distance of owners, renters, and students. According to the U.S. Department of Transportation, . "most people are willing to walk for five to ten minutes, or approximately ¼- to ½-mile to a transit stop." Figure 5.1 demonstrates that some areas of Cambridge are well supported by services during or after a natural hazard event but there are areas of Cambridge that are not as accessible due to their distance from services. Proximity to these assets has a significant impact on Cambridge's people and their ability to adapt to and respond to flooding, winter storms and Nor'easters, hurricanes and tropical storms, and extreme temperatures, as well as other natural hazards encountered less frequently.

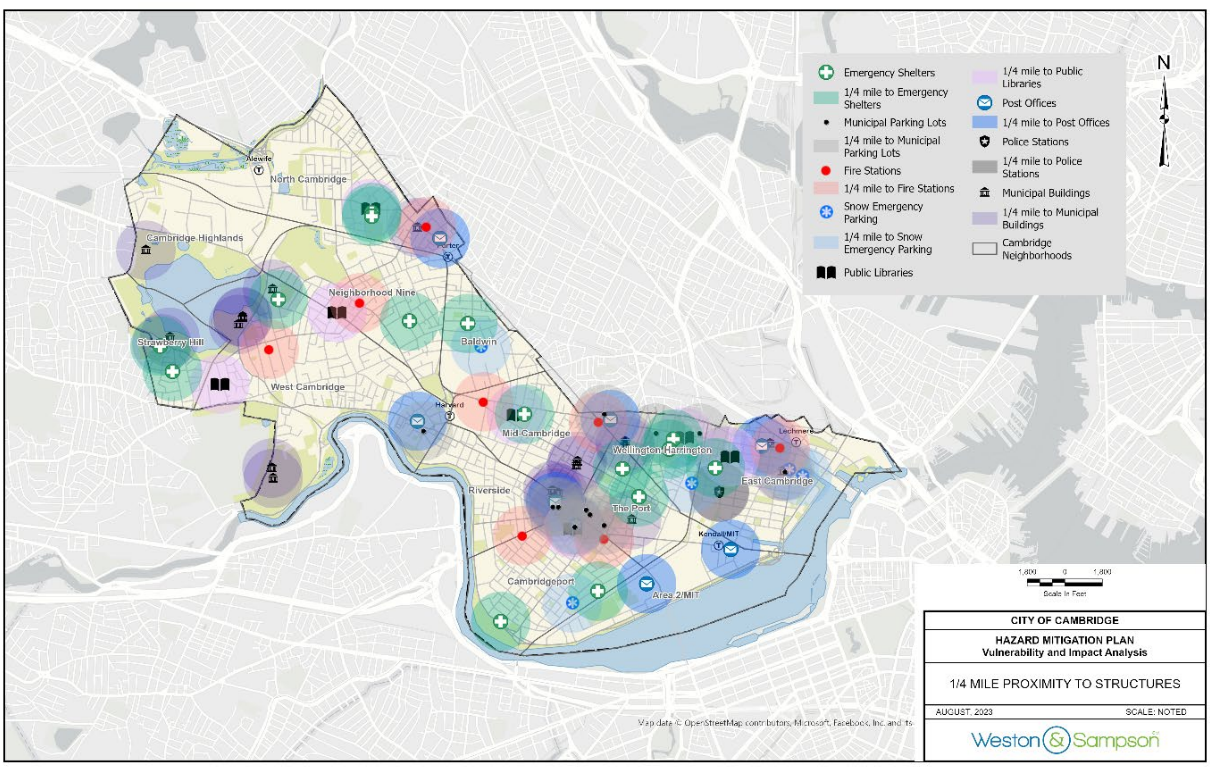


Figure 5-1: Areas of Cambridge well supported by services.

5.3. Assessment

5.3.1 | Inland Flooding (Stormwater and Riverine)

The impacts of flooding in Cambridge can include injury or death, property damage, and traffic disruptions. Erosion can also occur due to flooding events, which can compromise water quality, slope stability, and the stability of building foundations. Erosion puts current and future structures and populations at risk if they are in areas near steep slopes and embankments.

Inland flooding includes both stormwater and riverine flooding. Riverine flooding is most likely to impact areas closest to bodies of water, while stormwater flooding can occur all over the city. Property damage, public health hazards, and impacts to transportation networks are the primary concerns surrounding inland flooding. Stormwater flooding is often concentrated in smaller areas including parking lots and roadways, hindering emergency access, and leaving communities isolated.

My basement has flooded twice when we had storms that dumped 7-8 inches in 48 hours.

- Survey Respondent

Much of the infrastructure in Cambridge, including bridges, tunnels, stormwater systems, roadways, and the subway system, were designed based on historical rainfall events. With increased frequency and severity of storm events, inland flooding could become an increased vulnerability for the city to manage. Noted recently, more frequent occurrences of flood events larger than the historic normal have occurred and put this vital infrastructure at risk. Much of the community in Cambridge relies heavy on the public transportation system and road networks to get from place to place, and damage to any of these systems could impact thousands of people and result in inability for them to get to work, appointments, and other essential locations.

Hazard locations and extent of riverine flooding were determined using the FEMA FIRM for Zone A (100-year floodplain) and Zone X (500-year floodplain). A flood exposure analysis was conducted for assets throughout the city utilizing the most recent assessor's database, FEMA flood maps, and the city's flood viewer. Table 5.2 shows the number of assets likely to be impacted by inland flooding for a variety of flood scenarios. Table 5.3 lists the total number of buildings anticipated to be impacted by inland flooding for a variety of flood scenarios, and their associated assessed value based on the most recent assessor's database.

Table 5.2 Assets Impacted by Inland Flooding

Flood Scenario	Number of Assets Impacted
FEMA 100-year Floodplain	46
FEMA 500-year Floodplain	85
Precipitation Flooding - Present Day 10-year	194
Precipitation Flooding - Present Day 100-year	554
Precipitation Flooding - 2070 10-year	350
Precipitation Flooding - 2070 100-year	735

Table 5.3 Buildings Impacted by Inland Flooding

Flood Scenario	Number of Buildings Impacted	Assessed Value of Buildings
FEMA 100-year Floodplain	201	$3.63 billion
FEMA 500-year Floodplain	768	$6.29 billion
Precipitation Flooding - Present Day 10-year	661	$16.70 billion
Precipitation Flooding - Present Day 100-year	3,570	$31.22 billion
Precipitation Flooding - 2070 10-year	1,816	$22.77 billion
Precipitation Flooding - 2070 100-year	4,987	$37.98 billion

An exposure analysis was utilized to assess potential impacts on the vulnerable assets due to natural hazards. Table 5.4 lists these assets and the impacts. Appendix F includes maps showing community assets and vulnerability to inland flooding under a variety of storm events.

Table 5.4 Vulnerabilities and Impacts from Inland Flooding

Most Vulnerable Assets	**Likely Impacts**
Transportation Network	Transportation Infrastructure Damage • Disruption to MBTA and roadways • Water and debris block routes, making transportation networks impassable or unsafe. • “Failure of key roadway segments will have cumulative and cascading impacts on multiple critical transportation assets including MBTA bus routes and access to bridges. Major at-risk roads include Alewife Brook Parkway, Massachusetts Avenue, Monsignor O’Brien Highway, and Broadway” (City of Cambridge, November 2015).
Emergency Response (including police, fire, and operating centers)	• Approximately 5 of 9 assets are in an area that is likely to experience present day flooding (100-year storm event) • Approximately 7 of 9 assets are located in an area that is likely to experience future (2070) flooding (100-year storm event)
Power Grid	• “North Cambridge and Putnam electrical substations are the assets at greatest risk for energy system failure due to their vulnerable locations. They also have high consequences of failure, including cascading impacts on other energy infrastructure” (City of Cambridge, November 2015).
Water/Stormwater	• Areas with combined sewer systems may experience flooding which could cause more combined sewer overflows (CSOs)and impacts to water quality and public health as a result of increased CSOs (City of Cambridge, November 2015).
Municipal Facilities	• Approximately 6 of 24 assets are located in an area that is likely to experience present day flooding (100-year storm event) • Approximately 9 of 24 assets are located in an area that is likely to experience (2070) future flooding (100-year storm event)
Heath Centers and Health Related Services	• Approximately 5 of 13 assets are located in an area that is likely to experience present day flooding (100-year storm event) • Approximately 6 of 13 assets are located in an area that is likely to experience future (2070) flooding (100-year storm event)

Most Vulnerable Assets	Likely Impacts
Daycares and Schools	• Approximately 59 of 137 assets are located in an area that is likely to experience present day flooding (100-year storm event) • Approximately 68 of 137 assets are located in an area that is likely to experience future flooding (100-year storm event)
Emergency Shelters	• Approximately 8 of 15 assets are located in an area that is likely to experience present day flooding (100-year storm event) • Approximately 8 of 15 assets are located in an area that is likely to experience future (2070) flooding (100-year storm event)
Buildings and Structures	Building Damage • Water damage to internal and external of buildings • Damage to historic buildings
Businesses	Economic Impacts, Property Damage • Business interruption and potential job loss • Limited patrons resulting in reduced revenue. • Increased costs of maintenance and repair • Loss of diversity of businesses
All People	Physical Injuries, Loss of Life, Displacement, Psychological Impacts • Displacement due to building damage. • Isolation due to road closures
Public Health	Water and Sewer Impacts • Mold from water damage • Potential sewer overflow • Potential water source pollution
Vulnerable groups, including unhoused and isolated populations	Physical Injuries, Loss of Life, Displacement, Psychological Impacts • Displacement due to building damage. • Isolation due to road closures
Natural Resources	Environmental Impacts – Contamination, Ecological, Geological • Water pollution • Loss of habitat

Most Vulnerable Assets	Likely Impacts
	• Erosion • Changes in river and stream ecology
Activities that have Value to the Community	Impacts to Daily Life • Temporary loss of community activities due to flooding

5.3.2 | Winter Storms & Nor'easters

Cambridge is often subjected to harsh winters. Winter storms and Nor'easters bring with them heavy precipitation, ice, and below freezing temperatures. These storms can immobilize a city and cause significant disruptions to daily life. A citywide event shutting down Cambridge is estimated to cause at least $43 million (in current dollars) in daily economic losses (Cambridge, February 2017). Heavy precipitation and ice can cause road closures, travel delays and cancellations, business and school closures, and generally dangerous conditions. These storms also bring intense winds. High winds can cause structural damage to the built environment and bring down trees and power lines. This can cause severe and lasting power outages, which are especially dangerous during severe winter conditions as citizens may be unable to heat their homes. Below freezing temperatures can cause pipes to burst. Those without shelter or heat are especially vulnerable during these situations and are susceptible to severe life safety issues such as frostbite and hypothermia.

As described in Chapter 3, the City of Cambridge has experienced several severe winter storm events in recent years, most recently in January 2015 (Winter Storm Juno), March 2018 (3 nor'easters within two weeks), and January 2022 (blizzard with high winds). During these winter storm events, the City of Cambridge experienced a multitude of impacts, including a state shutdown, parking bans, closure of the MBTA and cancellation of flights at Logan International Airport, school closures, and loss of power.

> **Major blizzards have disrupted daily life and work, with power outages, mountains of snow to shovel, digging out the car, difficulty navigating on foot due to relentless ice that is never fully addressed by the community.**
>
> - Survey Respondent

Furthermore, these storms can cause dangerous disruptions to emergency operations. First responders may be unable to respond to emergency situations due to adverse travel conditions. First responders themselves are potentially vulnerable to injury due to dangerous travel conditions such as icy roads or low visibility. Evacuation routes may be impassable.

Though nor'easters may not always bring snow, they bring heavy precipitation. Such intense rainfall can overwhelm drainage systems and cause flooding. They also have the potential to create storm surge. Flooding impacts from these storms become particularly dangerous when storms occur during high tide; the combined effect of heavy precipitation, storm surge, and high tide can be extremely severe. The flooding impact from nor'easters is further exacerbated by sea level rise, and the frequency of such storms is expected to increase with climate change, with the potential for more frequent, more intense winter storms in the future.

A scenario analysis was utilized to assess potential impacts on the most vulnerable assets due to winter storms and nor'easters. Table 5.5 lists these assets and the likely impacts.

Table 5.5 Vulnerabilities and Impacts from Winter Storms and Nor'easters

Most Vulnerable Assets	Likely Impacts
MBTA	Utility Infrastructure Damage • Temporary and long-term route closures • Equipment breakdowns
Power Grid	Utility Infrastructure Damage • Power Outages
Emergency Response	Disruption to Lifelines • Adverse travel conditions can inhibit emergency response. • Injury to first responders • Impassable evacuation routes
All people	Physical Injuries, Loss of Life, Displacement, Psychological Impacts • Slips and falls. • Injuries during snow removal • Isolation due to road closures • Loss of heat during power outages • Vehicular crashes due to poor road conditions
Vulnerable groups, including elderly and isolated populations	Physical Injuries, Loss of Life, Displacement, Psychological Impacts • Slips and falls. • Injuries during snow removal • Isolation due to road closures • Loss of heat during power outages • Lack of accessible routes due to snow and ice

Most Vulnerable Assets	Likely Impacts
	• Unavailability of supports such as personal care attendants, and resultant adverse effects
Businesses	Economic Impacts, Property Damage • Business interruption • Limited patrons resulting in reduced revenue. • Increased costs of maintenance
Daycare and schools, impact to residents	Economic Impact • Lack of childcare • Wage loss for working caregivers
Heath centers and health related services	Disruption to Lifelines • Unable to attend scheduled appointments or access emergency care. • Delayed or cancelled prescription delivery services Impacts to those seeking services from health facilities. Delay / disruption to staff traveling to work at facilities.
Snow emergency parking restrictions	Economic Impacts • Inability to find reliable parking. • Additional parking costs • Towing costs for illegally parked vehicles
Flat roofed buildings (in particular, triple deckers and older buildings that were not designed for a high snow load)	Building Damage • Building closure • Building collapse
Activities that have value to the community	Impacts to Daily Life • Temporary loss of community activities due to danger for people going outdoors

5.3.3 | Coastal Flooding as a Result of Dam Failure

The Charles River and Amelia Earhart Dams provide coastal defenses between Cambridge and Boston Harbor. As discussed in Chapter 3, there have been no previous occurrences of dam failure at the Amelia Earhart or New Charles River Dams since their establishment in 1965 and 1978, respectively. However, continued increases in sea level rise may result in compromised infrastructure, leading to coastal flooding in previously inland areas which was studied in the Climate Change Vulnerability Assessment and in the Resilient Cambridge Plan. (Cambridge, February 2017). Coastal flooding as a result of dam failure could result in catastrophic impacts to Cambridge and the surrounding area. Cambridge's infrastructure, economy, and the well-being of the community would be at risk. Many of the same risks exist for coastal flooding as they do for riverine flooding, described in Section 5.2.2. For example, both types of flooding may block roadways and cause property damage. As sea level rise and other climate change impacts continue, this infrastructure will be at an even greater risk. A major storm surge, while not something that Cambridge currently experiences due to the existence of the Amelia Earhart and the Charles River dams, would have the potential to inundate multiple modes of transportation, rendering the system unusable for days at a time if either of the dams were to fail.

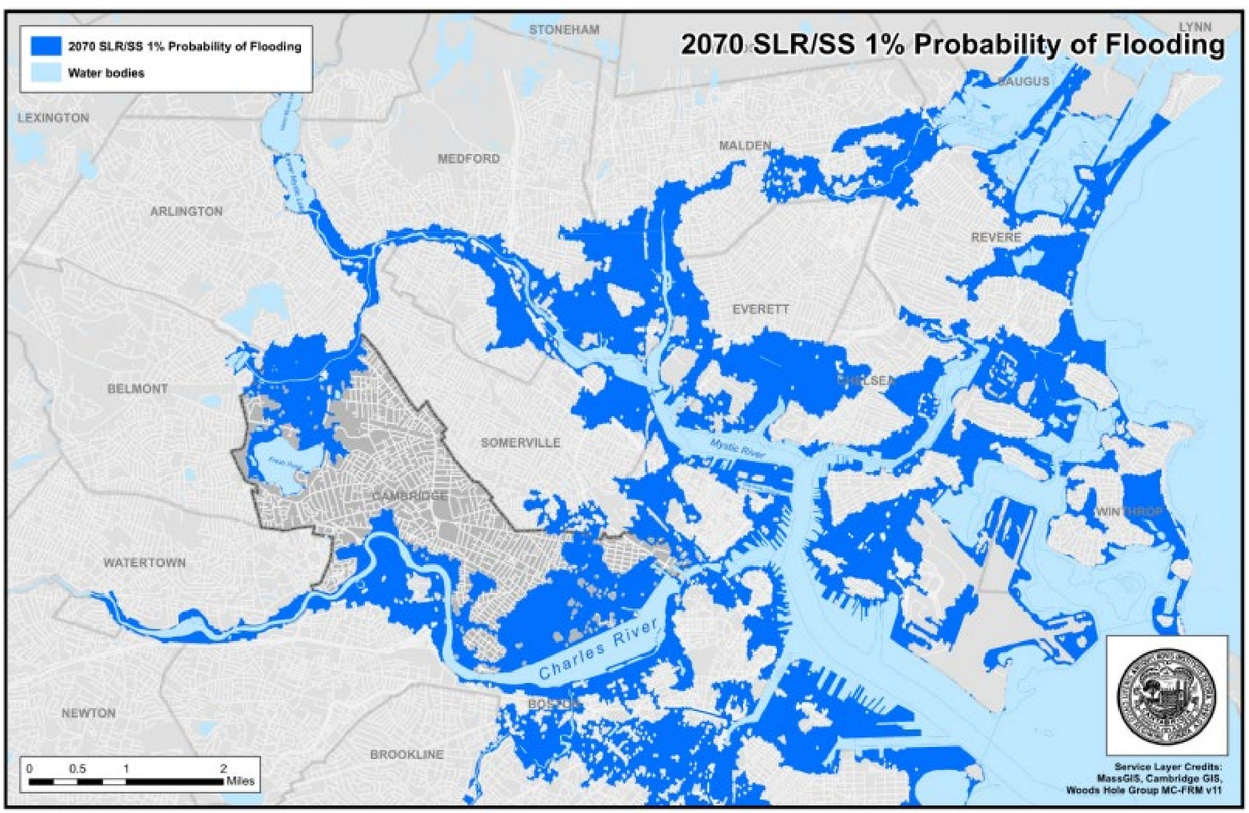


Figure 5-2: Regional flood exposure from 2070 1% SLR/SS event from the Resilient Cambridge Plan

Hazard locations and extents of coastal flooding were assessed using the Massachusetts Coast Flood Risk Model (MC-FRM) for future flooding extents. The MC-FRM utilized inundation predictions based on a combination of sea level rise and storm surge. The model dynamically includes impacts of tides, waves, and storm surge, as well as other parameters in a range of storm conditions to best assess impacts from coastal flooding. The flood analysis was conducted for assets in Cambridge utilizing this model in addition to data provided by the city. The number of assets impacted by coastal flooding due to dam failure was estimated using the predicted extent of flooding and mapped assets. Table 5.6 shows the number of assets likely to be impacted by coastal flooding under 10 year and 100-year storm events by 2070. Table 5.7 lists the total number of buildings anticipated to be impacted by coastal flooding for these two flood scenarios, and their associated assessed value based on the most recent assessor's database.

