Draft

CITY of BOSTON

2021 Natural Hazard Mitigation Plan Update

**challenges create an opportunity –
an opportunity to come together, to heal and build a better, more equitable city**

- MAYOR JANEY, 2021

ACKNOWLEDGEMENTS

The City of Boston's 2021 Natural Hazard Mitigation Plan (NHMP) was adopted by the City Council on Date to update and replace the City of Boston's 2014 Natural Hazard Mitigation Plan. The 2021 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.

City Leadership
Mayor Kim Janey
Chief Shumeane Benford, Office of Emergency Management
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Mike Brohel, Superintendent of Street Operations, Department of Public Works
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Street Team
Age Strong Commission
Department of Youth Engagement & Employment
Disability Commission
Language and Communications Access
Mayor's Office of Immigrant Advancement
Office of Neighborhood Services
SPARK Boston
Youth Homelessness Initiatives, Mayor's Office of Health and Human Services

Local Hazard Mitigation Team Participants

- All Aces
- Beth Israel Deaconess Medical Center
- Boston Children's Hospital
- Boston College
- Boston Fire Department
- Boston Police Department
- Boston Green Ribbon Commission
- Boston Groundwater Trust
- Boston Harbor Now
- Boston Planning and Development Agency
- Boston Public Health Commission
- Boston Public Schools
- Boston University
- Boston Water and Sewer Commission
- Bunker Hill Community College
- Charles River Watershed Association
- Chinatown Main Street Association
- City of Cambridge
- City of Watertown
- Columbia-Savin Hill Civic Association
- Coordinated Statewide Emergency Preparedness
- Department of Neighborhood Development
- Earthos
- East Boston Neighborhood of Affordable Housing (NOAH)
- Emergency Medical Services Department
- Greater Boston Food Bank
- Greater Boston Real Estate Board
- Housing Authority
- Inspectional Services Department
- JP Centre/South Main Streets
- Massachusetts Archives
- Massachusetts Bay Transportation Authority
- Massachusetts Department of Transportation
- Massachusetts Emergency Management Agency
- Massachusetts Executive Office of Energy and Environmental Affairs
- Massachusetts General Hospital
- Mayor's Office
- Mayor's Office of Language and Communications Access
- Merrimack College
- Metropolitan Area Planning Council
- Mission Hill Main Streets
- Museum of Science
- Neighborhood of Affordable Housing
- New Roots Church
- Northeast States Emergency Consortium
- Office of Budget Management
- Office of Public Health Preparedness
- Property Management Department
- SPARK Council
- Suffolk University
- The Greater Boston Foodbank
- Town of Brookline
- Town of Milton
- Tufts University
- United States Geological Survey
- University of Massachusetts
- Weston Observatory of Boston College
- Wharf District Council

For a full list of invitees, see Appendix C.

Consultant

Weston & Sampson℠

Letter from Leadership - forthcoming

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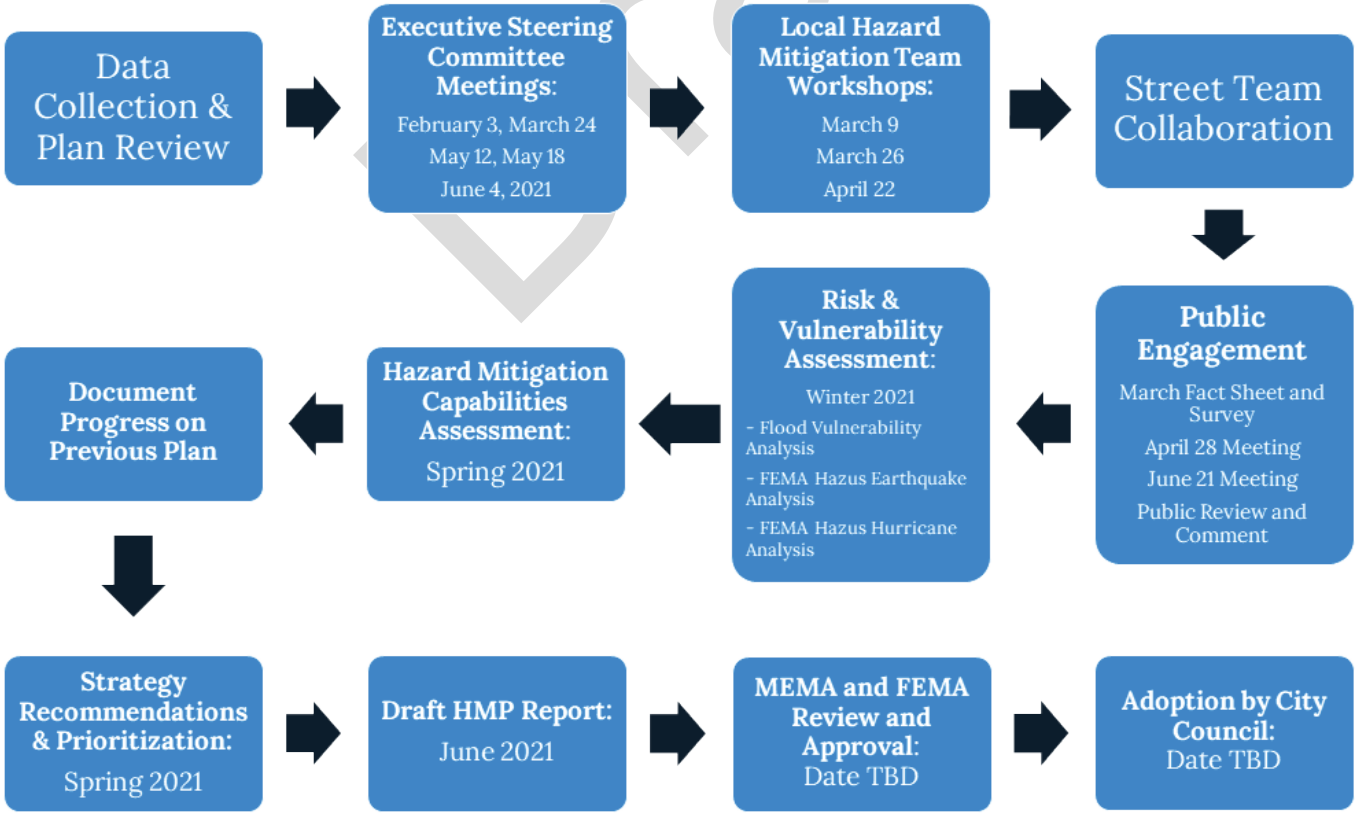
EXECUTIVE SUMMARY