Table 5.6 Assets Impacted by Coastal Flooding

Flood Scenario	Number of Assets Impacted
2070 10 year	348
2070 100 year	513

Table 5.7 Buildings Impacted by Inland Flooding

Flood Scenario	Number of Buildings Impacted	Assessed Value of Buildings
2070 10 year	1474	$27.24 billion
2070 100 year	3413	$35.70 billion

An exposure analysis was utilized to assess potential impacts on the most vulnerable assets due to winter storms and nor'easters. Table 5.8 lists these assets and the likely impacts. Appendix F includes maps showing community assets and vulnerability to coastal flooding under a variety of storm events.

Table 5.8 Vulnerabilities and Impacts from Coastal Flooding as a Result of Dam Failure

Most Vulnerable Assets	Likely Impacts
Transportation Network	Transportation Infrastructure Damage • Disruption to MBTA, roadways, and bike routes • Water and debris blocking routes, making transportation networks impassible or unsafe
Emergency Response (including police, fire)	• Approximately 1 of 9 assets are located in an area that is likely to experience 2070 10-year sea level rise and storm surge flooding.

Most Vulnerable Assets	Likely Impacts
	• Approximately 3 of 9 assets are located in an area that is likely to experience 2070 100-year sea level rise and storm surge flooding. • "Three important critical services are at risk of propagated flooding from [coastal flooding]: the Police Department Headquarters, the Professional Ambulance Services, and the Fire Company 2. Given that the city has all police services in the headquarters with no redundancy, this is an asset at elevated risk" (Cambridge, February 2017).
Telecommunications	• "The telecom system is impacted by [coastal flooding] with three critical assets being impacted, including the City Emergency Communication Center housed in the Police Department Headquarters" (Cambridge, February 2017).
Energy Infrastructure	• "The North Cambridge Substation is the largest electric substation by far and is at an elevated risk of flooding. Similarly, all of the natural gas used in the city is transmitted to the city through a single facility, Brookfield Street Take Station, which is also at a high risk from flooding. If both of these facilities were flooded, the economic and social consequences of energy and service disruption would be severe" (Cambridge, February 2017).
Water/Wastewater/Stormwater Infrastructure	Utility Infrastructure Damage • Damage to utility infrastructure resulting in loss of drinking water and wastewater systems, including pipes and pump stations, as well as damage to stormwater system. • "Contamination from salt water or hazardous pollutants could also damage water resources, such the Fresh Pond Reservoir" (City of Cambridge, 2015).
Municipal Facilities	• Approximately 3 of 24 assets are located in an area that is likely to experience 2070 10-year sea level rise and storm surge flooding. • Approximately 5 of 24 assets are located in an area that is likely to experience 2070 100-year sea level rise and storm surge flooding
Heath Centers and Health Related Services	• Approximately 1 of 13 assets are located in an area that is likely to experience 2070 10-year sea level rise and storm surge flooding.

Most Vulnerable Assets	Likely Impacts
	• Approximately 2 of 13 assets are located in an area that is likely to experience 2070 100-year sea level rise and storm surge flooding
Daycares and Schools	• Approximately 28 of 137 assets are located in an area that is likely to experience 2070 10-year sea level rise and storm surge flooding. • Approximately 44 of 137 assets are located in an area that is likely to experience 2070 100-year sea level rise and storm surge flooding
Emergency Shelters	• Approximately 4 of 15 assets are located in an area that is likely to experience 2070 10-year sea level rise and storm surge flooding. • Approximately 5 of 15 assets are located in an area that is likely to experience 2070 100-year sea level rise and storm surge flooding
Buildings and Structures	Building Damage • Water damage to internal and external of buildings • Damage to historic buildings
Businesses	Economic Impacts, Property Damage • Business interruption • Limited patrons resulting in reduced revenue. • Increased costs of maintenance
All People	Physical Injuries, Loss of Life, Displacement, Psychological Impacts • Displacement due to building damage. • Isolation due to road closures
Public Health	Mold from water damage
Vulnerable groups, including unhoused, older adults, children, people with disabilities, and isolated populations	Physical Injuries, Loss of Life, Displacement, Psychological Impacts • Displacement due to building damage. • Isolation due to road closures
Natural Resources	Environmental Impacts – Contamination, Ecological, Geological • Water pollution • Loss of habitat • Erosion

Most Vulnerable Assets	Likely Impacts
	• Changes in river and stream ecology
Activities that have Value to the Community	Impacts to Daily Life • Temporary loss of community activities due to flooding

5.3.4 | Hurricanes/Tropical Storms

As noted in Chapter 3, the most recent hurricanes and tropical storms to impact Cambridge include Hurricane Henri (2021) Hurricane Ida (2021) and Tropical Storm Elsa (2021). These storms caused significant impacts to Cambridge, including loss of power, downed trees, and flooding (the impacts of which are discussed in Sections 5.3.1 and 5.3.3).

Due to the large spatial extent of hurricanes and tropical storms, Cambridge's population and existing infrastructure, including critical facilities, are at risk. Potential impacts may include damage to buildings from both wind and water, business interruptions, loss of communication, damage to transportation networks, impairment of water supply and wastewater systems, and power failure. Flooding is a major concern during a hurricane, and slow-moving storms can discharge substantial amounts of rain over an area. Storm surge is also a risk that accompanies hurricanes and tropical storms.

After damage from Hurricane Sandy, I installed a generator running on city gas. Also, my car has been damaged twice by falling tree limbs.

- Survey Respondent

To provide City of Cambridge decision-makers with the best available information for estimating losses from Hurricanes, our team conducted a scenario analysis and utilized the Hazus Hurricane Loss Estimation Methodology to assess the potential impacts of a Category 2 and a Category 4 Hurricane. We used Hazus-generated probabilistic Category 2 and 4 storms to understand direct physical damage (essential facilities, transportation, utility systems, general building stock), induced physical damages (debris), and direct economic/social losses. Hurricane features used in this analysis include wind pressure, windborne debris, rainwater penetration, tree blowdown, and storm surge. Table 5.9 highlights the impacts from Category 2 and 4 storms on assets in the City of Cambridge, and Table 5.10 discusses general impacts that can be the result of hurricanes and tropical storms affecting Cambridge's assets.

Table 5.9 Impacts from a Category 2 and 4 Storm on Cambridge Assets

	Category 2	Category 4
Building Stock		
Estimated total number of buildings	19,000	
Estimated total building replacement value (Year 2014 $) (Millions of Dollars)	$19,826	
Building Damages		
# of buildings sustaining minor damage	1,182.49	3,668.96
# of buildings sustaining moderate damage	299.39	1,380.27
# of buildings sustaining severe damage	8.38	77.67
# of buildings destroyed	0.17	12.8
Population Needs		
# of households displaced	93	493
# of people seeking public shelter	48	266
Debris		
Total debris generated (tons)	14,512	42,514
Tree debris generated (tons)	2,417	5,651
Brick/wood debris generated (tons)	12,095	36,840
Concrete/steel debris generated (tons)	0	23
# of truckloads to clear building debris (@25 tons/truck)	484	1,475
Value of Damage (Thousands of Dollars)		
Total property damage	111,397.76	406,082.87
Total losses due to business interruption	10,680.88	83,725.98

Table 5.10 Vulnerabilities and Impacts from Hurricanes and Tropical Storms

Most Vulnerable Assets	Likely Impacts
Communication Towers	Utility Infrastructure Damage • High winds could knock down communication towers
Power Grid	Utility Infrastructure Damage • High winds can cause power outages
Buildings and Structures	Building Damage • Physical property damage to roofs, walls, and foundations
Tree Canopy	Forests, Environmental Impacts – Ecological • Increase in urban heat island. • Downed trees can block roads and damage infrastructure
All people	Physical Injuries, Displacement, Economic Impacts • Displacement • Physical injuries could occur when leaving the house. • Lost wages when unable to leave the house to work
Vulnerable groups, including unhoused and isolated populations, and those who require medical devices and medication	Physical Injuries, Loss of Life, Displacement, Disruptions to Lifelines • Potential lack of housing if shelters are damaged. • Ability for emergency response to reach vulnerable groups. • Limited access to, and storage for, medical devices and medication
Businesses	Economic Impacts • Business interruption • Limited patrons resulting in reduced revenue. • Increased costs of maintenance
Daycare and schools, impact to residents	Economic Impact • Lack of childcare • Wage loss for working caregivers
Heath centers and health related services	Disruptions to Lifelines • Unable to attend scheduled appointments or access emergency care. • Delayed or cancelled prescription delivery services

Most Vulnerable Assets	Likely Impacts
Natural resources	Environmental Impacts – Contamination, Ecological, Geological • Water pollution • Loss of habitat • Erosion • Changes in river and stream ecology • Disruption of migratory patterns • Loss of biodiversity
Cultural and historic resources	Impacts to Daily Life • Destruction of historic or cultural landmarks
Activities that have value to the community	Impacts to Daily Life • Temporary loss of community activities due to danger for people going outdoors

5.3.5 | Tornadoes

Chapter 3 outlines the previous occurrences of tornadoes impacting Middlesex County. In recent years, three tornadoes have touched down in the county, with the severity of EF1 occurring in 2016 and two EF0 tornadoes occurring in 2021. While there has yet to be a tornado that has touched down in Cambridge, the 2016 tornado in Middlesex County hit near the Cambridge Turnpike in Concord, MA, and headed northeast. This tornado caused roughly $1 million in property damages and one house suffered significant structural damage (NOAA NCEI, 2016).

During a tornado, debris becomes windborne and can cause extensive damage to people and property. If a tornado were to touchdown in or pass through Cambridge, damage would occur both in the tornado path and in the surrounding areas. Due to the high prevalence of older construction and the density of development that exists within the city, the community would be highly vulnerable to impacts, with structures built before current building codes likely more vulnerable. Evacuation, sheltering, debris clearance, distribution of food and emergency supplies, search and rescue, and emergency fire and medical services would be required as part of the emergency response to a tornado event. Critical evacuation and transportation routes may be impassable due to downed trees and debris, and recovery efforts may be complicated by power and communication outages.

A scenario analysis was utilized to assess potential impacts on the vulnerable assets due to tornadoes. Table 5.11 lists these assets and the likely impacts.

Table 5.11 Vulnerabilities and Impacts from Tornadoes

Most Vulnerable Assets	Likely Impacts
Communication Towers	Utility Infrastructure Damage • Tornado winds could knock down communication towers, limiting communication ability between residents and emergency management. • Electromagnetic interference with radio signals • Overload of communications systems
Transportation network	Transportation Infrastructure Damage • Disruption to MBTA and roadways • Debris blocking routes, making transportation networks impassible or unsafe
Buildings and Structure Roofs	Building Damage • Damage to entire buildings, especially those with foundations unable to withstand tornadoes. • Physical property damage
Power Grid	Utility Infrastructure Damage • Tornado winds can cause power outages
Tree Canopy	Environmental Impacts – Ecological • Increase in urban heat island. • Downed trees can block roads and damage infrastructure
All people	Physical Injuries, Loss of Life, Displacement, Economic Impacts, Psychological Impacts • Physical injuries could occur when leaving the house, or sheltering in a house that can't withstand tornadoes. • Lost wages when unable to leave the house to work. • Prohibitive cost of cleanup and repairs following a tornado
Vulnerable groups, including unhoused and isolated populations	Physical Injuries, Loss of Life, Displacement, Psychological Impacts, Disruption to Lifelines • Potential lack of housing if shelters are damaged. • Ability for emergency response to reach vulnerable groups
Businesses	Economic Impacts • Business interruption • Limited patrons resulting in reduced revenue.

Most Vulnerable Assets	Likely Impacts
	• Increased costs of maintenance • Increased insurance premiums
Daycare and schools, impact to residents	Economic Impacts • Lack of childcare • Wage loss for working caregivers
Heath centers and health related services	Disruption to Lifelines • Unable to attend scheduled appointments or access emergency care. • Delayed or cancelled prescription delivery services
Natural resources	Environmental Impacts – Contamination, Ecological, Geological • Damage to trees includes uprooting, removing bark, and stripping leaves and branches. • Soil erosion • Reduction in air quality • Disruption of habitat and food sources for wildlife
Activities that have value to the community	Impacts to Daily Life • Temporary loss of community activities due to danger for people going outdoors

5.3.6 | Earthquake

As discussed in Chapter 3, no earthquakes have ever been recorded as originating within Cambridge's boundaries. Although earthquakes are not common in Cambridge, the historical architecture of the city leaves many assets vulnerable to impacts of earthquakes if one were to occur, although the magnitude, location, and depth of the earthquake would determine the extent of the impact.

A scenario analysis was utilized to assess potential impacts on the vulnerable assets due to earthquakes. The Hazus Earthquake Loss Estimation Methodology was used to assess the potential impacts of a Magnitude 5.0 and a Magnitude 7.0 Earthquake. Specifically, Hazus-generated Magnitude 5.0 and 7.0 Earthquakes were evaluated to understand direct physical damages (essential facilities, transportation, utility systems, general building stock), induced physical damages (debris), and direct economic/social losses. Tables 5.12 and 5.13 show a summary of the likely impacts due to a Magnitude 5.0 and a Magnitude 7.0 earthquake.

Table 5.12: Impacts from a Magnitude 5 and 7 Earthquake

	Magnitude 5.0	Magnitude 7.0
Population Needs		
# of households displaced	4,377	35,300
#of people seeking public shelter	1,984	15,767
# life threatening injuries (depends on time of day)	99	1,442
# deaths (depends on time of day)	180	2,558
Debris		
Building debris generated (tons)	772,000	4,835,000
# of truckloads to clear building debris (@25 tons/truck)	30,880	193,400
Building-Related Economic Loss (Millions of Dollars)		
Income Losses	973.33	4,345.92
Direct Building Losses	3,447	25,540.12
Direct Repairs (transportation and utility)	20.04	152.29

Table 5.13: Impacts from a Magnitude 5 and 7 Earthquake

	Magnitude 5.0	Magnitude 7.0
Building Stock		
Estimated total number of buildings	19,000	
Estimated total building replacement value (Year 2014 $) (Millions of dollars)	19,826	
Building Damages		

	Magnitude 5.0	Magnitude 7.0
# of buildings sustaining slight damage	5,205	940
# of buildings sustaining moderate damage	3,750	3,170
# of buildings sustaining extensive damage	1,472	4,013
# of buildings completely destroyed	441	10,595

Earthquakes also have the potential to cause structural destruction. There are an estimated 19,000 buildings within the Cambridge city limits. Approximately 76% of the buildings are associated with residential housing. According to the Hazus model, a Magnitude 7.0 Earthquake has the potential to completely destroy almost 11,000 buildings and create 4.8 million tons of debris. Thousands more buildings would experience extensive or moderate damage. Even a Magnitude 5.0 Earthquake has the potential to destroy more than four hundred buildings. Table 5.14 shows the likeliness of structural damage on critical facilities from a Magnitude 5 and a Magnitude 7 earthquake.

Table 5.14: Structural Destruction from Earthquakes

Facility Type	Total	At Least Moderate Damage (>50%)		Complete Damage (>50%)		With Functionality >50% On Day 1	
		Mag 5	Mag 7	Mag 5	Mag 7	Mag 5	Mag 7
Hospitals	**3**	3	3	0	3	0	0
Schools	**38**	35	38	0	38	3	0
Emergency Op Centers	**2**	2	2	0	2	0	0
Police Stations	**4**	4	4	0	3	0	0
Fire Stations	**8**	7	8	0	8	1	0

An important aspect to consider is the potential damage to critical facilities and lifelines in the community, such as hospitals, schools, and emergency services buildings. The Hazus model shows that Cambridge should expect moderate to complete damage to the vast majority of its critical facilities in the event of a Magnitude 7.0 earthquake. Table 5.15 lists the most vulnerable assets and the likely impacts.

Table 5.15: Vulnerabilities and Impacts from Earthquakes

Most Vulnerable Assets	Likely Impacts
Communication Towers	Utility Infrastructure Damage • Ground shaking could knock down communication towers, limiting communication ability between residents and emergency management
Buildings and Structures	Building Damage • Damage to entire buildings and structures, especially those with foundations unable to withstand earthquakes. • Maintenance and replacement will be long-term
MBTA	Utility Infrastructure Damage • Damage to entire transit network
Power Grid	Utility Infrastructure Damage • Earthquakes could damage components of the power grid and cause power outages
Tree Canopy	Environmental Impacts - Ecological • Destruction of trees causes an increase in urban heat island. • Downed trees can block roads and damage infrastructure
All people	Physical Injuries, Loss of Life, Psychological Impacts, Property Damage, Economic Impacts, Displacement • Physical injuries could occur when leaving the house, or sheltering in a house that cannot withstand earthquakes. • Lost wages when unable to leave the house to work. • Prohibitive cost of cleanup and repairs following an earthquake
Vulnerable groups, including unhoused and isolated populations	Physical Injuries, Loss of Life, Psychological Impacts, Property Damage, Economic Impacts, Displacement • Potential lack of housing if shelters are damaged. • Ability for emergency response to reach vulnerable groups
Businesses	Economic Impacts • Business interruption • Limited patrons resulting in reduced revenue.

Most Vulnerable Assets	Likely Impacts
	• Increased costs of maintenance
Daycare and schools, impact to residents	Economic Impact • Lack of childcare • Wage loss for working caregivers
Heath centers and health related services	Disruption to Lifelines • Unable to attend scheduled appointments or access emergency care. • Delayed or cancelled prescription delivery services
Activities that have value to the community	Impacts to Daily Life • Temporary loss of community activities due to danger for people going outdoors

5.3.7 | Landslides

As discussed in Chapter 3, there are no documented previous occurrences of landslides in Cambridge. In addition, the overall flat topography of the city is generally not conducive for a landslide to occur. The City of Cambridge is classified as a stable area with an exceptionally low relative landslide ranking. It is likely that if a landslide were to occur in Cambridge, it would occur as a slow-moving slide rather than a fast-moving rock fall and impact a small area. Climate change has the potential to increase the risk of landslides due to an increase in the frequency and severity of precipitation events, rapid snow melt, and rain-on-snow events.

Depending on the location of a landslide, the assets that could be most vulnerable are roadways, buildings and structures, emergency response systems, the MBTA, the power grid, tree canopy, and people.

A scenario analysis was utilized to assess potential impacts on the vulnerable assets due to landslides. Table 5.16 lists the most vulnerable assets and the likely impacts.

Table 5.16: Vulnerabilities and Impacts from Landslides

Most Vulnerable Assets	Likely Impacts
Roadways	Transportation Infrastructure Damage • Damage to roadways in direct path of landslide
Buildings and Structures	Property Damage, Building Damage • Damage to buildings and structures within landslide path

Most Vulnerable Assets	Likely Impacts
Emergency Response	Disruptions to Lifelines • Damaged roadways could prolong emergency response time
MBTA	Transportation Infrastructure Damage • Damage to localized transit network
Power Grid	Utility Infrastructure Damage • Landslides could damage components of the power grid and cause power outages
Tree Canopy	Environmental Impacts - Ecological • Destruction of trees in landslide path causes an increase in urban heat island
All people	Loss of Life, Physical Injuries, Public Health, Displacement, Psychological Impact, Economic Impacts • Physical injuries could occur if someone is within the landslide path

5.3.8 | Tsunami

As discussed in Chapter 3, there is no documentation that either of the previous two tsunamis that occurred in Massachusetts affected the City of Cambridge. If a tsunami were to occur, the geographic location of the tsunami could potentially result in an impact to a significant part of the city, depending on the runup (NOAA & USGS, 2015). It is more likely that locations within Cambridge likely to experience coastal flooding will be the area impacted. Given the infrequency of tsunami occurrences along the East Coast, the probability of tsunamis affecting Cambridge is exceptionally low. Climate change has the potential to increase the risk of tsunami due to an increase in natural disasters such as melting ice and collapsing glaciers, earthquakes, volcanic activity, and landslides, which trigger tsunamis.

A scenario analysis was utilized to assess potential impacts on vulnerable assets due to tsunami. Table 5.17 lists the most vulnerable assets and the likely impacts due to a tsunami. Note that Hazus-MH can run a tsunami model to estimate economic loss and physical damage to buildings due to depth and force of tsunami waves. However, FEMA’s model is only set up to run in five elevated risk states: California, Washington, Oregon, Hawaii, and Alaska.

Table 5.16: Vulnerabilities and Impacts from Tsunamis

Most Vulnerable Assets	Likely Impacts
Hospitals	Disruptions to Lifelines • Hospitals may be unable to provide essential services due to damage. • Access by way of foot, personal vehicle, public transportation, and ambulance may be limited or impossible due to damage, debris, and flooding.
Emergency Response Systems	Disruption to lifelines • Emergency response access may be limited due to impassable roadways. • Emergency response communications could go down
MBTA	Transportation Infrastructure Damage • Damage to localized transit network
Power Grid	Utility Infrastructure Damage • Damage to utility infrastructure resulting in power outages potentially city-wide
Water/Wastewater/Stormwater Infrastructure	Utility Infrastructure Damage • Damage to utility infrastructure resulting in loss of drinking water and wastewater systems, and damage to stormwater system.
Communications Systems	Utility Infrastructure Damage • Damage to communications towers, radio signals, or internet
All People	Loss of Life, Physical Injuries, Public Health, Economic Impacts, Displacement, Psychological Damage • Due to the short warning time, people may not be able to get to a safer location before a tsunami hit

5.3.9 | Extreme Temperatures

As discussed in Chapter 3, it is well documented that extreme heat and extreme cold has occurred within the City of Cambridge. Extreme heat is often more severe in concentrated parts of the city that have less tree canopy, more pavement, and dark surfaces such as roofs that absorb more heat as shown in Figure 5.3. Extreme cold can occur city-wide. Climate change has the potential to increase the extent (severity or magnitude), probability, and location of extreme temperatures.

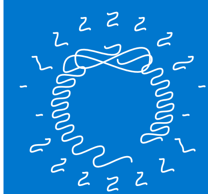
Figure 5-3: 90-degree day relative to streetscape. As the tree canopy increases, the "feels like" temperature decreases - Resilient Cambridge Heat Risk Storymap -2021

A historical analysis was utilized to assess potential impacts on the vulnerable assets due to extreme temperatures. Table 5.18 lists the most vulnerable assets and the likely impacts due to extreme heat or extreme cold.

Temperatures are expected to become more extreme as the climate continues to change. Given Cambridge's distinct four-season climate, it is expected that Cambridge will experience extreme temperatures on both ends of the spectrum, with extreme heat events in the summer and extreme cold events in the winter. Extreme temperatures can have far reaching impacts on infrastructure, transportation, public health, water resources, and energy.

Extreme cold events can create dangerous conditions and are sometimes accompanied by precipitation. They can impact daily commutes and transportation infrastructure. Cold events accompanied by extreme amounts of snow can cause public transportation closures and dangerous driving conditions, resulting in accidents, injuries, or even loss of life. In addition to transportation infrastructure, water infrastructure also has the potential to be severely disrupted during extreme cold events. Power outages can result in loss of heat, causing pipes to freeze and burst. Ground freezing can also result in buried pipes freezing and bursting. A broken water main can have devastating impacts on a large metropolitan area like Cambridge. Furthermore, power outages during wintry weather may result in inappropriate use of combustion heaters, cooking appliances, and generators in poorly ventilated areas, which can lead to increased risk of carbon monoxide poisoning and fires.

Extreme cold also has detrimental impacts on certain vulnerable populations. Those without homes or shelter are susceptible to hypothermia and frostbite. Those with insufficient resources to heat their homes are exposed to the same risk.



I used to live in an apartment without air conditioning, and it could get miserably hot in the summers. Extremes of heat and cold or heavy snow make it difficult and unpleasant for me to get around. I do not have a car, and I still have to walk to or from the bus stop or T station and wait for the bus in bad weather conditions.

- Survey Respondent

Though perhaps less obvious in a place like Cambridge, extreme heat events can and do occur. By 2030, annual days over 90 degrees Fahrenheit (90°F) may triple compared to the 1971-2000 baseline. By 2070, Cambridge may experience nearly three months over 90°F, compared with less than two weeks in the present day (Cambridge, February 2017). Heat waves in Cambridge are expected to be more frequent and of longer duration in the future. The duration and intensity of heat waves have significant public health implications- each passing day of extreme heat decreases a person's ability to cope with the heat stress, thereby making instances of heat stroke or heat-related death more likely (Cambridge, February 2017). Certain populations, such as homeless community members some people with disabilities, and community members without air conditioning are increasingly vulnerable to extreme heat impacts such as heat stress and heat stroke. The City of Cambridge Vulnerability Assessment found that portions of North Cambridge, the Port, and Riverside are more vulnerable to heat impacts than other parts of the City (Cambridge, February 2017) . Even young and healthy individuals can succumb to heat if they participate in strenuous physical activities during hot weather. This is especially true for those with jobs that involve physical labor outdoors, such as landscapers or those who work in construction. Impacts from heat stress can also exacerbate pre-existing respiratory and cardiovascular conditions. Extreme heat has been the number one weather-related cause of death since NOAA began reporting data for heat in 1988 (Cambridge, 2021).

Extremely hot summer days can also worsen air pollution, especially in urban areas. In areas of the Northeast that currently face problems with smog, inhabitants are likely to experience more days that fail to meet air quality standards. This can be especially problematic for individuals with certain respiratory issues, like asthma or allergies. Furthermore, warmer weather can also support the migration of invasive species and lead to an increase in vector-borne diseases. It can also increase the chance of infestation by pests in general, such as the Asian Longhorned Beetle, which could have a significant impact on the City's urban forest (City of Cambridge, 2015).

Table 5.17 Vulnerabilities and Impacts from Extreme Temperatures

Most Vulnerable Assets	Likely Impacts
MBTA	Transportation Infrastructure Damage • Damage to entire transit network • Damage to rails (rail buckling, sun kinks)

Most Vulnerable Assets	Likely Impacts
	• Damage to supporting electrical equipment
Critical Services	• Critical services failures "would likely be due to a combination of system-wide stress caused by increased demand for services and asset-level exposure to extreme heat, which could impact occupant health and safety as well as damage heat-sensitive equipment" (City of Cambridge, 2015).
Power Grid	Utility Infrastructure Damage • Power Outages • Outages and heat damage to emergency communications centers could have city-wide impacts, as they serve the entire city and provide critical system-wide and cross-system functions.
Telecommunications	• "Telecommunication assets, such as the City's Emergency Communications Center located at the Cambridge Police Department Headquarters, are main high-risk assets because they service the entire City and provide critical system-wide and cross-system functions" (City of Cambridge, 2015).
Tree Canopy	Environmental Impacts – Ecological • Prolonged extreme heat can damage the tree canopy, increasing urban heat island effect
All people	Physical Injuries, Public Health, Loss of Life • Extreme heat: Heat stress/stroke, dehydration, respiratory distress • Extreme cold: frost bite, hypothermia
Vulnerable groups, including unhoused and elderly populations and people with disabilities	Physical Injuries, Public Health, Loss of Life • Lack of access to air conditioning can exacerbate impacts described under "All people"
Activities that have value to the community	Impacts to Daily Life

Most Vulnerable Assets	Likely Impacts
	• Temporary loss of community activities due to public health hazard for people going outdoors

5.3.10 | Drought

Chapter 3 discusses the drought levels and previous occurrences of drought in Cambridge. Since 2020, there have been two consecutive months with a critical drought status, and eight months with a significant drought status. Higher drought status and longer time periods will have the greatest impact on the city, and these events are expected to increase into the future with climate change.

Cambridge's main potential vulnerability to a severe long-term drought would be a reduction in the availability of water from the City's local water supplies. The city owns and operates a separate water system, with storage reservoirs on Hobbs Brook and Stony Brook in the towns of Lexington, Lincoln, Waltham, and Weston. In a severe multi-year drought, the yields from these reservoirs would be sharply reduced. This could result in the implementation of water restrictions and use recommendations by the City. However, the City is also a member of the Massachusetts Water Resources Authority and has access to MWRA's regional water supply in the event of an emergency.

Drought also has the potential to increase the risk of brush fires. Increased dry conditions provide the perfect scenario for brush fires. Accidental human ignition or ignition by lightning are especially concerning during times of drought. Firefighting efforts can be impacted during drought conditions due to the low water supply, which can increase the risk of and damage from brush fires.

Other impacts from drought can be felt in aquatic or wetland ecosystems, such as Cambridge's rivers and streams. Drought can severely impact stream flow which can have adverse impacts on wildlife.

A scenario analysis was utilized to assess potential impacts on vulnerable assets due to drought. Table 5.19 lists the most vulnerable assets and the likely impacts due to a drought.

Table 5.18 Vulnerabilities and Impacts from Drought

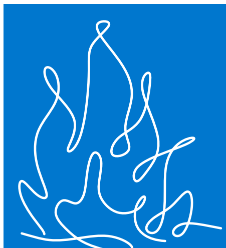
Most Vulnerable Assets	Likely Impacts
Water Supply	Environmental Impacts – Contamination, Utility Infrastructure Damage • Low water levels • Water restrictions
All people	Public Health

Most Vulnerable Assets	Likely Impacts
	• Water use restrictions
Natural resources	Environmental Impacts – Contamination, Ecological, Geological • Vegetation dieback • Tree loss • Stagnant water • Algae blooms

5.3.11 | Wildfire/Brush Fire

As discussed in Chapter 3, there have been previous wildfires/brushfires reported in Cambridge that the Fire Department responded to. Since 2017, 83 fires have impacted a total of 109 acres in Cambridge. Depending on the location of the fire and how quickly it spreads, wildfires and bushfires have the potential to devastate a community like Cambridge.

Wildfires and brushfires can lead to injury, death, property damage and impacts to natural resources. Smoke and air pollution can be a health hazard, especially for those with respiratory conditions such as asthma or allergies. Structures located in brush fire hazard areas are at risk, and closely situated buildings, especially those without fire barriers, increase the risk of brush fires spreading. The most vulnerable members of the population are those who would be unable to evacuate quickly, including the elderly, households with young children, people with mobility limitations, people with limited English proficiency or communication-related disabilities, and people with low socioeconomic status. First responders and firefighters are also at risk.



Recent wildfire smoke affected my health.

- Survey Respondent

Secondary effects from brush fire include contamination of reservoirs and destroyed power, gas, water, broadband, and oil transmission lines. Brush fires can also contribute to erosion and flooding. They strip slopes of vegetation, thereby decreasing soil stability and exposing the slopes to higher rates of runoff which can cause severe erosion, ultimately increasing the chance of flooding. Subsequent rains can worsen this erosion as vegetation and ground cover has been severely reduced and soils remain unstable.

A scenario analysis was utilized to assess potential impacts on the vulnerable assets due to a wildfire or brushfire. Table 5.20 lists the most vulnerable assets and the likely impacts.

Table 5.19 Vulnerabilities and Impacts from Wildfires / Brushfires

Most Vulnerable Assets	Likely Impacts
Buildings and Structures	Property Damage, Building Damage, Disruption to Lifelines • Loss of housing and public facilities • Loss of or damage to critical infrastructure
Utilities	Utility Infrastructure Damage • Destruction to utility lines
MBTA	Transportation Infrastructure Damage • Damage to entire transit network
Power Grid	Utility Infrastructure Damage • Damage to components of the power grid, causing power outages
Tree Canopy	Environmental Impacts – Ecological • Destruction of trees causes an increase in urban heat island. • Loss of structural integrity of trees could result in delayed damage as trees die
All people	Physical Injuries, Loss of Life, Public Health, Displacement, Economic Impacts, Property Damage • Physical injuries and death could occur if evacuation does not occur in time. • Respiratory problems from smoke • Lost wages • Loss of homes and belongings
Vulnerable groups, including unhoused and isolated populations	Physical Injuries, Loss of Life, Public Health, Displacement, Economic Impacts, Property Damage • Potential lack of housing if shelters are damaged. • Inability to evacuate quickly
Businesses	Economic Impact • Business interruption and loss
Daycare and schools, impact to residents	Economic Impact

Most Vulnerable Assets	Likely Impacts
	• Lack of childcare
Heath centers and health related services	Disruption to Lifelines • Unable to attend scheduled appointments or access emergency care. • Delayed or cancelled prescription delivery services
Natural resources	Environmental Impacts – Contamination, Ecological, Geological • Destroy trees and vegetation. • Water contamination • Air pollution • Destruction of wildlife and habitat
Cultural and Historic Resources	Impacts to Daily Life • Damage or destruction of cultural and historic resources
Activities that have value to the community	Impacts to Daily Life • Loss of community activities

5.3.12 | Invasive Species

As discussed in Chapter 3, there are numerous invasive plants, insects, and fungi species that persist in Massachusetts. The extent and growth of these species is predicted to increase in the future with climate change, thus increasing the impact on a community. Invasive species persist town-wide, and it is difficult to predict where they may spread to within the city.

Invasive species pose a great threat to native ecosystems and ecosystem services. Invasive species can often outcompete native species as they have no natural predators in their new range. This allows invasive species populations to grow unchecked, leading to a decrease in biodiversity as the invasive species becomes the dominant species in the area. A decrease in biodiversity also decreases the resilience of the ecosystem; ecosystems depend on a diverse range of organisms carrying out their roles to remain stable. A disruption in diversity can lead to the collapse of the ecosystem or lost ecosystem services. A warming climate adds cause for concern as warmer temperatures may allow for longer breeding seasons or further expansion for some invasive species.

A scenario analysis was utilized to assess potential impacts on vulnerable assets due to invasive species. Table 5.21 lists the most vulnerable assets and likely impacts due to invasive species.

Table 5.20 Vulnerabilities and Impacts from Invasive Species

Vulnerable Assets	Impacts on Assets
Tree Canopy	Environmental Impacts – Ecological • Insects causing destruction of trees causes an increase in urban heat islands. • Loss of structural integrity of trees could result in delayed damage as trees die
All people	Public Health • Vector-borne diseases
Agriculture	Environmental Impacts – Ecological, Economic Impacts • Damage to crops
Natural Resources	Environmental Impacts – Ecological • Destruction of trees and vegetation • Destruction of wildlife and habitat • Water quality degradation

Chapter 6:

Capability Assessment

6. Capability Assessment

The City of Cambridge has a unique set of capabilities, in the form of laws, policies, programs, staff, funding and other resources, to carry out the NHMP and increase resilience. This chapter reviews the City's capabilities and describes which resources Cambridge has available to accomplish hazard mitigation and reduce disaster losses now or in the future. An aspect of capability is compliance with the National Flood Insurance Program. This program is described in Section 6.1. There are many other capabilities that Cambridge has which are described in Section 6.2

6.1. National Flood Insurance Program (NFIP) Compliance

Communities across the country build their flood management capabilities by participating in the National Flood Insurance Program (NFIP). The NFIP supports flood risk reduction before and after disasters. It helps reduce the socioeconomic impact of floods. The NFIP allows property owners and renters in participating communities to purchase federal flood insurance policies to recover financial losses after a flood. To participate in the NFIP, communities adopt and enforce floodplain management policies to reduce the effects of flooding. The NFIP is a key capability for Cambridge.