Hazard mitigation planning is a proactive process used to systematically identify policies, actions, and programs that can be used to reduce the impacts of natural hazards on society, the environment, property, and human life. Climate adaptation planning recognizes that climate change will exacerbate the vulnerabilities and risks associated with natural hazards. The City of Boston completed a planning process focused on both hazard mitigation planning and climate adaptation, which provides a robust assessment and implementation plan to build the City's resilience. By completing the Natural Hazard Mitigation Plan (NHMP), the City remains eligible for hazard mitigation funding through the Federal Emergency Management Agency (FEMA). This funding will be used to support the implementation of this plan and other ongoing natural hazard mitigation and climate adaptation efforts in Boston.

Planning Process

The NHMP planning process proceeded according to the timeline below. Critical input was received from the Executive Steering Committee, Local Hazard Mitigation Team, Street Team, and Public Engagement Meetings. A description of these teams, their purpose, and participants can be found in Chapter 1.



Hazard Mitigation and Climate Adaptation Goals

Fundamentally, the NHMP intends to equitably support Boston's neighborhoods by protecting public health and safety, increasing awareness of steps to mitigate damages from natural hazards, and promoting preparedness for climate change. The Executive Steering Committee, representing the City of Boston, endorsed, the following set of hazard mitigation and climate adaptation goals. Each goal was assigned a set of objectives, which can be found in Chapter 2. These goals informed the selection and prioritization of future adaptation and mitigation actions.

1 **Equitably protect the health and safety of the public through awareness, preparedness, and connections.**

2 **Increase resilience by protecting and enhancing natural resources.**

3 **Implement hazard mitigation and climate adaptation projects that meet strategic priorities.**

4 **Invest in protecting properties and structures.**

5 **Ensure that essential services and infrastructure will function during and after a hazard event and prepare essential services for projected climate change.**

Vulnerability and Risk Assessment

The NHMP Plan documents the vulnerabilities, strengths, and risks hazards across several community lifelines and sectors, including infrastructure, community assets, economic centers, and natural resources. Each of these asset categories is critical to the resilience of Boston residents and is discussed in greater detail in Chapter 3. Using the 2018 State Hazard Mitigation and Climate Adaptation Plan (EEA and EOPSS), the 2014 NHMP (City of Boston, 2016c), and Climate Ready Boston (City of Boston, 2016a) as a guide for the types of hazards that occur, we have developed hazard profiles containing information on the severity, location, historic occurrences, future climate projections, and vulnerability and risk for the following hazards:

Flooding Hazards

- Riverine
- Inland/Stormwater
- Coastal
- Tidal

Geological Hazards

- Earthquakes
- Landslides

Drought Hazards

- Drought

Dam Hazards

- Dam Failure

Fire Hazards

- Brushfires
- Urban Conflagrations

Winter Storm Hazards

- Snow and Blizzards
- Ice Storms

Wind-Related Hazards

- Severe Storms and Thunderstorms
- Hurricanes and Tropical Storms
- Tornados
- Nor'easters

Extreme Temperature Hazards

- Extreme Heat
- Extreme Cold

Hazard Mitigation and Climate Adaptation Strategy

The City of Boston is already implementing measures to mitigate local hazards in day-to-day operations, planning, and enforcement of regulations. The NHMP documents the City's current operational capacity and discusses potential improvements (Chapter 5). The City also developed a list of priority hazard mitigation and climate adaptation strategies through a multi-faceted approach. The priority list includes actions from the previous plan that were not completed or partially completed as documented in Chapter 6.

The following table details the top 33 priority actions, out of 58, which were selected based on their ability to protect lives, property, contributions to community benefits, contribution to a healthy environment, and technical and political feasibility. More information about the priority actions, such as the implementation responsibility, cost, and time frame for completion is available in Chapter 7.

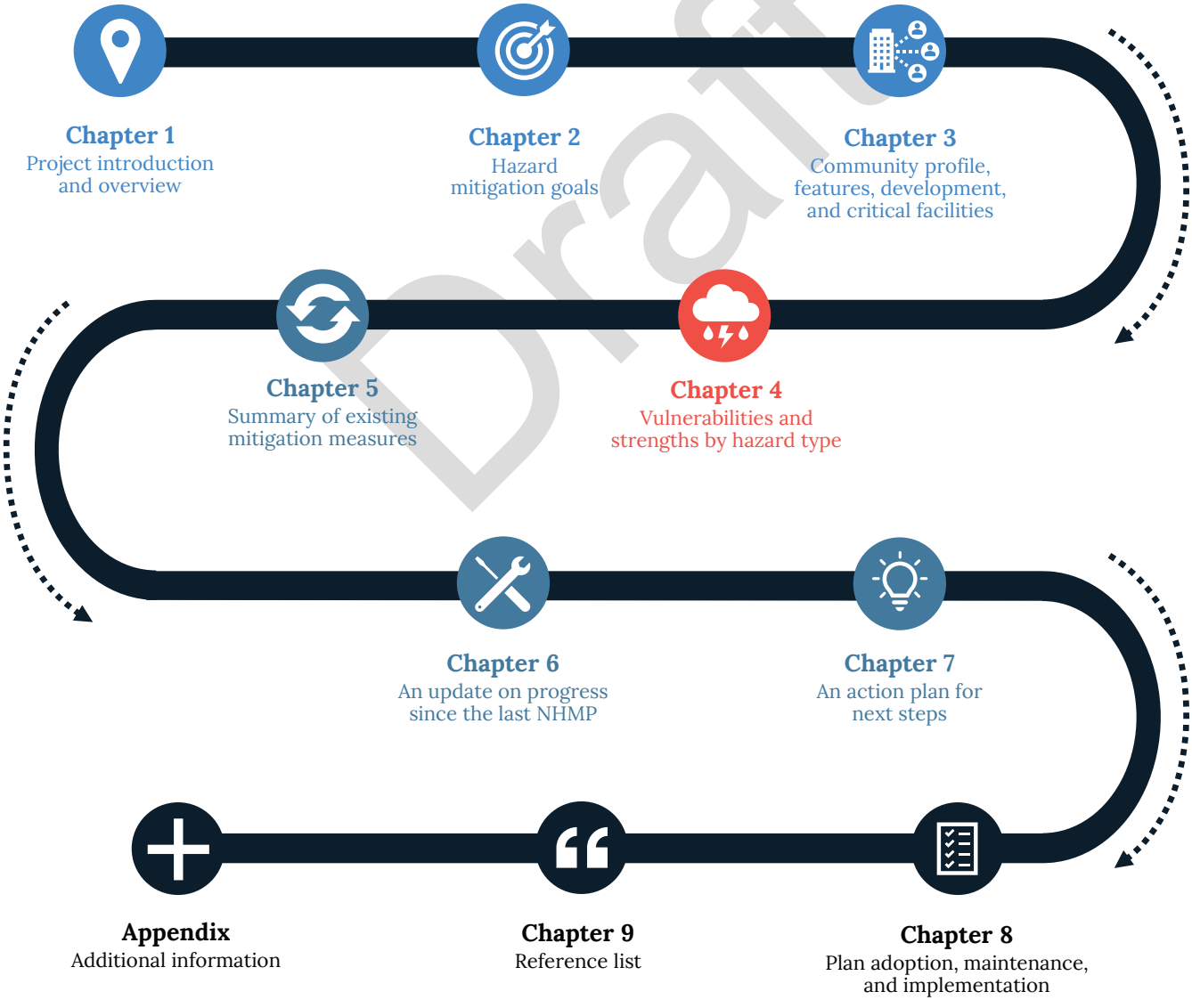
Next Steps

The City of Boston is dedicated to implementing the findings of this plan and documenting the process as described in Chapter 8. The City will look to secure resources and work with regional and local stakeholders to complete the projects identified within the plan. The City will also continue to document hazard impacts and areas in which capacity building is needed to support mitigation and adaptation efforts. Finally, the City will proactively incorporate the hazard mitigation and climate adaptation goals into municipal planning, budgeting, and operations. By doing so, the City will be ready to update this plan in five years to maintain its eligibility for grant funding through FEMA.

High Priority Hazard Mitigation and Climate Adaptation Actions			
ID	Action	Year of Completion	Responsibility
A1	Physical Adaptations and Operational Changes to the MBTA Stations and Service Lines to Address Climate Impacts	2030	MBTA
A2	Adapt Morrissey Boulevard for Flood Resilience	2030	DCR, MassDOT, BPDA
A6	Introduce Hazard Mitigation and Resiliency Into Regulations and Ordinances at the Local Level and Advocate for Changes at the State Level	2023	BPDA, Environment Department, Parks and Recreation
A7	Emergency Notification System Upgrades for Increased Access	2023	OEM
A9	Citywide Energy Demands Assessment Update and Reduce Stress on Grid Demand During Peak Usage	2030	BPDA, Environment Department
A10	Emergency Evacuation Route Improvements and Outreach	2022	OEM
A11	Emergency Shelter Assessment and Improvements	2025	OEM
A12	Feasibility Assessment of District Energy Solutions for Large Scale Developments	2025	BPDA, Environment Department, BPHC
A13	Implement the Findings of the Tunnel Vulnerability Assessment and Flood Mitigation Feasibility Study	2040	MassDOT
A14	Public Housing Vulnerability Assessments and Adaptations	2025	Boston Housing Authority
A17	Evaluate Incentives and Finance Tools to Promote Resiliency in Buildings, Installation of Green Infrastructure, and Tree Management	2025	ISD, BPDA, Environment Department, Parks and Recreation
A19	Develop a Green Infrastructure Location Plan for Public Lands and Public Right of Way	2025	Public Works, Department of Transportation Environment Department, BWSC
A20	Implement District-Scale Resilient Design Options	2030	BPDA, Environment
A22	Franklin Park Action Plan and Resilience	2025	Parks and Recreation
A25	Continue to Develop a Resilience Assessment and Education Program for Property Owners and Tenants	2024	ISD, Environment Department
A30	Prepare Parks and Outdoor Facilities for Climate Change	2025	Parks and Recreation