6.1.1 | Staff Resources

The City of Cambridge has one Certified Floodplain Manager (CFM) on staff who acts as the Floodplain Administrator. This staff member also serves as the Director of the Conservation Commission and as a Senior Engineer. Staff have been adequately trained through FEMA programs, state programs, and courses from the Association of State Floodplain Managers. The Floodplain Administrator also tracks and compiles any Letters of Map Changes that affect the Cambridge area. Staff adhere to FEMA guidelines regarding matters of substantial damage and substantial improvement.

The City of Cambridge is looking to expand their staff capacity for floodplain management.

6.1.2 | Regulation

Cambridge entered the NFIP on June 21, 1974. The first Flood Insurance Rate Maps (FIRMs) were effective on July 5, 1982 (FEMA, Community Status Book Report, 2023). The current FIRMs for Cambridge are effective as of June 4, 2010. These FIRMs are available digitally in a variety of locations in city mapping, including the Flood Viewer.

Preliminary FIRMs are available on FEMA's Map Service Center and are dated August 13, 2021. These FIRMs are not yet effective. FEMA will notify the city as soon as those maps go from being "preliminary" to "effective." Once FEMA notifies these FIRMs are effective, the city Ordinance and maps need to be updated locally and all new and re-development will be held to the new flood map standard as soon as the new maps become effective.

The city maintains elevation certificates in accordance with Community Rating System requirements and tracks the number of buildings located in the special flood hazard area and reports this number annually during the annual CRS certifications. Staff are working toward a digital database for elevation certificates. There are currently 184 buildings in the Special Flood Hazard Area in Cambridge. The City of Cambridge issues development permits in the SFHA through the Conservation Commission (310 CMR 10.00) in accordance with the Wetlands Protection Act. The Commission and the Floodplain Administrator are responsible for issuing permits in the SFHA. This is a transparent and public process, where the application is publicized, and a public hearing is held on the matter.

After a permit is issued, the Floodplain Administrator is responsible for monitoring and compliance throughout the construction phase and through the end of the project. The Floodplain Administrator ensures there is proper signage, and erosion and sediment control measures, and conducts a site visit at least every other week. At the end of the permitting process, an Order of Conditions is issued and recorded with the property deed at the Middlesex South Registry of Deeds.

In addition, DPW has a permitting process separate from the Conservation Commission. This is the Stormwater Control Permit, which is related to predicted flooding in the years 2050 and 2070, not FEMA FIRMs. There is coordination between DPW and the Floodplain Administrator in these permits, as well.

The City of Cambridge's largest barrier to an improved floodplain management program is the lack of technology and digital record-keeping. The city is working toward digital record-keeping while keeping accessibility in mind. The city is moving toward a simple and streamlined electronic permitting process. An additional barrier identified by the City is staff capacity. The City is working to expand their floodplain management staff capacity.

6.1.3 | Community Rating System

Cambridge is a participant in the Community Rating System (CRS) as of October 1, 2015 (FEMA, Community Status Book Report, 2023). The Community Rating System is an incentive-based program that rewards communities for exceeding the minimum standards of floodplain management set by the National Flood Insurance Program. The CRS has 19 creditable activities for which communities can obtain points. These activities include but are not limited to public education and outreach, mapping standards, higher regulatory standards, open space preservation, and stormwater management regulations. Communities that exceed minimum NFIP standards in these 19 activities are rewarded with a discount on flood insurance premiums for citizens of that community. Cambridge's CRS Class Ranking is a 9, which is almost the lowest (10 is the lowest) (FEMA, Community Status Book Report, 2023). This means that citizens of the City of Cambridge will receive a 5% discount on their flood insurance premiums. This discount will grow as the City of Cambridge continues to improve in the program. The city is looking to improve their rating to an 8 but must meet the pre-requisite of adopting a one-foot freeboard requirement within the Special Flood Hazard Area.

6.1.4 | Insurance Summary

There are three repetitive loss properties within the city, which is an increase from the two structures identified in the 2015 HMP. FEMA defines a repetitive loss property as “an NFIP-insured structure that has had at least 2 paid flood losses of more than $1,000 each in any 10-year period since 1978.” (FEMA, Repetitive Loss Structure, 2020) As of May 15, 2023, building losses have totaled $99,768.39 and contents losses have totaled $83,899.91, totaling $183,668.30 in losses, an increase over the $168,421.73 documented in the 2015 HMP.

The staff is also responsible for conducting public outreach with regard to flood insurance. A paper/physical flyer is distributed annually to each structure in the Special Flood Hazard Area that describes the importance of flood insurance, especially for properties within a flood zone. There are two flyers; one is specific to repetitive loss properties, and one is for all other structures located in the SFHA.

6.1.5 | Compliance History

There are no outstanding compliance issues for the City of Cambridge. The next Community Assistance Visit for the review of Cambridge’s Community Rating System participation is scheduled for 2024. Community Assistance Visits occur every five years for the City of Cambridge

6.2. Mitigation Capabilities of Cambridge

There are four key types of mitigation capabilities in accordance with FEMA’s Local Mitigation Planning Handbook:

6.2.1 Planning and regulatory capabilities are the codes, ordinances, policies, laws, plans and programs that guide growth and development.

6.2.2 Administrative and technical capabilities are the city’s staff, skills and tools.

6.2.3 Financial capabilities are the resources to fund mitigation actions.

6.2.4 Education and outreach capabilities are programs and methods that can communicate about and encourage risk reduction.

Many of the capabilities or gaps in capabilities identified in this chapter are anticipated or have been observed while preparing for, responding to, or recovering from local hazards, which have been identified and outlined in Chapter 3. The capability gaps identified in this chapter were used to inform the development of the mitigation actions in Chapter 7.

6.2.1 | Planning and Regulatory Capabilities

Planning and regulatory capabilities encompass a wide range of tools such as codes, ordinances, policies, laws, plans, and programs that guide growth and development. These capabilities play a crucial role in either supporting risk reduction or creating areas that are more vulnerable to disasters. These strategies are aimed at breaking the cycle of disaster damage and reconstruction. Additionally, effective law and regulation for disaster risk reduction are critical in shaping choices for sustainable development and building resilience to disasters. The following strategies outline the planning and regulatory capabilities to address hazards in Cambridge.

6.2.1.1. Building Code

Cambridge has a multi-century history of development and building throughout many eras of trade practices and editions of codes. A challenge for the capabilities of a community or region can be the use of an updated building code which reflects industry best practices and standard of care. Currently, the City of Cambridge utilizes the latest Commonwealth of Massachusetts Building Code (Ninth Edition), which is Code of Massachusetts Regulations 780. According to the mass.gov website, "the Massachusetts State Building Code includes international model codes and state specific amendments adopted by the Board of Regulations and Standards (BBRS). The BBRS regularly updates the state building codes as new information and technology becomes available and change is warranted."

The Massachusetts building code addresses natural hazards through elevation requirements aligning with guidance from FEMA, hazard-resistant standards from ASCE 24 and ASCE 7, recognition of floodplain overlay districts, and enforcement.

In addition to the building code, Massachusetts also has the Massachusetts Stretch Energy Code, adopted by Cambridge in 2009, which requires enhanced energy performance above the mandatory base building code. Cambridge adopted the Specialized Stretch Energy Code which builds upon the 2023 Stretch Energy Code update with more restrictive use of fossil fuels and additional net-zero ready requirements for new buildings and qualified renovations. The Specialized Stretch Code went into effect on July 1, 2023, and is aligned with Cambridge's Net Zero Action Plan. On August 7th, 2023 the City adopted an ordinance that will require future buildings to be fossil fuel free as part of the Fossil Fuel Free Demonstration Project, driven by state legislation. Effective date pending state approval. The Stretch Energy Code and Specialized Stretch Energy Code provide Cambridge with additional capabilities to withstand the impacts of extreme temperatures.

6.2.1.2. Land Use / Development Ordinances and Regulations

The following discusses various municipal codes related to natural hazard mitigation and climate change resilience. (City of Cambridge, 2023)

Tree Protection

The City of Cambridge Commissioner for Public Works adopted a Tree Protection Ordinance to regulate removal of "significant trees". Significant trees are identified as trees with a diameter at breast height (DBH) of six inches or greater at four and a half feet above the ground. A Tree Removal Permit is required to remove a significant tree and the city has identified specifications for replacement trees. Trees play a critical role in hazard mitigation and provide cooling through shade and evaporation, help with erosion control, and management of stormwater. Trees also sequester carbon helping to reduce greenhouse gas emissions. (Cambridge, Climate Resilience Zoning, 2023)

Building Energy Use Disclosure Ordinance (BEUDO)

The Building Energy Use Disclosure Ordinance (BEUDO) was enacted by Cambridge City Council on July 28, 2014. The ordinance supports the city's goal of reducing greenhouse gas emissions. Energy use in buildings accounts for approximately 80% of greenhouse gas emissions in Cambridge, particularly large buildings such as commercial, institutional, and mixed-use buildings. The BEUDO ordinance requires owners of large buildings to track and report their annual energy usage. In 2023, Cambridge passed an amendment to this ordinance which requires large non-residential buildings to be net-zero by 2035, and medium-sized non-residential buildings to be net-zero by 2050. (Cambridge, Building Energy Use Disclosure Ordinance, 2023)

Wastewater and Stormwater Drainage System

Cambridge regulation Chapter 13.16 addresses maintenance and management of the wastewater and stormwater drainage systems. The City Engineer is ultimately responsible for construction and administration of activities pertaining to the system.

The city has also adopted a stormwater management program that includes mitigation actions to help control stormwater runoff volume and quality. Guidelines through this program are based on the Municipal Separate Storm Sewer System (MS4) EPA National pollution Discharge Elimination Program. The City of Cambridge also holds a National Pollution Discharge Elimination System (NPDES) Combined Sewer Overflow (CSO) permit for the eleven CSOs it owns and operates. Under water quality Variances for CSO discharges to the Charles River Basin and the Alewife Brook/Upper Mystic River Basin the City is developing an Updated CSO Control Plan for the City's CSO outfalls. The Updated CSO Control Plan will reduce the activation frequency and volume of combined sewer discharges to local water bodies. The City is proactively incorporating future climate projections into the development of the updated plan. Implementation of this plan is anticipated to take several decades.

6.2.1.3. Zoning Code & Local Plans

The following discusses zoning code related to natural hazard mitigation and climate change resilience. (Cambridge, The Zoning Ordinance, 2023)

Climate Resilience Zoning and Building Requirements

The City Council adopted new zoning requirements in February of 2023 that address the long-term impacts of increased flooding and heat from climate change. These requirements apply to new buildings that are over 25,000 square feet, new additions to buildings that increase the square footage by 50%, the creation of occupiable or habitable space in basements that is exempt from Gross Floor Area (GFA) requirements, and surface parking lots. The new zoning uses 2070 projections as a milestone since buildings constructed today are expected to have at least a 50-year lifespan.

Flood Resilience Standards require new developments to protect vulnerable spaces that have a likelihood of flooding based on future climate projections. The city is referring to its elevation requirements for these spaces as "Long-Term Flood Elevations" which are based on 2070 projections. Applicants must review the elevations for precipitation and sea level rise and use the higher of the two. Elevations are accessible on the City's flood viewer website.

The Green Factor Standard is a new performance-based standard that encourages heat mitigation through site and landscape designs that have a cooling benefit. Sites will need to achieve a "Cool Score" by including features like trees (both preserving mature trees and planting new trees), shrubs and other plantings, green roofs, shade canopies, and cool pavements. Applicants must fill out a "Cool Score Sheet" based on the elements included in site and building design. (Cambridge, Climate Resilience Zoning, 2023). Many of the practices in the Green Factor Standard will also contribute to the reduction of stormwater run-off and flood prevention.

Article 22 Green Building Requirements promotes sustainable and energy efficient design. This article applies to buildings that are 25,000 square feet or more, including new construction and some types of substantial renovation. These requirements include demonstration that the design meets the standards of a Green Building Rating System such as USGBC LEED – Gold Rating, Passive House Institute, or Enterprise Green Communities. While an official rating is not required, a green building professional must verify that the standard has been met. (Development C. o., 2023)These green building requirements increase the capabilities of occupants to withstand extreme temperature changes and disruptions in power.

Local Plans

There are a variety of local plans that informed the NHMP, as previously discussed in Chapter 2. In addition to those plans, several departments have plans to build the capabilities and capacity of the staff to respond to emergencies. These plans include:

- Department Emergency Operations Plan
  - Fire Department
  - Public Health Department
  - Water Department
  - Emergency Communications Department.
- Continuity of Operations Plan
  - Fire Department

    - Public Health Department
    - Water Department
    - Emergency Communications Department
- Archives Emergency Plan
    - Historical Commission
- Succession Plan
    - Public Health Department
- Water Sanitation and Hygiene Emergency Protocol for People Experiencing Homelessness
    - Public Health Department

6.2.2 | Administrative and Technical Capabilities

To assess the City's administrative and technical capacity, the STC identified several departments which play a key role in preparedness, response, and recovery to be surveyed, and key staff provided input on capabilities to prepare for and respond to natural hazard events. Cambridge has over 45 offices, departments, and commissions, all with varying degrees of involvement in natural hazard and climate change planning, mitigation, and adaptation actions. In addition to the capabilities under the purview of the city, Cambridge is also home to non-governmental organizations which provide support to the residents of Cambridge. Representatives from many of these departments were invited to participate in the Local Hazard Mitigation Planning Team workshops to provide input on capabilities of the city. The following sections summarize input from city staff and community members on the administrative and technical capabilities of Cambridge.

The feedback provided in the survey demonstrated that Cambridge has well-rounded departments and has invested both time and funding into addressing natural hazard concerns. Some staff identified that there can be silos of information developed or understood throughout the city and a central person or office should be identified for leading such efforts.

Throughout engagement on this topic, capabilities were identified which reflect the city's robust resources and identified gaps which could be addressed by mitigation actions.

6.2.2.1. Staff Capacity and Training

City staff are often considered to be first responders during an emergency event. From police to public works staff, resources are called to action to protect the assets described in Chapter 4. However, these resources are only as good as the preparedness training and capacity of the staff to respond.

Existing Capabilities: Due to the wealth and resources in the city, the feedback provided by staff and other stakeholders in the process was that Cambridge was well positioned to respond appropriately to most hazard events which the majority of respondents identified as flooding and extreme heat. Departments including but not limited to Emergency Communications, Fire, Police, Public Works, Water, Inspectional Services, Information Technology, and Historical Commission, have trained staff on hazard mitigation.

Capability Gaps: Staff expressed the city's need for more structure to be able to provide clear command and control, well-articulated roles and responsibilities, disaster scenario planning, interdepartmental training, and drilling. This includes a need for expanding training on hazard mitigation to more departments and staff.

6.2.2.2. Internal and External Communications

Communication during a disaster is crucial for ensuring the safety and well-being of the affected community. Effective communication can include alerts and warnings to the public, but also the ability to effectively message expectations and roles internally amongst city staff.

Existing Capabilities: Several departments within the city have Communications Managers, who meet weekly with the Public Information Office to do resource and info sharing. Information from those meetings is sometimes shared with the Language Access Manager and Community Engagement Teams. In addition to internal communications coordination, the Language Access Manager and Community Engagement have developed mechanisms and relationships to convey information to the public through trusted channels of communication.

Capability Gaps: To further enhance hazard mitigation capabilities, departments recognize the need for organizational coordination policy and cross agency training on disaster and resiliency efforts. In addition to information sharing, hardening communication infrastructure was identified to provide continuity of communication during an event.

6.2.2.3. Regional Coordination & Collaboration

It is crucial for the city to maintain close relationships with regional partners to ensure effective communication and coordination. The city contributes to building regional resilience against natural hazards through collaborating with external partners, stakeholders, organizations, and residents.

Existing Capabilities: Examples of collaboration efforts include the Community Development Department (CDD) and the Public Works Department (DPW) working with the Mystic River Watershed Association to develop a proposal for a needs assessment and implementation plan for communicating with frontline communities during climate emergencies. The DPW is also leading regional work to identify and further the implementation of 9 coastal flood pathways from the Mystic and Charles rivers. The team identified nine flood pathways and secured a FEMA grant to further the development of the coastal intervention plans.

And CDD also works with partners in Cambridge to provide access to cooling shelters during heat waves and implemented the "shade as social justice" project working with artists and communities in three neighborhoods to design and deploy shade structures.

The Department of Human Service Programs has supported community partners by providing space when flooding has impacted their programs. The Traffic, Parking, and Transportation Department works with parking garage owners to make parking available to residents during snow emergency parking bans. The Commission for Persons with Disabilities has an advisory board consisting of people with disabilities, family members of people with disabilities, and representatives of city departments. The Cambridge Water Department is a member of the Massachusetts Water Resource Authority with interconnections to their system as a backup water supply. Several departments, including the Fire and Police departments have mutual aid agreements or MOUs to utilize other agencies' resources in times of need to address various hazards and support other communities. The Cambridge Public Health Department is a member of the state-funded Metro Regional Preparedness Coalition, which fosters regional health and medical readiness for emergency events in 60 communities, including Cambridge.

Table 6.1 below lists some of the collaborating partners that city departments rely on to ensure regional and community resilience:

Table 6.1: City Partners

Department	Resources, other City departments, or external partners that departments identified as a collaborator when providing services related to hazards:
City Manager's Office	Fire Department, Police Department, Department of Public Works Massachusetts Emergency Management Agency, Federal Emergency Management Agency
Commission on Persons with Disabilities	Department of Public Works, Cambridge Public Health Department, Community Development Department, Boston Center for Independent Living, Department of Human Services Program,
Community Development	Department of Public Works, Department of Human Services Program, Community Engagement Team, Health Department, Metropolitan Area Planning Council, Heat Health Working Group, non-profits
Emergency Communications	Fire Department, Police Department, Department of Public Works
Fire Department	Massachusetts Emergency Management Agency, MetroFire & Metro Boston Urban Area Security Initiative (UASI)
Historical Commission	Community Development Department, Inspectional Services, Massachusetts Emergency Management Agency
Human Service Programs	Fire Department, Police Department, Cambridge Public Health Department, Department of Public Works, food pantries, faith-based organizations, public housing entities
Police Department	City Manager's Office, Fire Department, Department of Public Works, Cambridge Public Health Department, Police Department, Department of Human Services Program, Massachusetts State Police, Adjacent municipal Police Departments,
Public Health	Fire Department, Cambridge Public Health Department, Department of Human Services Program, food pantries, faith-based organizations,

Department	Resources, other City departments, or external partners that departments identified as a collaborator when providing services related to hazards:
	public housing entities, regional health departments, Massachusetts Department of Public Health
Public Schools	State Department of Education, afterschool care providers, Fire Department, Police Department.
Public Works	City Manager's office; Community Development Department, Water Department, Massachusetts Water Resources Authority, Electrical, Fire, Police, Traffic, Parking, & Transportation, Cambridge, MA Department of Conservation and Recreation, and large private property owners, consultants.
Water Department	Department of Public Works, Fire Department, Police Department, Massachusetts Water Resources Authority

6.2.2.4. Local Committees and Task Forces

Cambridge has an engaged population focused on climate resilience. There are many subgroups within departments, independent community organizations and over 50 commissions and boards with diverse goals and purposes that directly or indirectly contribute to the capabilities of the community to adapt or respond to natural hazards.