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions			
ID	Action	Year of Completion	Responsibility
A32	Develop and Deploy an Environmental Sensors Strategy to Track Performance Against Climate Goals Across the City	2025	Environment Department, MONUM
A33	Storrow Drive Reconstruction and Drainage Improvements	2030	DCR
A34	Implement Recommended Actions in Boston's Citywide Heat Resiliency Study	2022	Environment Department, Parks, BPHC, OEM
A35	Muddy River Flood Control	2023	Army Corp of Engineers, DCR, Parks and Recreation, Town of Brookline
A37	Establish Flood Protection Overlay Districts	2025	BPDA, Environment Department
A38	Continue to Refine a Consistent Evaluation Framework for Prioritizing Climate Resilience and Adaptation Implementation	2023	BPDA, Environment Department
A40	Develop Design Guidelines for Green Infrastructure on Public and Private Property	2023	Parks and Recreation, Environment Department
A41	Implement an Action Plan to Enhance Boston's Urban Tree Canopy and Protect Residents From the Impacts of Extreme Heat	2030	Parks and Recreation, Environment Department
A45	Expand Citywide Climate Readiness Education, Engagement, and Leadership Development Campaigns	2024	Environment Department, OEM
A46	Building Resiliency around the Fort Point Channel Area	2030	BPDA, Parks and Recreation, BWSC
A47	East Boston Coastal Resilience Barrier	2027	BPDA
A48	Construct Boston Marine Industrial Park Stormwater Management System Stormwater Improvements	2024	BPDA
A49	Moon Island Seawall Rehabilitation to Mitigate Coastal Hazards	2024	Property Management Department, Neighborhood Development, BFD, Public Facilities
A50	Stabilize Coastal Bank Along the Eastern Side of Long Island	2025	Property Management Department, DCR

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions			
ID	Action	Year of Completion	Responsibility
A51	Update Storm Ready Certification with National Weather Service	2023	OEM
A54	Rutherford Ave/Charlestown Underpass –Replace Tunnel With Urban Boulevard and Drainage Improvements	2030	Transportation Department
A58	Address Vulnerabilities to Tidal Flooding at McCormack and Dever schools, (315 Mt. Vernon Street, Columbia Point, Dorchester)	2035	Property Management Department



ONE: INTRODUCTION

The City of Boston through the Office of Emergency Management (OEM) prepared a Natural Hazard Mitigation Plan (NHMP) to create an action roadmap to reduce the impacts of natural hazards and climate change within the community and the region. This project is funded by a Federal Emergency Management Agency (FEMA) grant.

What are...?

Natural hazards can include flooding, extreme wind events, winter weather, earthquakes, fires, extreme temperatures, drought, and more.

Hazard Mitigation is the effort to reduce impacts from natural hazards through planning, policy, education, infrastructure projects, and more.

A Natural Hazard Mitigation Plan (NHMP) is a strategy to reduce risks and vulnerabilities associated with natural hazards and climate change, to protect homes, businesses, and the critical infrastructure that keeps our City running.

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

1.1 What is a Natural Hazard Mitigation Plan?

Natural hazards, such as earthquakes, hurricanes, and flooding, can result in loss of life, disruptions to everyday life, and property damage. Hazard mitigation is the effort to reduce these impacts through community planning, policy changes, education programs, infrastructure projects, and other activities (FEMA, 2021). Natural hazard mitigation planning uses a stepped process with the participation of a wide range of stakeholders to:

1. define local hazards
2. assess vulnerabilities and risks
3. review current mitigation measures
4. develop priority action items

The resulting plan and implementation of action items saves lives and money. For every dollar spent on federal hazard mitigation grants, an average of six dollars are saved (NIBS, 2019).

Benefits of Natural Hazard Mitigation Planning

Increases public awareness of natural hazards that may affect the community

Allows state, local, and tribal governments to work together and combine hazard risk reduction with other community goals and plans

Focuses resources and attention on the community's greatest vulnerabilities

What is...?

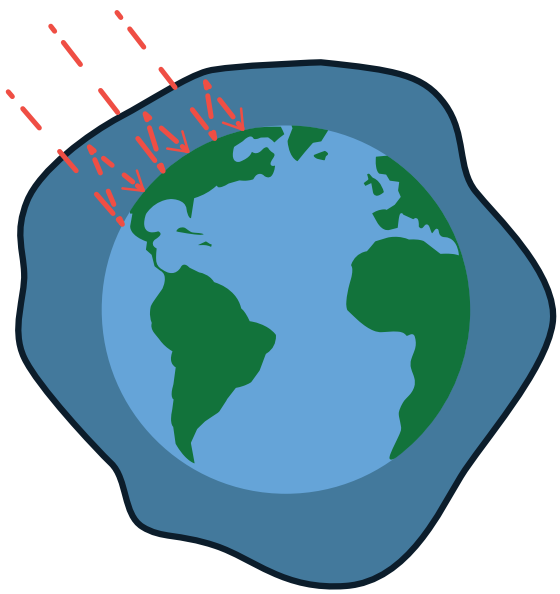
Climate change
According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), climate change is "a change in the state of the climate that can be identified by statistical changes of its properties that persist for an extended period, whether due to natural variability or as a result of human activity." Changes in climate impact the NHMP development process, making it necessary to consider climate change predictions even for a five-year plan.

Climate adaptation
An action that seeks to reduce vulnerability and risk to an anticipated climate impact. This may include flood barriers, living shorelines, elevated buildings, and increased tree canopy.

Wondering what's in the plan? See page 14!

By completing an NHMP, municipalities also become eligible for specific federal funding which allows the use of potential funding sources to reflect a community's priorities (FEMA, 2020). Hazard mitigation funding is available through the Federal Emergency Management Agency (FEMA). To be eligible for FEMA Grants, local governments are required to prepare an NHMP meeting the requirements established in the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended by the Disaster Mitigation Act of 2000. Please refer to Chapter 7 for more information on FEMA grants and other potential funding sources.

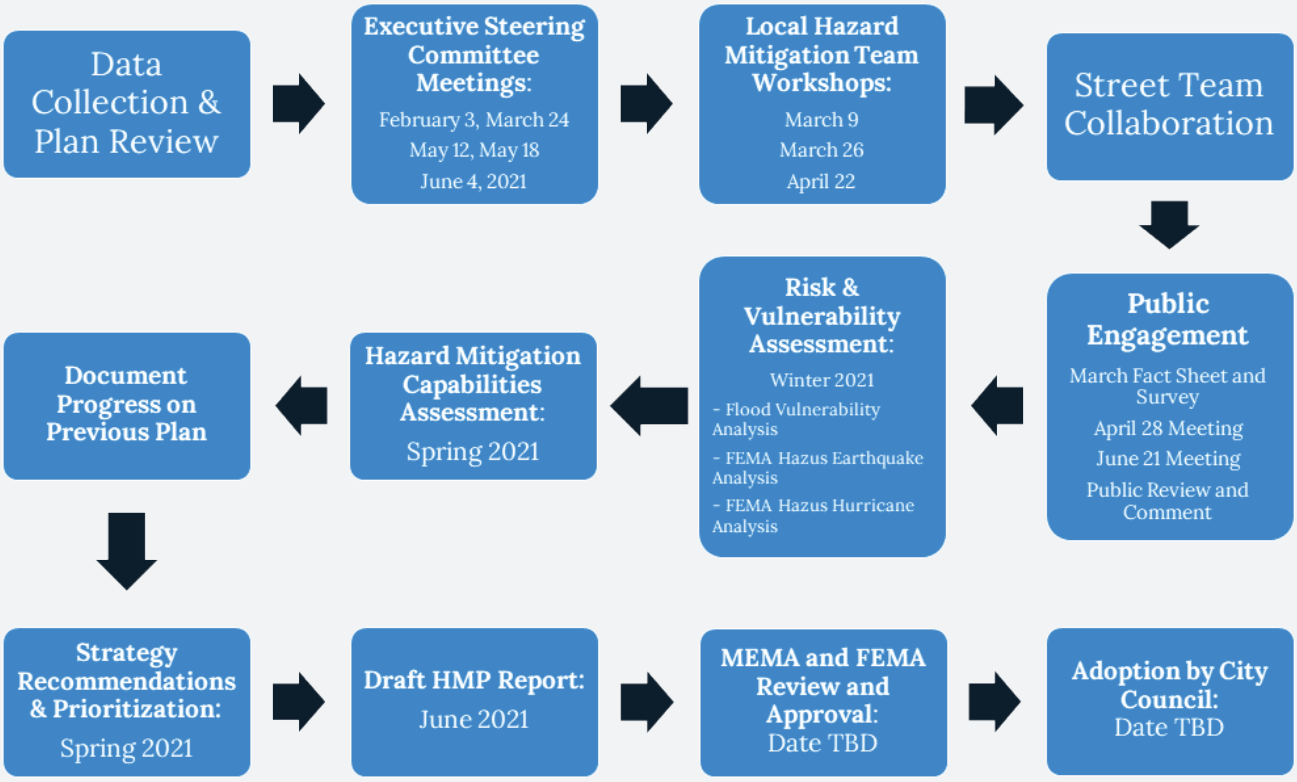
Many of the hazards that Boston commonly experiences are projected to worsen due to climate change. Climate change refers to changes in regional weather patterns that are linked to warming of the Earth's atmosphere as a result of both human activity and natural fluctuations. The Earth's atmosphere has naturally occurring greenhouse gases (GHGs) like carbon dioxide (CO_2) that capture heat and contribute to the regulation of the Earth's climate. When fossil fuels (including oil, coal and gas) are burned, GHGs are released into the atmosphere and the Earth's temperature tends to increase. The global temperature increase affects the jet stream and climate patterns.