Existing Capabilities: Robust interest in the topic of climate change in recent years has led to the development and prioritization of this topic for many organizations. The following provides some examples of the committees and task forces involved in natural hazard planning and response:

- The **Cambridge Climate Committee** (formerly the Climate Protection Action Committee) is composed of community members who take an active interest in climate change issues in Cambridge and who live or work in the city. The City Manager appoints the standing committee as an advisory committee to assist in the implementation of greenhouse gas reduction and climate change preparedness and resilience plans. The Committee serves as a conduit between community members and the city, reviews policy and program proposals, and develops recommendations to the City Manager. (Committee, 2023)

- **The Cambridge Community Corps (C3)** is a program led by the Cambridge Public Health Department. Ambassadors inform the public and answer questions on public health messaging topics such as staying safe during a pandemic, vaccines, safety during periods of extreme heat, mosquito-borne diseases and emergency preparedness.

- **The Community Engagement Team** at the Community Development Department is a multi-lingual team of outreach workers. The team represents the American Born Black community and underserved linguistic communities. The team builds deep relationships with community members and community-based organizations. CET@CDD & DHSP works with communities who are underserved, underheard, and historically excluded to do outreach and engagement within their communities on hazard mitigation and climate change preparedness.

Gaps: The city has worked hard to develop materials to educate and inform the community. There is still work to be done to make materials more accessible and understandable by all community members.

6.2.2.5. Assistance from Non-Governmental Organizations

Nongovernmental organizations including community-based organizations, educational, faith, and cultural institutions, and health and safety services help support the needs of residents and priority populations facing the impacts of natural hazards and climate change. Community organizations and institutions play a role in emergency response and recovery; for example, after a storm a church might collect needed items for residents with damaged homes or provide places for people to stay.

Existing Capabilities: Cambridge is fortunate to be the home of many non-governmental organizations providing support to the community at large. A primary way in which the city utilizes the services of these organizations is to disseminate information to communities who are hard to reach or have a lack of trust in information provided by the government. Social capital, or community resilience, is a key indicator of an individual's ability to prepare, respond, or recover from an adverse event.

- **Community-based organizations (CBOs):** Community resilience if often reliant on the connectedness of community members such as those who have friends or family that can check on them during an extreme event may be safer or recover more quickly. Community organizations, community centers, non-profits, community development corporations, job training centers, art centers, and other CBOs provide the venue for residents to build essential bonds and fill the gaps in feeling connected during a time of crisis. They also may provide financial assistance, educational or material resources, and support related to adverse events.
- **Educational facilities and places of faith:** Educational facilities are often the backbone or heart of a community. They are places to meet friends and neighbors and receive information about what is happening in the community. Pre-schools, elementary schools, high schools, colleges, universities, adult learning centers, tutoring centers, and childcare centers provide spaces to enhance the opportunity to meet other Cambridge residents. These spaces also often play roles in disaster relief providing emergency shelter, supplies, or food to those impacted by storms or other events.

Capability Gaps: Distribution of information to these organizations can be difficult. There are many of these entities in Cambridge and it can be challenging to reach all of them. Additionally, materials have not been developed to reflect the needs of each of the organization's constituents.

6.2.3 | Financial Capabilities

The City of Cambridge has invested in the development of resilient infrastructure and programs in the city through a variety of avenues. The following funding sources are identified in Chapter 7 Mitigation Strategy.

Existing Capabilities: Cambridge manages two primary types of budgets: the operating budget and the capital budget. These budgets serve different purposes and cover distinct types of expenses.

- The operating budget covers day-to-day expenses required to deliver services to residents. It includes costs such as staff wages, office supplies, utilities, and other recurring expenses. Some of this money is typically set aside to provide funding for planned events, such as road salt for winter storm response.
- The capital budget is used for long-term investments in infrastructure and facilities, such as road repairs, machinery, and maintenance. It funds major improvements to city facilities and infrastructure and is based on the first year of needs in the five-year Capital Improvements Program (CIP) Plan. An example of how Cambridge has used this money is to make improvements to the city's stormwater infrastructure.

Capability Gaps: The City is unable to always cover the expenses needed to address climate mitigation due to the competing needs to fund other important initiatives in the city. To supplement this need, the city has applied for grants from the state or federal government. Examples of grant programs which have explicitly address climate resilience and hazard mitigation include EEA's Municipal Vulnerability Preparedness Program and MAPC's Accelerating Climate Resilience Grant Program.

6.2.4 | Education and Outreach

Education and outreach capabilities are essential programs and methods that play a crucial role in communicating about and encouraging risk reduction. By providing people with the knowledge, skills, and values needed to understand and address the impacts of natural hazards, education empowers individuals and communities to act. It helps eliminate fear and facilitates preparedness by providing information. Education can also promote climate-smart behaviors, adaptation, and mitigation, making it essential in creating a more resilient Cambridge.

Existing Capabilities: The city has made a concerted effort to develop public education and materials about climate resilience and hazard mitigation. One example of the city's education and outreach effort is a climate focused public health training curriculum and outreach plan that is currently in development for the Cambridge Community Corps and other partners to use. The city has also developed a flood viewer for residents to look up their risk to flooding and homeowner and small business toolkits provide guidance on how to adapt to flood and extreme heat.

Capability Gaps: One of the challenges for Cambridge is providing emergency response to priority populations before, during, and after natural hazard events. The intent of the city is to provide access to emergency management resources and **enhance the education** of first responders to provide services to persons with disabilities and those with language barriers.

Chapter 7:

Mitigation Actions: Past, Present, and Future

7. Mitigation Actions: Past, Present, and Future

7.1. Overview of Mitigation Actions

The mitigation actions are among the most important components of the Hazard Mitigation Plan. They serve as the blueprint for reducing the potential losses identified in the risk and vulnerability assessment. They can be a measure, project, plan, or activity proposed to achieve the city's mission and goals and reduce current and future vulnerabilities described in the risk assessment (Chapter 5).

There are many distinct types of hazard mitigation actions that generally fall into the following four categories (FEMA, Local Mitigation Planning Handbook, 2023):

Local Plans and Regulations: These actions include government authorities, policies or codes that influence the way land and buildings are developed and built.

Structure and Infrastructure Projects: These actions involve modifying existing structures and infrastructure to protect them from a hazard or remove them from a hazard area. This could apply to public or private structures as well as critical facilities and infrastructure.

Natural Systems Protection and Nature-based Solutions: This type of action can include green infrastructure and low impact development, and bioengineering to incorporate natural features or processes into the built environment to reduce, treat and store rainwater.

Education and Awareness Programs: These types of actions keep residents informed about potential natural disasters. Many of these types of actions are eligible for funding through the FEMA HMA program.

Through a stakeholder and community engagement process discussed in Chapter 2, mitigation actions and an action plan for implementation were developed to help achieve the mitigation goals (See Chapter 1 Section 1.4). This provides a framework to prioritize and implement actions to reduce risks during hazards. Section 7 reviews the mitigation actions created in 2015 and outlines mitigation actions for Cambridge for the next five years.

7.2. Status of 2015 Mitigation Actions

At the April 24, 2023, meeting of the Steering Committee, city staff reviewed the mitigation measures identified in the 2015 HMP and determined whether measures identified in that plan had been implemented or deferred. Implemented projects were categorized as either complete or in progress, with the latter referring to projects still under development or begun but not yet completed. If measures had been deferred, the STC evaluated whether the measure should be deleted or carried forward into this 2023 NHMP Update. The decision on whether to delete or retain a particular measure was based on the STC's assessment of the continued relevance or effectiveness of the measure and whether the deferral of action on the measure was due to the inability of the city to take action on the measure because it is outside of the city's control. Table 7.1 lists all mitigation actions from the 2015 HMP and their current status.

Table 7.1: Status of 2015 HMP Mitigation Actions

2015 HMP Letter Designation	Action	Geographic Coverage	Priority	Timeframe	Status
A	Complete hydraulic modeling for city	City-wide	High	2014-2018	Complete
B	Complete sewer separation and stormwater management program for areas east of Fresh Pond Pkwy (area #6) and between Concord Avenue rotaries and New Street (area #5)	Area Specific	High	2014-2016	Complete
C	Complete sewer separation and stormwater management program for Kirkland Street, Myrtle Street, Magnolia Street	Area Specific	High	2014-2018	In progress *Portions of this are complete. Next phase is Kirkland Street Project,*

2015 HMP Letter Designation	Action	Geographic Coverage	Priority	Timeframe	Status
	and Cambridge Street (CAM #011, areas 18 and 19)				*scheduled for design in FY25.*
D	Complete sewer separation at Porter Square (CAM 002 CSO area)	Area Specific	High	2014-2018	In progress *Scope of this project is part of the updated CSO Control Plan development with MWRA and City of Somerville.*
E	Improve collection and conveyance system at area east of 2nd Street and north of Charles Street (area #27)	Area Specific	High	2014-2018	Complete
F	Implement additional stormwater management measures: School, Pine, Cherry, and Windsor Streets (area #26)	Area Specific	High	2014-2018	In progress *Part of Port Infrastructure Program currently under design.*
G	Complete Cambridgeport stormwater management program:	Area Specific	High	2014-2018	In progress Projects currently under

2015 HMP Letter Designation	Action	Geographic Coverage	Priority	Timeframe	Status
	Newton, Green, Franklin, and Sidney Streets (CAM 017, area #28)				design and construction underway on River Street FY24 which are part of these Cambridgeport improvements
H	Complete sewer separation and stormwater management program for Irving, Bryant, Crescent, Carver, and Sacramento Streets (CAM011, areas #16 and 17)	Area Specific	High	2014-2017	Complete
I	Complete sewer separation and stormwater management program for Ellery Street and Broadway (CAM011, area #24)	Area Specific	High	2014-2017	Complete
J	Establish funding program for residential structural improvements & floodproofing	City-wide	Medium	2016-2018	Deferred
K	Floodplain Management	City-wide	Low	2014-2018	In progress

2015 HMP Letter Designation	Action	Geographic Coverage	Priority	Timeframe	Status
					Ongoing compliance
L	Floodplain Mapping	City-wide	Low	2014-2018	In progress *Flood Viewer was developed and is starting the process to update the data.*
M	Expand program to clear snow and maintain public ROWs (e.g., travel ways for non- vehicular mobility, access for priority populations)	City-wide	Medium	2014-2018	In progress *Always in progress. Biggest challenge is enough equipment and people for bicycle facilities being added and storing of snow.*
N	Determine vulnerability of roadways and utilities to earthquakes in the high liquefaction areas	City-wide	Medium	2016-2018	Deferred
O	Provide facility for additional priority populations	City-wide	Medium	2014-2016	Complete

2015 HMP Letter Designation	Action	Geographic Coverage	Priority	Timeframe	Status
	during extreme temperature event				
P	Increase public education on the benefits and proper care of trees on private property	City-wide	Low	2015-2017	In progress *Ongoing through Urban Forestry Master Plan.*
Q	Complete Climate Change Vulnerability Assessment	City-wide	High	2014	Complete
R	Complete Climate Change Adaptation Plan	City-wide	High	2014-2015	Complete
S	Encourage installation of solar photovoltaic systems, cogeneration, and other energy supplies	City-wide	Low	2014-2017	In-progress *Always in progress. This action continues to be implemented through the Cambridge Energy Alliance program.*
T	Encourage energy efficiency in buildings through zoning requirements and community outreach	City-wide	Low	2014-2017	In progress/ complete *Zoning ordinance implementation is in progress.*

2015 HMP Letter Designation	Action	Geographic Coverage	Priority	Timeframe	Status
U	Evacuation Protocol Review	City-wide	High	2015-2016	Complete
V	Develop program for enhanced staffing for disaster recovery	City-wide	Medium	2014-2016	Deferred
W	Ensure generators are located in areas protected from hazards	City-wide	Medium	2015-2017	Complete
X	Conduct maintenance activities to monitor and reduce brushfire risks	Area Specific	Low	2014-2018	In progress *This action is continually ongoing.*

7.3. Mitigation Action and Adaptation Strategy for 2023-2028

The Planning Committee developed an updated natural hazard mitigation action and adaptation strategy for the 2023 NHMP. There are **44 actions** developed from a multi-faceted approach, including the following:

- The goals and objectives endorsed by the Steering Committee; more detail about this is available in Chapter 1.
- Input from stakeholders through the HMPT workshops and the community through public meetings and survey input; more detail about this is available in Chapter 2.
- A hazard and climate change risk and vulnerability assessment; more detail about this is available in Chapter 3.
- The City's capacity to mitigate and respond to hazard events as described in Chapter 6.
- The progress of actions from the 2015 HMP; more detail about this is available in Chapter 7 Section 7.2.

- Actions included in related plans and reports; more details about this is available in Chapters 2 and 6.

The actions in Chapter 7 include both specific projects and broader results to be achieved by implementing a project. The level of specificity differs based on the input received and the currently available data associated with the mitigation action. In some cases, actions are broader because the specific steps to accomplish the result may not be determined at this point in time. These actions will all be tracked and updated during the quarterly plan maintenance and review, discussed in greater detail in Chapter 8.

7.3.1 | Overview of Mitigation Action Characteristics

Based on each mitigation action characteristic, the city will be able to complete the following:

- assign a lead in-house entity.
- understand general cost and benefit of an action, location, and extent of the action's effort.
- understand available funding source(s).
- determine if the action should start in the short, mid-, or longer portion of the 5-year update.
- tie the action to goals and natural hazards.
- confirm consistency with other local plans.
- and consider equity and inclusion co-benefits.

See definitions as follows.

Lead Department: Many hazard mitigation actions and climate adaptation measures will require a multi-department strategy where several departments share responsibility. The designation of implementation responsibility was assigned based on general knowledge of the responsibility of each department. Additionally, some mitigation actions may require cooperation with outside entities, such as Massachusetts state departments, neighboring communities, regional organizations, or private entities. In those cases, the relevant entities are included in additional to the city department.

Cost: Costs listed in the mitigation action spreadsheet are estimated and are based on the cost of similar projects and professional estimates. Actual costs may vary based on the specific site, project, and scope of work. Cost estimates should be verified during the financial planning stage of a project. For the mitigation action spreadsheet, cost was classified into one of four categories:

- High = Over $1M
- Medium = Over $100 - $1M
- Low = Up to $100K

Geographic Coverage: This column pertains to the geographic area over which a mitigation action will be carried out. Geographic coverage can be classified into one of four categories-

- Regional: a regional mitigation action would extend beyond the city limits of Cambridge and involve regional partners
- City-wide: a city-wide mitigation action pertains to the entire City of Cambridge
- Neighborhood specific: a neighborhood-specific mitigation action applies only within the boundaries of a certain neighborhood or smaller area within the city.
- Site-specific: a site-specific mitigation action applies on the smallest, most localized scale at a specific point within the City of Cambridge

Funding Source: The City's general funds or capital budgets are considered a default potential funding source unless the City pursues additional funding. The identification of potential funding sources is preliminary and may vary depending on numerous factors. These factors include but are not limited to changes in grant eligibility criteria, program objectives, and funding availability. The funding sources identified are not a guarantee that a specific project will be eligible for or receive funding. Upon adoption of this plan, the local representatives responsible for implementation should begin to explore potential funding sources in more detail. Potential grants were assigned based on eligibility and competitiveness, but the recommendations may not be comprehensive. Please note that grant eligibility and scoring criteria should also be reviewed prior to applying. Grants may also only be a source of funding for a single stage of a project. In many cases, the actions will require a combination of funding sources.

- Capital budget.
- Operating budget
- Municipal bond
- Grant funding: refers to any monies that come from federal, state, or local grants.
- Staff time: implies that there is no additional cost associated with implementing this mitigation action other than typical staff hours.

Timeframe to Start: This column indicates whether the action is in progress. If the action is not yet in progress, the estimated time remaining until the project starts is listed.

- In progress
- Less than 1 year
- 1-2 years
- 2-5 years

Associated Goals: This column lists which goals the mitigation action aims to accomplish. Some actions contribute toward more than one goal. The five goals of the Hazard Mitigation Plan are as follows:

- Equitably protect health and safety
- Communicate
- Coordinate and collaborate.
- Sustainably invest.
- Monitor and respond

Hazards: Actions may mitigate a single or multiple hazards, which will be indicated for each action. All the hazards discussed in Chapter 3 were addressed when developing the priority list, and there is at least one action associated with each hazard. Some actions address all hazards and are listed as such.

Consistency with Other Plans: It is crucial that the Hazard Mitigation Plan be aligned with other long-range planning documents for the City of Cambridge. This column demonstrates areas where mitigation actions overlap with the intent of other planning documents.

Inclusion and Equity/Co-Benefits: The City of Cambridge recognizes the importance of equity in hazard mitigation planning. Inclusion and equity are vital so that all voices are heard during the planning and implementation processes. Actions were developed with equity and inclusion in mind. Some actions also have indirect benefits associated with them, also known as "co-benefits." There are many co-benefits associated with the City of Cambridge's mitigation actions. Some include:

- A positive impact on students
- A positive impact on priority populations
- Enhances community education.
- A positive impact on renters
- Equitable implementation

7.3.2 | Prioritization

Actions were prioritized based on based on staff capacity and available funding. Staff capacity was assessed in Chapter 6 – Capabilities Assessment. Priority was given to actions which also have a high likelihood of receiving federal, state, or local funding. The questions to assess likelihood of funding were:

- Does this action contribute to regional resilience?
- Is the action part of other plans?