A diagram of the greenhouse gas effect

Due to these changes, the future climate in Massachusetts is expected to resemble historic climate patterns of Southern New England or Mid-Atlantic States more closely, depending upon GHG emission scenarios. Climate change has already started to impact Boston and these trends are likely to continue. Climate change is likely to affect the typical precipitation cycle, leading to more intense rainfall and storms and more episodic or flash droughts. Temperatures will increase in both summer and winter. Climate change will also lead to sea level rise and more frequent and intense coastal storms. Chapter 4 includes more information on hazard severity, risk, and more.

1.2 Planning Process

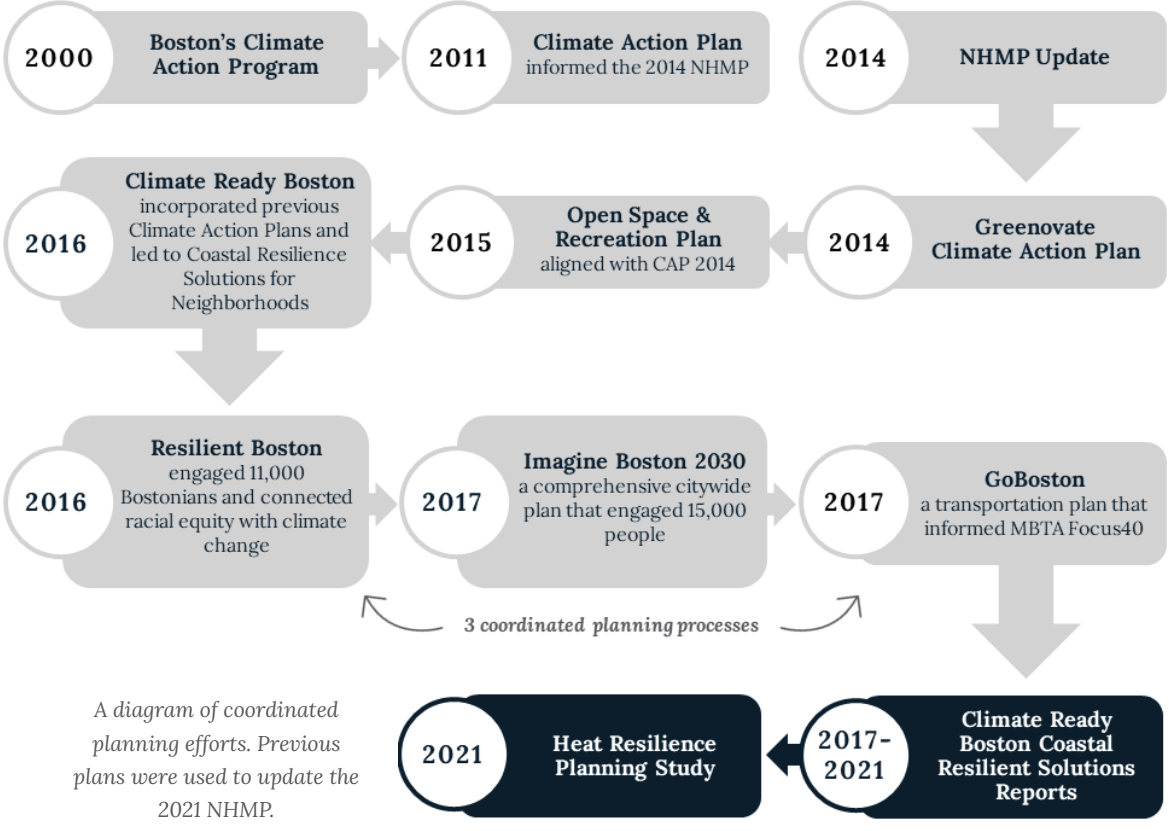


The NHMP planning process proceeded according to the timeline above. More information on the Executive Steering Committee, Local Hazard Mitigation Team, Street Team, and Public Meetings is included on the subsequent pages.

1.2.1 Executive Steering Committee

The City of Boston convened the Executive Steering Committee (ESC) for the development of the NHMP. The ESC met several times to set goals for the planning process, provide input on historic hazard events, and plan for the Local Hazard Mitigation Workshop. More information on these meetings and a list of ESC members is included in Appendix B. The ESC continued to provide regular input through email and played an important role in identifying critical infrastructure, involving key stakeholders, and capturing the City's capacity to mitigate hazards alongside ongoing operations.

To assist in drafting the plan, the ESC also suggested or made available reports, maps, and other pertinent information related to natural hazards in Boston. These included the reports listed in the timeline diagram below. Additional data, reports, and resources that informed this NHMP are listed in Chapter 9: References. A crosswalk of resources reviewed is included in Appendix A.



A diagram of coordinated planning efforts. Previous plans were used to update the 2021 NHMP.