- Does the action positively impact residents of Low to Moderate Income (LMI) or Environmental Justice (EJ) census block groups (based on EEA's viewer)?
- Is this action a nature-based solution?
- Would the action mitigate economic loss/damage?
- Will the action reduce risk to life/safety?
- Does the action address future climate change projections?
- Does the action leverage innovation/technology?

7.3.3 | Funding Sources

Traditional funding sources within the City of Cambridge, such as funding from capital budgets, operating budgets, municipal bonds, and staff time, should cover the majority of costs associated with the mitigation action items detailed in Table 7-2. This has been noted in the funding source column in Table 7-2.

Grant funding is another option. There are a variety of funding sources available for Massachusetts municipalities, both through the state and federal governments. A full list of funding opportunities can be found on the Community Grant Finder webpage: https://www.mass.gov/lists/community-grant-finder#community-development-. The Community Grant finder provides a streamlined interface where municipalities can easily learn about grant opportunities. Table 7-2 notes where grant funds are a desired source of funding for a mitigation action.

Table 7.2: 2023 NHMP Mitigation Actions

#	Action	Lead Dept	Cost	Geographic Coverage	Funding Source	Timeframe to Start	Associated Goal(s)	Hazards	Consistency with Other Plans	Enhances Inclusion and Equity / Co-Benefits	Priority
			High = $1M Medium = Over $100k up to $1M Low = Up to $100k	regional city-wide neighborhood specific site specific	Capital Budget Operating Budget Municipal Bond Grant Staff Time	In Progress Less than 1 year 1-2 years 2-5 years	1. Equitably Protect health and safety 2. Communication 3. Coordinate and Collaborate 4. Sustainably invest 5. Monitor and Respond			Positive Impact on Priority Populations Positive Impact on Renters Positive Impact on Students Enhances Community Education Equitable Implementation	
1	Improve collection and conveyance system in the Port Neighborhood.	Department of Public Works	High	Neighborhood specific	Municipal Bond	In progress	#1 Protect, #4 Sustainably Invest	Precipitation Flooding	DPW 10-year Sewer Plan - Goal 4: Manage stormwater quality and quantity	Equitable Implementation	High
2	Identify areas for green stormwater infrastructure and reducing impervious surfaces	Department of Public Works	Medium	City-Wide	Bond/Capital funding	In progress	#4 Sustainably Invest	Precipitation Flooding	Resilient Cambridge Handbook -Strategy D3: Reduce Impervious Area - Strategy D4: Seek Green Infrastructure Opportunities		High
3	Upgrade sewer and stormwater infrastructure to reduce flooding (and CSOs)	Department of Public Works	High	City-Wide	Municipal Bond / Grant Funding	In progress	#1 Equitably protect health and safety	Precipation Flooding	CSO Control Plan	Positive Impact on Priority Populations Positive Impact on Renters Positive Impact on Students	High
4	Design and construct updates to metering stations for Combined Sewers	Department of Public Works	Medium	City-Wide	Capital Budget	In progress	#5 Monitor & Respond	Precipitation Flooding	DPW 10-year Sewer Plan - Goal 4: Manage stormwater quality and quantity. Resilient Cambridge Handbook - Strategy C5: Upgrade Stormwater Storage		Medium
5	Undertake interventions as a regional collaboration at Charles River and Amelia Earhart Dam to reduce overtopping/flanking	Department of Public Works, Town of Arlington	High	Regional	Grant	In progress	#3 Coordinate & Collaborate, #4 Sustainably Invest	Coastal Flooding	Resilient Cambridge Handbook - Strategy A7: Enhance Emergency Response Plans	Positive Impact on Priority Populations	High
6	Upgrade deicing / snow removal equipment, including smaller equipment that is able to accommodate bicycle facilities and pedestrian paths	Department of Public Works	Medium	City-Wide	Operating Budget	In progress	#5 Monitor & Respond	Winter Storms	Resilient Cambridge Handbook - Strategy A7: Enhance Emergency Response Plans	Positive impact on students, positive impact on Priority Populations	High
7	Complete study to evaluate shade needs (other than trees) referred to as "The Shade Study", and implement recommendations (e.g., adding shade structures)	Community Development Department	Low	City-Wide	Operating Budget	In progress	#1 Protect	Extreme Heat	Resilient Cambridge Handbook - Strategy A2: Enhance Resilient Public Amenities	Positive impact on Priority Populations, Equitable implementation	High
8	Install water fountains and cooling features locations along bus/bike routes	Department of Public Works, Community Development Department	Medium	City-Wide	Bond funding and participatory budget	In progress	#1 Protect, #5 Monitor & Respond	Extreme Heat	Resilient Cambridge Handbook - Strategy A2: Enhance Resilient Public Amenities	Positive Impact on Students Positive Impact on Priority Populations	High

#	Action	Lead Dept	Cost	Geographic Coverage	Funding Source	Timeframe to Start	Associated Goal(s)	Hazards	Consistency with Other Plans	Enhances Inclusion and Equity / Co-Benefits	Priority
			High = $1M Medium = Over $100k up to $1M Low = Up to $100k	regional city-wide neighborhood specific site specific	Capital Budget Operating Budget Municipal Bond Grant Staff Time	In Progress Less than 1 year 1-2 years 2-5 years	1. Equitably Protect health and safety 2. Communication 3. Coordinate and Collaborate 4. Sustainably invest 5. Monitor and Respond			Positive Impact on Priority Populations Positive Impact on Renters Positive Impact on Students Enhances Community Education Equitable Implementation	
9	Update and Improve Floodplain Mapping (Cambridge Flood Viewer)	Department of Public Works	Low	City-Wide	Operating Budget	In progress	#2 Communication	Precipitation Flooding, Coastal Flooding	Resilient Cambridge Handbook - Strategy A7: Enhance Emergency Response Plans	Enhances Community Education, Equitable Implementation	High
10	Encourage energy efficiency in buildings through zoning requirements and community engagement and support	Community Development Department	Low	City-Wide	Staff Time	In progress	#5 Monitor & Respond	Extreme Heat, Extreme Cold	Net Zero Action Plan. Resilient Cambridge Handbook - Strategy B9: Encourage Resiliency of Building Scale Energy	Positive impact on renters	Low
11	Identify recommendations for municipal facility improvements for resiliency, including an updated flood duration study using MC-FRM	Facilities Department	Low	City-Wide	Municipal Bond	In progress	#3 Coordinate & Collaborate	Extreme Heat, Precipitation Flooding, Coastal Flooding			Medium
12	Implement actions of Cambridge Urban Forest Master Plan	Department of Public Works, Community Development Department	Low	City-Wide	Operating Budget	In progress	#1 Protect, #4 Sustainably Invest	Extreme Heat, Precipitation Flooding, Drought	Cambridge Urban Forest Master Plan - Action #31: Increase current efforts to coordinate and implement community-based tree planting, and other urban forest stewardship activities, across different neighborhoods and land uses in the City.	Positive impact on Priority Populations	High
13	Continue to engage with the Charles River Climate Compact and Mystic River Watershed Association on regional collaboration	Department of Public Works, Community Development Department	Low	Regional	Operating Budget	In progress	#3 Coordinate & Collaborate	Precipitation Flooding, Coastal Flooding, Extreme Heat			Medium
14	Prioritize clean energy solutions for power such as solar, battery, geothermal, etc. where feasible	Department of Public Works, CDD	Low	City-Wide	Capital Budget and Grant funds	In progress	#5 Monitor & Respond	All	Resilient Cambridge Handbook - Strategy C6: Support Sustainable Energy Infrastructure		Low
15	Begin to develop a central emergency response plan and centralize emergency response within the city	City Manager	Low	City-Wide	Operating Budget	Less than 1 year	#3 Coordinate & Collaborate	All		Positive Impact on Priority Populations, Equitable implementation	Medium

#	Action	Lead Dept	Cost	Geographic Coverage	Funding Source	Timeframe to Start	Associated Goal(s)	Hazards	Consistency with Other Plans	Enhances Inclusion and Equity / Co-Benefits	Priority
			High = $1M Medium = Over $100k up to $1M Low = Up to $100k	regional city-wide neighborhood specific site specific	Capital Budget Operating Budget Municipal Bond Grant Staff Time	In Progress Less than 1 year 1-2 years 2-5 years	1. Equitably Protect health and safety 2. Communication 3. Coordinate and Collaborate 4. Sustainably invest 5. Monitor and Respond			Positive Impact on Priority Populations Positive Impact on Renters Positive Impact on Students Enhances Community Education Equitable Implementation	
16	Coordinate with the MBTA their efforts to protect critical regional transit infrastructure in Cambridge	Traffic, Parking, and Transportation; CDD; DPW	Low	Regional	Grant	Less than 1 year	#3 Coordinate & Collaborate, #4 Sustainably Invest	All			High
17	Collaborate with energy providers to protect critical community infrastructure	Department of Public Works	Medium	Regional	Operating Budget	Less than 1 year	#3 Coordinate & Collaborate, #4 Sustainably Invest	All	Resilient Cambridge Handbook - Strategy C2: Increase the Resiliency of the Electrical Distribution System	Positive impact on Priority Populations, Equitable implementation	High
18	Extend swimming pool operational hours and season	Human Services and DCR	Low	City-Wide	Operating Budget	1-2 years	#1 Protect	Extreme Heat	Resilient Cambridge Handbook - Strategy A2: Enhance Resilient Public Amenities	Positive impact on Priority Populations, Equitable implementation	Low
19	Perform a study to evaluate the replacement of manually operated components with remote operated components, including the evaluation of cybersecurity vulnerability of the public water supply system	Water Department	High	City-Wide	Operating Budget	1-2 years	#5 Monitor & Respond	Loss of Water Supply	DPW 10-year Sewer Plan - Goal 1: Address high-risk infrastructure conditions		Medium
20	Conduct maintenance activities to monitor and reduce brushfire risks	Fire	Low	City-Wide	Staff Time	1-2 years	#5 Monitor & Respond	Brushfire			Low
21	Update the climate change vulnerability assessment to include up-to-date climate information	Department of Public Works, Community Development Department	Low	City-Wide	Bond/Capital funding	1-2 years	#3 Coordinate & Collaborate	Extreme Heat, Precipitation Flooding, Coastal Flooding	2015 CCVA		Medium
22	Integrate resiliency strategies and considerations into implementation of open space projects.	Department of Public Works, Community Development Department	Low	City-Wide	Capital Budget	1-2 years	#1 Protect	Extreme Heat, Precipitation Flooding, Drought	Resilient Cambridge D recommendations	Positive impact on Priority Populations	Medium
23	Develop an operations plan for DPW and Police on how to respond to flooding in the roadway	Department of Public Works and Police	Low	City-Wide	Operating Budget	1-2 years	#1 Protect, #5 Monitor & Respond	Precipitation Flooding, Coastal Flooding	Resilient Cambridge Handbook - Strategy C3: Enhance the Resiliency of the Transportation System	Equitable implementation	Medium
24	Succession planning should be integrated into the City's Continuity of Operations Plan (COOP) and revisited on a yearly basis by June 30 of every year and updated to reflect staff changes and required trainings for staff identified as part of the planning process	Emergency Management Director, police, fire, health	Low	City-Wide	Operating Budget	1-2 years	#5 Monitor & Respond	All	2015 HMP		Medium

#	Action	Lead Dept	Cost	Geographic Coverage	Funding Source	Timeframe to Start	Associated Goal(s)	Hazards	Consistency with Other Plans	Enhances Inclusion and Equity / Co-Benefits	Priority
			High = $1M Medium = Over $100k up to $1M Low = Up to $100k	regional city-wide neighborhood specific site specific	Capital Budget Operating Budget Municipal Bond Grant Staff Time	In Progress Less than 1 year 1-2 years 2-5 years	1. Equitably Protect health and safety 2. Communication 3. Coordinate and Collaborate 4. Sustainably invest 5. Monitor and Respond			Positive Impact on Priority Populations Positive Impact on Renters Positive Impact on Students Enhances Community Education Equitable Implementation	
25	Develop an emergency community support reference guide which provides a list of health services which are operational during extreme events for community reference(i.e. dialysis centers)	Public Health Dept., Community Development Department	Low	City-Wide	Operating Budget	1-2 years	#1 Protect, #2 Communications	All	Resilient Cambridge Handbook - Strategy A3: Create Support Systems for Populations at Risk	Enhances community education	Low
26	collaborate with Cambridge public housing authority and community centers to identify community rooms to use as cooling centers and shelters during storms	The new emergency management department	Low	Site Specific	Staff Time	1-2 years	#1 Protect	All	Resilient Cambridge Handbook - Strategy A1: Provide Neighborhood Resilience Hubs	Positive impact on renters, Positive impact on Priority Populations, Equitable implementation	Low
27	Coordinating with adjacent communities for hazard preparation and response	Department of Public Works	Low	Regional	Operating Budget	1-2 years	#3 Coordinate & Collaborate	All	Resilient Cambridge Handbook - Strategy A7: Enhance Emergency Response Plans		Medium
28	Create an emergency response higher education and city collaboration plan	emergency management department	Low	Site specific	Staff Time	1-2 years	#3 Coordinate & Collaborate, #5 Monitor & Respond	All	Resilient Cambridge Handbook - Strategy A7: Enhance Emergency Response Plans	Positive impact on students, Positive impact on Priority Populations, equitable implementation	Low
29	Conduct study to identify how to engage with the disability community during an emergency.	Commission of Persons with Disabilities Cambridge Public Health	Low	City-Wide	Operating Budget	1-2 years	#1 Protect	All		Positive Impact on Priority Populations, Enhances Community Education	Low
30	Develop an annual media campaign about signing up for code red notifications	Emergency Communications	Low	City-Wide	Operating Budget	1-2 years	#2 Communication	All		Enhances Community Education, Equitable implementation	Medium
31	Provide a central location on the City's website to provide up-to-date notification and items such as extreme weather, air quality alerts, etc.	Emergency Communications City Comms Staff	Low	City-Wide	Staff Time	1-2 years	#2 Communication	All	Resilient Cambridge Handbook - Strategy A4: Strengthen Emergency Communication Systems	Enhances Community Education	Medium
32	Purchase emergency radios for critical staff to utilize when an emergency event is expected where power and cell phone service may be compromised. Develop a plan for distribution and use.	Department of Public Works	Medium	City-Wide	Operating Budget	1-2 years	#5 Monitor & Respond	All	Resilient Cambridge Handbook - Strategy A4: Strengthen Emergency Communication Systems		Medium
33	Each department shall ensure identified staff have been trained in ICS and NIMS and continuing education and training shall be determined by each department head or training division	Emergency Management Director, police, fire, health	Low	City-Wide	Operating Budget	1-2 years	#1 Equitably protect health and safety	All			High

#	Action	Lead Dept	Cost	Geographic Coverage	Funding Source	Timeframe to Start	Associated Goal(s)	Hazards	Consistency with Other Plans	Enhances Inclusion and Equity / Co-Benefits	Priority
			High = $1M Medium = Over $100k up to $1M Low = Up to $100k	regional city-wide neighborhood specific site specific	Capital Budget Operating Budget Municipal Bond Grant Staff Time	In Progress Less than 1 year 1-2 years 2-5 years	1. Equitably Protect health and safety 2. Communication 3. Coordinate and Collaborate 4. Sustainably invest 5. Monitor and Respond			Positive Impact on Priority Populations Positive Impact on Renters Positive Impact on Students Enhances Community Education Equitable Implementation	
34	Design and construct sewer separation work for the Baldwin neighborhood	Department of Public Works	medium	Neighborhood specific	Municipal Bond	2-5 years	#1 Protect, #4 Sustainably Invest	Precipitation Flooding	DPW 10-year Sewer Plan - Goal 4: Manage stormwater quality and quantity. Resilient Cambridge Handbook - Strategy C5: Upgrade Stormwater Storage.		Low
35	Update and improve the City's HeatViewer with best available information	Department of Public Works, Community Development	Low	City-Wide	Operating Budget	2-5 years	#2 Communication	Extreme Heat		Enhances Community Education, Equitable Implementation	Medium
36	Perform a study to identify how to best protect Fresh Pond reservoir from saltwater intrusion	Department of Public Works	Low	Site Specific	Capital Budget	2-5 years	#1 Protect, #3 Coordinate & Collaborate, #4 Sustainably Invest	Coastal Flooding	Resilient Cambridge Handbook -Strategy C1: Protect Fresh Pond Reservoir	Equitable Implementation	Low
37	Prepare an Earthquake Emergency Plan	emergency management director, Police Department, CDD, Fire Department	Low	City-Wide	Staff Time	2-5 years	#1 Protect, # Monitor & Respond	Earthquake	Resilient Cambridge Handbook - Strategy A7: Enhance Emergency Response Plans	Positive Impact on Students, Positive Impact on Renters, Equitable Implementation	Low
38	Prepare a Pest Vulnerability Matrix using the most recent tree inventory and develop a management options report	Department of Public Works	Low	City-Wide	Grant	2-5 years	4. Sustainably Invest, #5 Monitor & Respond	Invasive Species	Cambridge Urban Forest Master Plan - Action #24: Prepare a Pest Vulnerability Matrix or similar pest and disease threat assessment and management options report utilizing 2014 street tree inventory data		Low
39	Create a program that offers support to property owners located in the 2070 10% flood area, as determined by the City's flood viewer, to help them make improvements that increase the resiliency of their properties against flooding.	Department of Public Works	Medium	City-Wide	Grant	2-5 years	#1 Protect	Precipitation Flooding, Coastal Flooding	2015 HMP Resilient Cambridge Handbook - Strategy B3: Encourage Flood Protection for Existing Buildings	Positive impact on Priority Populations, positive impact on renters	Low
40	Perform a vulnerability assessment of vaults where hard copy records are kept	Department of Public Works	Low	Site specific	Grant	2-5 years	#3 Coordinate & Collaborate, #5 Monitor & Respond	Precipitation Flooding, Coastal Flooding	Resilient Cambridge Handbook - Strategy B10: Develop Flood Protection and Operations Planning for Historic and Critical Facilities		Low

#	Action	Lead Dept	Cost	Geographic Coverage	Funding Source	Timeframe to Start	Associated Goal(s)	Hazards	Consistency with Other Plans	Enhances Inclusion and Equity / Co-Benefits	Priority
			High = $1M Medium = Over $100k up to $1M Low = Up to $100k	regional city-wide neighborhood specific site specific	Capital Budget Operating Budget Municipal Bond Grant Staff Time	In Progress Less than 1 year 1-2 years 2-5 years	1. Equitably Protect health and safety 2. Communication 3. Coordinate and Collaborate 4. Sustainably invest 5. Monitor and Respond			Positive Impact on Priority Populations Positive Impact on Renters Positive Impact on Students Enhances Community Education Equitable Implementation	
41	Develop flood protection and operations planning for historic and critical facilities.	Community Development Department	Low	City-Wide	Grant	2-5 years	#3 Coordinate & Collaborate	Precipitation Flooding, Coastal Flooding, Extreme Heat	Resilient Cambridge Handbook - Strategy B10: Develop Flood Protection and Operations Planning for Historic and Critical Facilities		Medium
42	Develop and update materials to support homeowners in completing retrofits related to flooding & heat (e.g., trainings, & educational materials on funding assistance)	Department of Public Works, Community Development Department	Low	City-Wide	Operating Budget	2-5 years	#1 Protect	Extreme Heat, Precipitation Flooding, Coastal Flooding	Resilient Cambridge Handbook - Strategy B5: Support Building Management for Flood and Heat Protection	Positive impact on Priority Populations, Equitable implementation	Low
43	Evaluate use of Microgrid(s) for critical facilities and implement recommendations	Community Development Department, Capital Building Projects Department, and DPW (Buildings & Electrical)	Medium	Site specific	Grant	2-5 years	#5 Monitor & Respond	All	Resilient Cambridge Handbook - Strategy C2: Increase the Resiliency of the Electrical Distribution System		Medium
44	Develop an enhanced communication plan and program related natural hazards in collaboration with community groups	CDD, public health, and public safety staff (Police, Fire, and Emergency	Low	City-Wide	Grant	2-5 years	#2 Communication	All		Positive Impact on Priority Populations, Enhances Community Education, Equitable implementation	Low

Chapter 8:

Plan Maintenance

8. Plan Maintenance

Hazard Mitigation Plans are intended to serve as living documents. To be impactful, they must be regularly updated to reflect the current state of hazards, vulnerabilities, goals, strategies, and public sentiment. The three main components of plan maintenance are: *monitoring*, *evaluating*, and *updating* the plan.