1.2.2 Stakeholder Involvement: Local Hazard Mitigation Team Workshops

Due to the public health crisis surrounding COVID-19, stakeholder workshops could not be conducted in person. Instead, the City hosted a series of three online workshops organized around topic areas that included:

1. Hazard, vulnerability, and strength identification
2. Action development
3. Action prioritization

Stakeholders, known as the Local Hazard Mitigation Team (LHMT), with subject matter expertise and local knowledge and experience were invited to attend. These stakeholders included City of Boston affiliates, state and regional stakeholders, nonprofit organizations, community groups, and neighboring communities. During these workshops, Weston & Sampson provided information about local features and hazards impacting the City of Boston. Participants identified and prioritized key actions that would 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 C, along with the materials from each workshop. The broad representation of local and regional entities that participated in these workshops ensures that the NHMP aligns with the operational policies and hazard mitigation strategies at different levels of government and implementation. A summary of key findings from each workshop is included on the following page.

Entities Regulating Development

Stakeholders that regulate development were invited to participate in the LHMT Workshops, including the Boston Planning & Development Agency (BPDA) and the Conservation Commission.

Regional Entities & Neighbors

Hazard impacts do not end at geographic or political boundaries. To facilitate the identification of adaptation actions that could benefit the surrounding region, regional entities and surrounding communities were invited to participate in the LHMT Workshops, including:

- City of Cambridge
- City of Chelsea
- City of Everett
- City of Somerville
- City of Quincy
- Town of Milton
- Town of Dedham
- Town of Brookline
- City of Watertown
- City of Newton
- City of Winthrop
- City of Revere
- Town of Canton
- Northeast States Emergency Consortium

Webinar #1: Identifying Hazards, Vulnerabilities, and Strengths

Sixty-seven participants joined the workshop and were asked to brainstorm key local features in Boston related to infrastructural, societal, and environmental categories. Attendees then identified the hazards that each feature was vulnerable to, and if the feature was a vulnerability or strength. The workshop format included a presentation of natural hazards, historic impacts, and future climate change projections; interactive polling; and breakout room discussions.

Key findings from the workshop:

- The top three hazards of concern identified by participants included flooding, wind-related events, and winter weather
- The top three locations identified as experiencing frequent flooding included the Seaport, Morrissey Boulevard, and Long Wharf
- Impacts cited from this year's winter weather included power outages, downed branches, and icy conditions
- Key infrastructural features identified during Breakout Room sessions included transportation infrastructure, stormwater system, and communications
- Key societal considerations identified during Breakout Room sessions included shelters, food security, vulnerable populations, and healthcare
- Key environmental features identified during Breakout Room sessions included parks, wetlands, and the harbor/shoreline