Included in this chapter is a multi-pronged strategy to always keep the city's Natural Hazard Mitigation Plan as effective as possible. Monitoring, evaluating, and updating the plan will be intertwined with public engagement, integration with other local, regional, and state planning mechanisms, and plan implementation. These processes will all run on an ongoing basis with the expectation there is coordination and collaboration between monitoring, evaluating, and updating the plan.

A representative from the City Manager's Office will take ownership of monitoring, evaluating, and updating the plan.

The representative from the City Manager's Office will:

- Track the progress of the NHMP Mitigation Actions (see Section 8.1).
- Reconvene the Steering Committee annually to monitor, evaluate, update, and integrate the plan (see Section 8.1, 8,.2, 8.3, and 8.4).
- Share NHMP progress with the public, every thirty months. (See Section 8.5).
- Make all monitoring information publicly available (see Section 8.1).
- Notify the public when added information has been posted or updated (see Section 8.5; and
- Provide the public opportunities to give input on this information (see Section 8.5).

8.1. Monitoring the Plan

According to FEMA, monitoring means tracking the implementation of the NHMP over time.

Who: The representative from the City Manager's Office will take ownership of monitoring the plan.

How: The representative from the City Manager's Office will monitor the status of mitigation actions (Chapter 8) through an internal tracking system using Excel. This documentation should be made publicly available on a website.

When: Monitoring will take place on an ongoing basis with annual meetings of the Steering Committee to formally update the status of Mitigation Actions. In advance of this meeting, the representative from the City Manager's Office will send out notices to the Steering Committee that will include a shared document where all Committee members can collaborate to review status of mitigation actions and identify any new mitigation actions that may be under consideration or in progress as part of ongoing City efforts.

8.2. Evaluating the Plan

According to FEMA, evaluating means assessing the effectiveness of the plan at achieving its stated purpose and goals.

Who and When: The Steering Committee will meet annually, ideally before the budget season, to evaluate the effectiveness of the plan. The Steering Committee may also be called to meet after a major event or storm to evaluate the effectiveness of the plan.

How: The Steering Committee will:

- Review the 2023 NHMP Goals and Objectives presented in Chapter 1; and
- Discuss how mitigation actions are or are not meeting 2023 NHMP Goals and where improvements or adjustments may be needed (e.g., re-prioritization of projects, integrating with other planning processes more effectively, adding new data to climate projections, etc.)

8.3. Updating the Plan

8.3.1 | Plan Updates to Maintain FEMA Funding Eligibility

According to FEMA, updating means reviewing and revising the NHMP at least once every five years.

Hazard Mitigation Plans expire five years from the date approved by FEMA. To maintain eligibility for certain types of non-emergency disaster assistance from FEMA, an entity such as the City of Cambridge must have an approved active Hazard Mitigation Plan.

Hazard Mitigation Plans should be reviewed and updated at least every five years. The representative from the City Manager's Office will initiate the process to complete a comprehensive update to the NHMP. As a best practice, the comprehensive update should be initiated at least 18 months prior to this NHMP's expiration. This process includes:

- Re-engaging the Steering Committee.
- Considering expansion of the Steering Committee.
- Confirming FEMA's and MEMA's most recent requirements and guidance.
- Gathering updated information and relevant documents.
- Defining a list of stakeholders (such as the HMPT discussed in Chapter 2).
- Initiating an outreach and engagement process, as appropriate.
- Undertaking the planning steps to prepare required Plan sections; and
- Completing and reviewing the draft Plan and submitting for approval.

The city may elect to complete this process in-house or with guidance from an outside contractor.

8.3.2 | Plan Updates Due to Major Disaster Events or New Conditions

FEMA recommends that NHMPs also be revisited and updated after a major disaster event (a State or Federally declared disaster) or if new conditions significantly change risk (such as new climate projections or local risk and vulnerability assessment efforts). The representative from the City Manager's Office will initiate the process to complete any updates needed in these circumstances. The decision to update the plan will be based on the annual monitoring and evaluation process.

8.4. Integrating the NHMP

To be impactful, the NHMP must be effectively integrated into other City planning mechanisms. This will increase co-benefits of hazard mitigation projects, streamline planning and implementation activities, and help secure funding for NHMP projects.

Integrating the ideas, information, and strategy of a mitigation plan into other planning mechanisms can be achieved through plan integration. Plan integration involves a two-way exchange of information and incorporation of ideas and concepts between hazard mitigation plans and other planning mechanisms. Some ways Cambridge will integrate the ideas, information, and strategy of a mitigation plan into other planning mechanisms are:

Building and Zoning Regulations: The local hazard mitigation plan can integrate with building and zoning regulations to ensure that new construction and development are designed to withstand potential hazards.

Community Plans: Community planning mechanisms can be integrated into hazard mitigation plans to ensure that community needs and concerns are considered when developing hazard mitigation strategies. As other local plans, such as Envision Cambridge, Resilient Cambridge, the Urban Forest Master Plan, and the Parks & Open Space Plan, are reviewed and updated, relevant information from this NHMP will be incorporated. Funding to undertake mitigation actions described in Chapter 7 will be included in the city's budget process.

Emergency Management Plan: The local hazard mitigation plan can integrate with the relevant emergency management plans led by staff in the Police, Fire, and Health Departments, to ensure that hazard mitigation strategies are coordinated with emergency response efforts. In addition, mitigation actions included in Chapter 7 will be incorporated into the budgeting process for Police, Fire, and Health Departments.

Partnerships: Developing strong partnerships between planners and emergency managers can help to fully integrate land use and hazard planning efforts. For example, staff from CDD work collaboratively with the Cambridge Public Health Department to plan for and employ public health emergency response.

Integration will be a topic of discussion at each annual update meeting. NHMP goals and mitigation actions will be integrated into other City planning mechanisms. At each annual Steering Committee meeting, there will be an update on the progress of integration of mitigation actions into relevant planning mechanisms and a discussion of other planning mechanisms that should be integrated into the next five-year NHMP update.

8.5. Public Participation throughout Plan Maintenance

Public engagement is a critical part of the plan maintenance process. Public input, education, and support are crucial to ensuring that the plan is effective, equitable, and impactful. During this project, a StoryMap was prepared to document findings and can be updated as a reference point for the public.

A coordinated public engagement effort will be led by the representative from the City Manager's Office, however, should be coordinated or delegated to community engagement staff to ensure alignment with other City outreach efforts.

Below are four categories of engagement activities that will solicit diverse types of results.

- **Public Education** activities are solely focused on transparency and providing the public with information regarding the monitoring, evaluation, and implementation of the Plan. Additionally, providing supporting general education on how to make individualized hazard preparedness plans for households.
- **Public Input** activities are focused on soliciting feedback, ideas, concerns, and other input. These activities will aim to be as inclusive and accessible as possible. Public input intends to gather feedback from all communities, particularly those who are:
    - most affected by hazards
    - underheard
    - underserved
    - historically excluded.
- **Active Engagement** refers to the steering committee’s role to continue monitoring and adjusting to the effectiveness, performance, and equity of the NHMP as it goes through maintenance, implementation, and integration with other planning mechanisms.
- **Reactionary Engagement** refers to activities that directly follow a large storm or event. These activities will be particularly concerned with the safety of residents, performance of projects, and impacts on priority populations.

Below are activities in each of these categories that the City may undertake, as appropriate for the situation, at the discretion of the representative from the City Manager's Office, and the Steering Committee:

Chapter 9:

Plan Adoption

9. Plan Adoption

Once the draft of the Cambridge Natural Hazard Mitigation Plan is reviewed by the STC, HMPT, and the general public, the Plan is reviewed by MEMA and FEMA. When the Plan is finally approved by FEMA, it enters into the five year “maintenance” phase.

This Section describes the timeline for plan adoption and includes documentation of the Plan adoption by the City Council.

9.1. Timeline for Plan Adoption

The timeline for Plan Adoption is as follows:

12/5/2023	Recommendation from the City Council's Health and Environment Committee to appear on Council agenda (Appendix D)
DATE	Adoption of the Plan by the City Council.
DATE	The Cambridge Natural Hazard Mitigation Plan was submitted to MEMA.
DATE	MEMA reviewed the Plan and returned it to the City with required edits.
DATE	The Cambridge Natural Hazard Mitigation Plan was submitted to FEMA for final review.
DATE	FEMA issued an Approved Pending Adoption status.

9.2. Plan Adoption

The Certificate of Adoption is provided on the following page.

City of Cambridge

IN CITY COUNCIL
___________, 2023

CITY OF CAMBRIDGE, MASSACHUSETTS
RESOLUTION NO. _____________

A RESOLUTION OF THE CITY OF CAMBRIDGE ADOPTING THE 2023 HAZARD MITIGATION PLAN UPDATE

MAYOR SIDDIQUI

WHEREAS the City Council recognizes the threat that natural hazards pose to people and property within the City of Cambridge; and

WHEREAS the City of Cambridge has prepared a multi-hazard mitigation plan, hereby known as the City of Cambridge 2023 Natural Hazard Mitigation Plan Update, in accordance with federal laws, including the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended; the National Flood Insurance Act of 1968, as amended; and the National Dam Safety Program Act, as amended; and

WHEREAS the City of Cambridge 2023 Natural Hazard Mitigation Plan Update identifies mitigation goals and actions to reduce or eliminate long-term risk to people and property in the City of Cambridge from the impacts of future hazards and disasters; and

WHEREAS duly-noticed public meetings on the 2023 Natural Hazard Mitigation Plan Update were held by the City on June 13, 2023 and two on October 25, 2023; and

WHEREAS the City Council authorizes Departments to executive their responsibilities demonstrated in the 2023 Natural Hazard Mitigation Plan Update; and

WHEREAS adoption by the City Council demonstrates its commitment to hazard mitigation and achieving the goals outlined in the City of Cambridge 2023 Natural Hazard Mitigation Plan Update; now therefore be it

Resolved: That in accordance with M.G.L. 40 §4 or the charter and ordinances of the City of Cambridge, the City Council adopts the City of Cambridge 2023 Natural Hazard Mitigation Plan Update. While content related to the City of Cambridge may require revisions to meet the plan approval requirements, changes occurring after adoption will not require the City of Cambridge to re-adopt any further iterations of the plan. Subsequent plan updates following the approval period for this plan will require separate adoption resolutions.

In City Council __________, 2023.
Adopted by a yea and nay vote:-
Yeas __; Nays___; Absent___.
Attest:- _________________, City Clerk
A true copy;

ATTEST:-
________________, City Clerk

Glossary

Glossary of Terminology

Terms	Description	Options or Examples
1% Annual Storm or 100-year 24-hour Precipitation Event	A 24-hour storm that has a 1% chance of happening in any year.	
100-year floodplain	Area with a 1% annual chance of flooding (or 1 in 100 chance)[1]. Also known as a 1% Annual Exceedance Probability (AEP) flood event (see definition for Annual Exceedance Probability below).	Flood Insurance Rate Maps (FIRM) show the extent of the FEMA-defined 100-year floodplain. See definition for Flood Insurance Rate Map below.
500-year floodplain	Area with a 0.2% annual chance of flooding (or 1 in 500 chance).[1] Also known as a 0.2% Annual Exceedance Probability (AEP) flood event (see definition for Annual Exceedance Probability below).	Flood Insurance Rate Maps (FIRM) show the extent of the FEMA-defined 500-year floodplain. See definition for Flood Insurance Rate Map below.
Adaptive Capacity	The ability of a system, service, or asset to adapt or prepare for an anticipated hazard or climate impact.	Buildings that have been floodproofed or elevated have a better chance of withstanding impacts from flooding.
Analyzing a comprehensive range	Considering mitigation alternatives spanning all types of solutions. These may include local plans and regulations, structure and infrastructure projects, natural systems protection, and education and awareness programs. This analysis helps a jurisdiction select actions for implementation, based on each jurisdiction's capabilities, as well as the social, technical and economic feasibility of the action.[2]	

1 Federal Emergency Management Agency (FEMA), "Flood Zones." https://efotg.sc.egov.usda.gov/references/public/NM/FEMA_FLD_HAZ_guide.pdf

2 FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
Annual Exceedance Probability (AEP)	Probability of a flood event being equaled or exceeded in a given year.	The 0.2% AEP flood event has a 1 in 500 chance of being equaled or exceeded in any year (return period of 500 years, "500-year flood").
Approvable Pending Adoption	The plan has met the elements in the Local Plan Requirements but has not yet been officially adopted by the participating communities.[3]	
Assets	Resources, both physical and human, that contribute to a community's well-being and resilience.	People, Structures, Systems, Resources, and Activities
Assets	Determined by the community and include, but are not limited to: people; structures; systems; natural, historic, and cultural resources; and/or activities that have value to the community.[4]	
Biodiversity	Biodiversity is the variety of all forms of life and it is essential to the existence and proper functioning of all ecosystems (see Ecosystem definition below).	
Boston Harbor Flood Risk Model (BH-FRM)	A hydrodynamic model created in 2015 to identify projected flood risk and depth from coastal storms and sea level rise.	
Capability Assessment	An evaluation of the abilities and resources that are already in place in the city to reduce hazard risk.	Laws, policies, programs, staff, funding and other resources, to carry out the HMP and increase resilience.
Capital Improvement	Long-term investments in physical infrastructure and facilities aimed at reducing vulnerabilities to hazards and enhancing overall community resilience.	

[3] FEMA Local Mitigation Planning Policy Guide, 2022
[4] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
Changes in development	means recent development (for example, construction completed since the last plan was approved), potential development (for example, development planned or under consideration by the jurisdiction), or conditions that may affect the risks and vulnerabilities of the jurisdictions (for example, climate change, declining populations or projected increases in population, or foreclosures) or shifts in the needs of underserved communities or gaps in social equity. This can also include changes in local policies, standards, codes, regulations, land use regulations and other conditions.[5]	
Climate Change	According to the Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) climate change refers to "a change in the state of the climate that can be identified by statistical changes of its properties that persist for an extended period, whether due to natural variability or as a result of human activity."[6]	Temperatures are increasing, rainfall events are becoming more frequent and intense, and sea levels are rising.
Climate Change	Refers to "changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events, and changes to other features of the climate system." (U.S. Global Change Research Program, 4th National Climate Assessment).[7]	

[5] FEMA Local Mitigation Planning Policy Guide, 2022
[6] Massachusetts State Hazard Mitigation and Climate Adaptation Plan, 2018. https://www.mass.gov/service-details/massachusetts-integrated-state-hazard-mitigation-and-climate-adaptation-plan
[7] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
Climate Vulnerable Populations	Climate vulnerable populations are those who have lower adaptive capacity or higher exposure and sensitivity to climate hazards like flooding or heat stress due to factors such as access to transportation, income level, disability, racial inequity, health status, or age.	Climate vulnerable populations could include people with disabilities, people experiencing homelessness, elderly residents, children, and others.
Combined Sewer / Combined Wastewater Systems	A combined sewer system collects rainwater runoff, domestic sewage, and industrial wastewater into one pipe. When the amount of runoff exceeds the capacity of the wastewater treatment plant, untreated stormwater and wastewater flows into nearby waterbodies.	
Community Lifelines	The most fundamental services in the community that, when stabilized, enable all other aspects of society to function. The integrated network of assets, services and capabilities that provide community lifeline services are used day to day to support recurring needs. Lifelines enable the continuous operation of critical government and business functions and are essential to human health and safety or economic security, as described in the National Response Framework, 4th Edition.[8]	
Community Resilience	The ability of a community to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions. Activities such as disaster preparedness (which includes prevention, protection, mitigation, response and recovery), and reducing community stressors (the underlying social, economic and environmental conditions that can	

[8] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
	weaken a community) are key steps to resilience.[9]	
Community Resources	Community resources can provide places of refuge, help in preparing for climate events, and recovery support. Community resources provide opportunities for residents to bond with one another, which serve as cornerstones of resiliency.	
Critical Facilities and Infrastructure	This is defined by FEMA as a facility where even a low risk of disruption would constitute a severe threat. FEMA includes hospitals, fire stations, police stations, critical record storage facilities, and similar structures within this scope. The American Society of Civil Engineers also includes facilities related to energy, water, transportation, communication systems, and natural and virtual resources within their definition of critical facilities.	
Dam Failure	The sudden breach or collapse of a dam, resulting in the release of stored water and potential downstream flooding.	
Days Per Year With Maximum Temperature > 95°F, >90°F, <32°F	Temperatures above 90°F and above 95°F are considered heat and extreme heat events in New England, respectively. Temperatures below 32°F are considered freezing events. An increase in Number of Days Per Year with Maximum Temperature above 90°F and 95°F may lead to an extended summer season. A decrease in Number of Days per Year with Minimum Temperatures below 32°F may lead to less snowfall and a shorter "traditional" New England winter season.	
Design Storm	The magnitude and temporal distribution of precipitation from a storm event	The present day 10-year 24-hour design storm for

[9] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
	defined by probability of occurrence (e.g., five-year storm) and duration (e.g., 24 hours), used in the design and evaluation of stormwater management systems.[10]	Worcester, MA is 4.9 inches of rainfall depth according to NOAA Atlas 14.
Duration of Flooding	Duration of Flooding is the length of time from when the tide surpasses the mean higher high water (MHHW) tidal datum to when it recedes below the MHHW. Duration of Flooding is important because it correlates to the level of impact of the flood (e.g., the amount of damage done, the amount of time power is out, etc.).	
Ecosystem	All living things and non living things in an area, as well as the interaction between them.	
Ecosystem Services	The direct and indirect benefits as a result of ecosystems provided by natural resources.	Flood protection, stormwater infiltration, pollution protection, oxygen production, wildlife habitat, etc.
Equity	The consistent and systematic fair, just and impartial treatment of all individuals.[11]	
Evaluating	Means assessing the effectiveness of the plan at achieving its stated purpose and goals.[12]	
Exposure	The extent to which something is in direct contact with climate parameters or their related climate change impacts. Exposure is often determined by examining the number of people or assets that lie within a geographic area affected by a climate parameter, or by	For example, measurements of flood depth outside a building or number of heat waves experienced by a county are measurements of exposure.

[10] Philadelphia Stormwater Management Guidance Manual, Version 3.1., 2018. By the Philadelphia Water Department. https://www.pwdplanreview.org/manual/appendices/a.-glossary
[11] FEMA Local Mitigation Planning Policy Guide, 2022
[12] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
	determining the magnitude of the climate change impact.	
Extent	The range of anticipated intensities of the identified hazards. The information must relate back to each of the plan participants or the planning area, depending on the hazard. Extent is most commonly expressed using various scientific scales.[13]	
Fauna	A collective term for the animals or animal life of any particular region.	
Flanking and Overtopping Dams	Uncontrolled release of water over parts of the dam that are not designed to pass flow.	
Flood Elevation	The height floodwaters would reach at a particular site during the occurrence of a specific flood.	
Flood Exposure Analysis	A study that examines the extent to which areas and assets are at risk of flooding.	
Flood Insurance Rate Map (FIRM)	Official map of a community on which FEMA has delineated the Special Flood Hazard Areas (SFHAs), the Base Flood Elevations (BFEs), and the risk premium zones applicable to the community, based on historic information.[14] See definitions for 100- and 500-year floodplains, and BFE, above.	FIRMs are available on the FEMA Flood Map Service Center online.
Floodplain	Any land area susceptible to being inundated by floodwaters from any source.	
Floodplain Management	Comprehensive planning and regulations aimed at minimizing flood	

[13] FEMA Local Mitigation Planning Policy Guide, 2022
[14] FEMA National Flood Insurance Program Terminology Index, 2020. https://www.fema.gov/flood-insurance/terminology-index

Terms	Description	Options or Examples
	risks and guiding development within flood-prone areas.	
Floodplain Mapping	The creation of detailed maps that indicate areas susceptible to flooding, aiding in hazard assessment, land-use planning, and emergency response.	
Flora	The plants or plant life of any particular region.	
Goals	Broad, long-term policy and vision statements that explain what is to be achieved by implementing the mitigation strategy.[15]	
Green Stormwater Infrastructure	Sustainable approaches to managing stormwater runoff using natural systems such as vegetated swales, rain gardens, and permeable pavements to reduce flooding and improve water quality.	
Hazard mitigation	Any sustained action taken to reduce or eliminate the long-term risk to human life and property from hazards.[16]	
Hazard Mitigation Planning Team (HMPT)	Stakeholders with subject matter expertise and local knowledge and experience.	
Heat Index	The National Weather Service (NWS) Heat Index or the "real feel" is based on temperature and relative humidity. The Heat Index is what the temperature feels like to the human body when relative humidity is combined with the air temperature and is measured in °F. The NWS Heat Index considers shady and light wind conditions but does not account for strong winds or full sun exposure. Exposure to full sunshine can increase Heat Index values by up to 15°F and strong wind of very hot dry air can be detrimental to public health and	

[15] FEMA Local Mitigation Planning Policy Guide, 2022
[16] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
	safety. The NWS uses the Heat Index to issue warnings and advisories relevant to public health considerations when daytime heat indices is more than 100°F for two or more hours.	
Heat Stress Events	A number of instances when a 3-day moving average of temperature is above 86 °F.	
Hydrologic & Hydraulic Modeling	An engineering analysis studies the movement of water, and is used to evaluate the impact of waterbodies, pipes, culverts, and rainfall on a specific area.	
Impacts	The consequences or effects of each hazard on the participant's assets identified in the vulnerability assessment. For example, impacts could be described by referencing historical disaster damages with an estimate of potential future losses (such as percentage of damage vs. total exposure).[17]	
Inland Flooding	Inland floods can occur after rain falls for many days in a row, as a result of brief periods of intense precipitation, when snowpack melts quickly, or when dams or levees fail. Whenever the volume of water on land overcomes the capacity of natural and built drainage systems to carry it away, inland flooding can result.	
Invasive Species	A type of plant, animal, or other organism that does not naturally live in a certain area but has been introduced there, often by people. An invasive species can spread quickly, hurt native species, and disrupt ecosystems.	
Invasive Species	Non-native plant, animal, or microorganism species that can harm	

[17] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
	ecosystems, disrupt habitats, and potentially exacerbate natural hazards.	
Location	The unique geographic boundaries within the planning area, or assets outside of geographic boundaries that may be affected by the identified hazard. Maps are an efficient way to illustrate location. However, location may be described through plan narratives or other formats.[18]	
Low Impact Development (LID)	Planning and design strategies that aim to minimize the impact of urban development on the environment by using practices such as reducing impervious surfaces, conserving water, and promoting natural drainage.	
Massachusetts Coast Flood Risk Model (MC-FRM)	The projected sea level rise / storm surge data values provided through the Tool are based on the Massachusetts Coast Flood Risk Model (MC-FRM) outputs as of 9/13/2021, which included GIS-based data for three planning horizons (2030, 2050, 2070) and six return periods (0.1%, 0.2%, 0.5%, 1%, 2%, 5%). These values are projections based on assumptions as defined in the model and the LiDAR used at the time, for a hydrodynamic, probabilistic model that considers hundreds of thousands of historic and simulated storms. For additional information on the MC-FRM, review the additional resources provided on the Start Here page.	
Mitigation action	A measure, project, plan or activity proposed to reduce current and future vulnerabilities described in the risk assessment.[19]	

[18] FEMA Local Mitigation Planning Policy Guide, 2022
[19] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
Monitoring	Tracking the implementation of the plan over time. For example, monitoring may include a system for tracking the status of the identified hazard mitigation actions.[20]	
Natural hazards	A source of harm or difficulty created by a meteorological, environmental or geological event. Natural hazards, such as flooding and earthquakes, impact the built environment, including dams and levees.[21]	
NOAA Atlas 14	Precipitation frequency estimates data server, provided by NOAA.[22]	
Number of Heat Waves Per Year & Average Heat Wave Duration	A Heat Wave is defined as three or more consecutive days with maximum temperatures of 90°F or above. Number of Heat Waves represents number of events (with one event representing at least three consecutive days with maximum temperatures of 90°F), and Average Heat Wave Duration represents the number of days for the average duration of each event over the year. Heat Waves are a public health and safety threat that may result in heat-related deaths. According to World Health Organization (WHO), Heat Waves, "can burden health and emergency services and also increase strain on water, energy and transportation resulting in power shortages or even blackouts. Food and livelihood security may also be strained if people lose their crops or livestock due to extreme heat."	
Outreach	The proactive and ongoing efforts to engage with individuals, communities,	

[20] FEMA Local Mitigation Planning Policy Guide, 2022
[21] FEMA Local Mitigation Planning Policy Guide, 2022
[22] NOAA Atlas 14 Point Precipitation Frequency Estimates: Northeastern States; NOAA Atlas 14, Volume 10, Version 3

Terms	Description	Options or Examples
	and organizations to raise awareness, educate, and gather input.	
Pests	Pests are any organisms (including plants and animals) that pose health, environmental, economic, or aesthetic risks.	
Plan expiration date	The date after which the participating jurisdiction(s) must update the plan and have it reapproved by FEMA. FEMA sets this date at five years after the plan approval date. For multi-jurisdictional plans, this date is the same for all participating jurisdictions. The plan expiration date is stated on the signed FEMA approval correspondence.[23]	
Planning mechanisms	The governance structures used to manage local land use development and community decision-making, such as budgets, comprehensive plans, capital improvement plans, economic development strategies, climate action plans or other long-range plans.[24]	
Probability of future hazard events	The likelihood of the hazard occurring or reoccurring. It may be defined in historical frequencies, statistical probabilities, hazard probability maps and/or general descriptors (e.g., unlikely, likely, highly likely). If general descriptors are used, they must be quantified or defined in the plan. For example, "highly likely" could be defined as "100% chance of occurrence next year" or "one event every year."[25]	
Protect	Adaptation strategy that blocks/prevents the climate parameter from impact.	Flood barrier, dry floodproofing, reflective roofs, lighter colored paver materials, bio retention

[23] FEMA Local Mitigation Planning Policy Guide, 2022
[24] FEMA Local Mitigation Planning Policy Guide, 2022
[25] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
		basins, infiltration trenches, underground storage tank.
Public Engagement	Activities that are solely focused on transparency and providing the public with information regarding the monitoring, evaluation, and implementation of the plan.	Providing website updates, flyers, Storymaps, presentations, social media posts, up to date GIS maps and data as appropriate, in multiple languages and with accessibility considerations.
Qualitative Analysis	Assessment based on non-numerical information, such as narratives, descriptions, and expert opinions, to evaluate hazards, vulnerabilities, and mitigation strategies.	
Quantitative Analysis	Evaluation based on numerical data, statistics, and measurable criteria to assess hazards, vulnerabilities, and the effectiveness of mitigation measures.	
Recurrence Intervals	Also known as return period. Please refer to definition of return period.	
Regulatory flood mapping products	Intended to be used as the basis for official actions required by the NFIP.[26]	
Relative Humidity	The percentage of water vapor in the atmosphere that can be retained in the atmosphere without condensation.	
Repetitive loss structure	One covered under an NFIP flood insurance policy that (1) has incurred flood-related damage on two occasions, in which the cost of repair, on average, equaled or exceeded 25% of the value of the structure at the time of each such flood event; and (2) at the time of the second incidence of flood-related damage, the contract for flood insurance contains increased cost of compliance coverage. (44 CFR § 77.2(i))[27]	

[26] FEMA Local Mitigation Planning Policy Guide, 2022
[27] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
Resilience	The ability to withstand and swiftly recover from an extreme event. Ideally, resilient systems "bounce forward" to create healthier, greener, and more equitable systems and spaces.	
Return Period	Annual probability of occurrence of an event. Also known as recurrence interval. Used in design based on risk tolerance of the asset.	For example, a critical building, such as a hospital that needs to be functioning at all times, has a lower risk tolerance and hence the 0.1% (or 1000-year) recurrence interval is recommended for design. However, a recreational facility, such as a recreation center, has a higher risk tolerance and hence the 20% (or 5-year) recurrence interval is recommended for design.
Risk	According to SHMCAP, risk is defined as "the potential for an unwanted outcome resulting from a hazard event, as determined by its likelihood and associated consequences; and expressed, when possible, in dollar losses. Risk represents potential future losses, based on assessments of probability, severity, and vulnerability."[28]	For example, if a state highway is flooded that also serves as an evacuation route, it will have a high probability of flooding and its consequence of flooding (as measured by its severity, with respect to geographic area and people affected, economic impacts and cascading impacts to other infrastructure) will also be high, which would lead to a high risk rating.
Risk	For the purpose of hazard mitigation planning is the potential for damage or loss created by the interaction of natural hazards with assets, such as buildings,	

[28] Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, 2018. https://www.mass.gov/service-details/massachusetts-integrated-state-hazard-mitigation-and-climate-adaptation-plan

Terms	Description	Options or Examples
	infrastructure or natural and cultural resources.[29]	
Riverine Flooding	Flooding that occurs when rivers, streams, or other bodies of water overflow their banks, often due to heavy rainfall or snowmelt. River flooding primarily results from an extended precipitation event that occurs at, or upstream from, the affected area. River flooding can also occur when traditional flood-control structures, such as levees and dikes, are overtopped.	
Sea level rise (SLR)	The worldwide average rise in mean sea level, which may be due to a number of different causes, such as the thermal expansion of sea water and the addition of water to the oceans from the melting of glaciers, ice caps, and ice sheets; contrast with relative sea-level rise.[30]	
Sensitivity	The impact of a natural hazard due to the existing conditions or characteristics of the asset	An older building with an older roof could have a higher sensitivity to wind damage and may lose its ability to function or keep rain out of a building.
Severe repetitive loss structure	One that is covered under an NFIP flood insurance policy and has incurred flood-related damage (1) for which four or more separate claims have been made under flood insurance coverage, with the amount of each claim (including building and contents payments) exceeding $5,000 and with the cumulative amount of such claims payments exceeding $20,000; or (2) for which at least two separate flood insurance claims payments (building payments only) have	

[29] FEMA Local Mitigation Planning Policy Guide, 2022

[30] NH Coastal Flood Risk Science and Technical Advisory Panel, 2020. New Hampshire Coastal Flood Risk Summary, Part II: Guidance for Using Scientific Projections. Report published by the University of New Hampshire, Durham, NH.

Terms	Description	Options or Examples
	been made, with cumulative amount of such claims exceeding the value of the insured structure. (44 CFR § 77.2(j))[31]	
Severity	Used to evaluate criticality of an asset and is defined as the consequences that are associated from the loss or inoperability of an asset.	For example, a lower severity Public Health and Safety Impact would be that loss of building may result in minor injuries. A higher severity would be that loss of life is expected as a result of loss of building.
Sewer Separation	The process of separating wastewater and stormwater sewer systems to prevent overflow of wastewater during heavy rainfall events, reducing pollution and flooding risks.	
Social vulnerability	The potential for loss within an individual or social group, recognizing that some characteristics influence an individual's or group's ability to prepare, respond, cope or recover from an event. These characteristics can overlap within populations to create heightened vulnerability, which may be compounded by infrastructure deficiencies within communities and historic or existing discriminatory government policies.[32]	
Stakeholders	Individuals, groups, and organizations that have a vested interest in the outcome of hazard mitigation planning and implementation. They often contribute diverse perspectives, expertise, and resources to the process.	
State Hazard Mitigation and Climate Adaptation Plan (SHMCAP)	The SHMCAP for the Commonwealth was adopted on September 17, 2018. This plan, the first of its kind to comprehensively integrate climate change impacts and adaptation	

[31] FEMA Local Mitigation Planning Policy Guide, 2022
[32] FEMA Local Mitigation Planning Policy Guide, 2022

Terms	Description	Options or Examples
	strategies with hazard mitigation planning, also complies with current federal requirements for state hazard mitigation plans and maintains the Commonwealth's eligibility for federal disaster recovery and hazard mitigation funding under the Stafford Act.[33]	
Steering Committee (STC)	A designated group of representatives responsible for guiding the development, implementation, and oversight of the hazard mitigation plan. Members may include key stakeholders, agency officials, and community leaders.	
Storm Surge	An abnormal rise in sea level accompanying a hurricane or other intense storm, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone.[34]	Storm surge is usually estimated by subtracting the normal or astronomic tide from the observed storm tide.
Stormwater Flooding	Stormwater flooding can be caused by excessive rainfall that overwhelms drainage systems and leads to water accumulation in low lying areas. It can also be caused or exacerbated by snowmelt. More frequent and intense downpours, projected for all regions of the country, can overwhelm the design capacity of municipal stormwater management systems. Overwhelmed stormwater management systems can lead to backups that cause localized flooding.	
Stormwater Management	Strategies and techniques to control the quantity and quality of stormwater runoff, mitigating flooding and pollution impacts on local water bodies.	

[33] https://resilientma.org/shmcap-portal/index.html#/

[14] Glossary – Storm Surge, 2009. National Weather Service. https://w1.weather.gov/glossary/index.php?word=Storm+Surge

Terms	Description	Options or Examples
Tree Canopy	Tree canopy refers to the part of a city that is shaded by trees.	
Underserved Communities	Populations sharing a particular characteristic, as well as geographic communities that have been systematically denied a full opportunity to participate in aspects of economic, social and civic life. The barriers to opportunity and participation these communities face have been occurring throughout history and continue today.[35]	
Urban Heat Island Effect (UHI)	Dark, paved, and impervious surfaces, such as asphalt roads and buildings with black roofs, contribute to the urban heat island effect. These surfaces absorb more heat than vegetated or light colored surfaces, and they release this heat back into the surrounding environment.	
Vulnerability	A description of which assets, including structures, systems, populations and other assets as defined by the community, within locations identified to be hazard-prone, are at risk from the effects of the identified hazard(s).[36]	
Water Surface Elevation	Water Surface Elevation is the projected elevation for a specific future flood event, considering storm surge, tides, and wave setup. This is provided as a data value output of the Tool from the Massachusetts Coastal Flood Risk Model (MC-FRM).	Water Surface Elevations from the MC-FRM, for an example project site. *Max* = 11.1 ft-NAVD-88 *Min* = 10.8 ft-NAVD-88 *Area Weighted Average* = 10.9 ft-NAVD-88

[35] FEMA Local Mitigation Planning Policy Guide, 2022
[36] FEMA Local Mitigation Planning Policy Guide, 2022

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