Top topics discussed by participants at LHMT Workshop #1

Flood locations identified by participants in LHMT Workshop #1

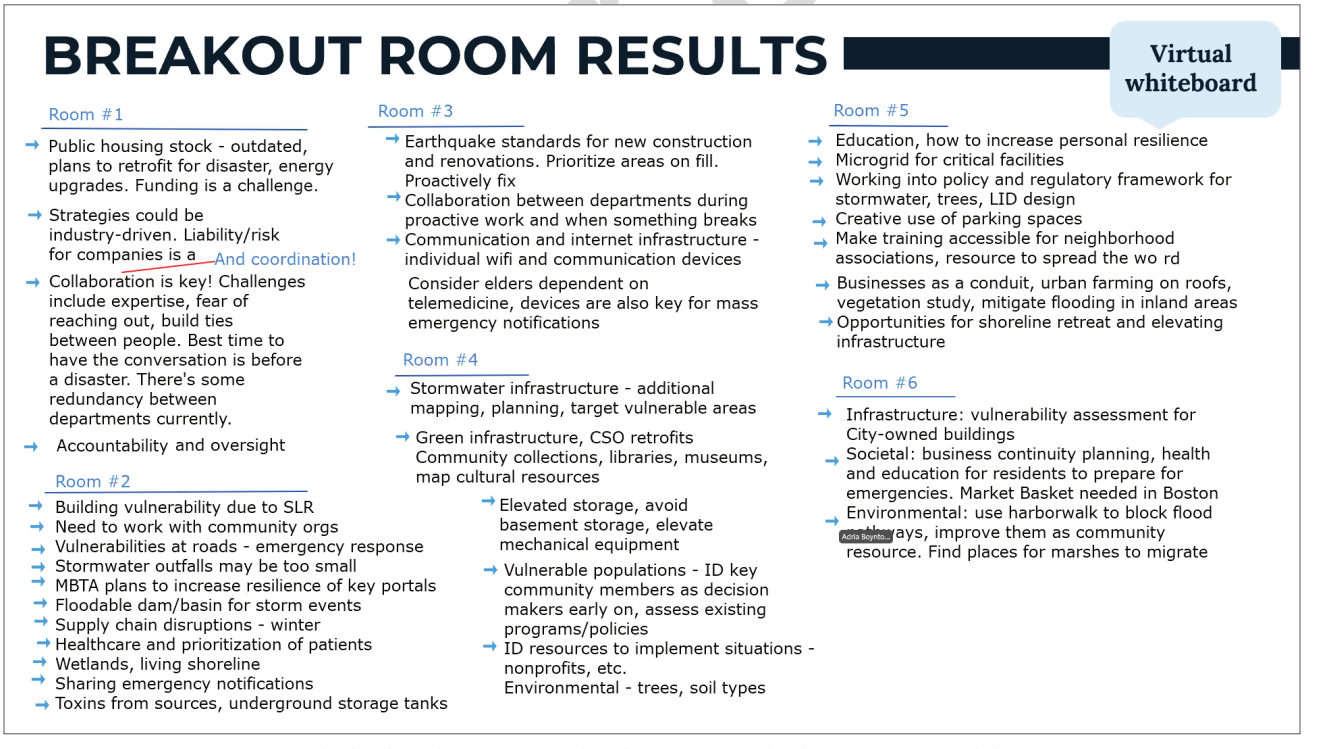
LHMT Workshop #1 Participants

Webinar #2: Action Identification

Forty-eight participants joined the workshop and were asked to brainstorm adaptation action items to address the hazards and vulnerabilities identified during Workshop #1. The workshop format included a presentation of action item and project examples, interactive polling, and breakout room discussions.

Key findings from the workshop:

- The top three identified resources that City departments need to prepare for natural hazards included funding for climate adaptation, staff/training, and climate projection data
- 19% of attendees had been involved in the 2014 NHMP, 23% had been involved in the 2016 Climate Ready Boston process, and 52% of attendees had not been involved in a previous related planning process
- Key considerations for the development of action items included racial equity, social justice, and planning for climate refugees
- Community or societal project themes included collaboration and communication, partnering with community organizations and leaders, emergency notifications, protecting cultural resources, and increasing the resilience of businesses
- Environmental project themes included protecting wetlands, implementing living shorelines, installing green infrastructure, and nature-based solutions
- Infrastructural project themes included retrofitting transportation and stormwater infrastructure, increasing flood storage, and elevating infrastructure



A virtual whiteboard summarizing breakout room results during LHMT Workshop #2

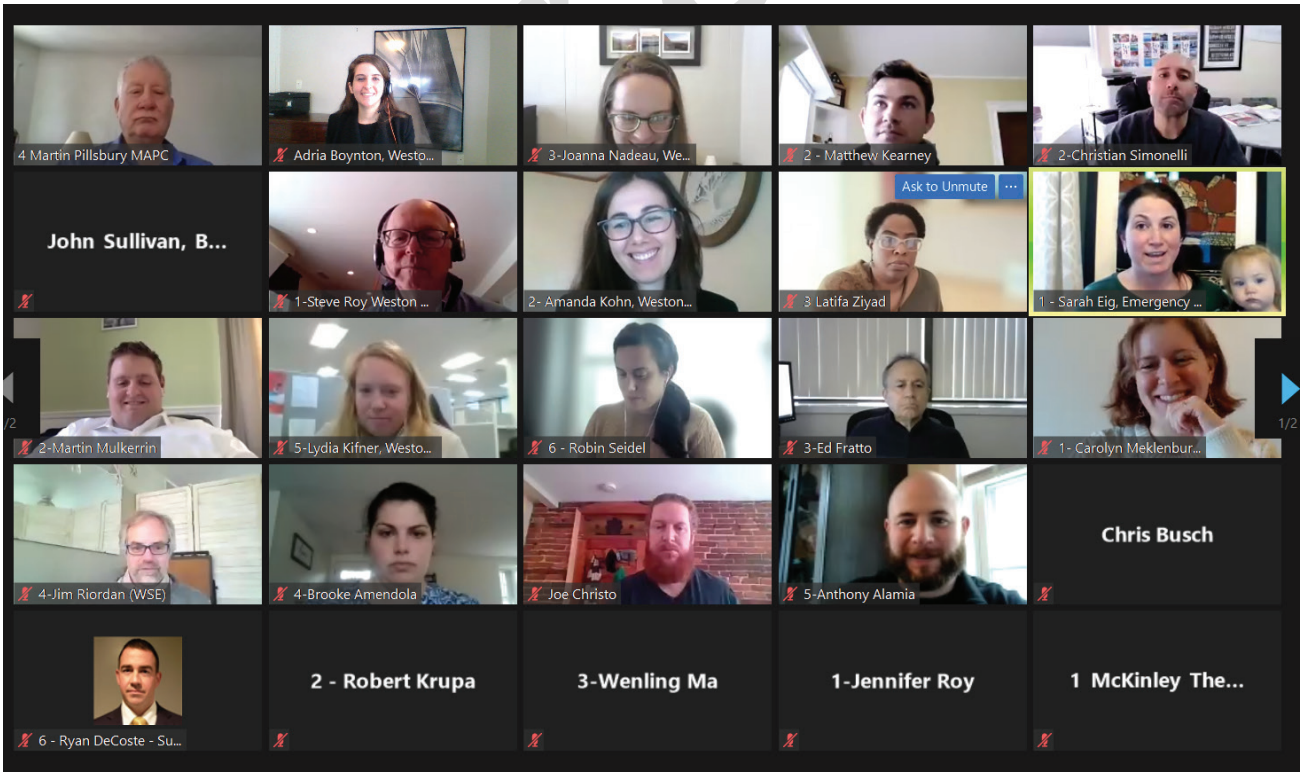
Webinar #3: Action Prioritization

Forty-eight participants joined the workshop, and were asked to prioritize and assign time frames to the adaptation action items identified during Workshop #2. The workshop format included a presentation of prioritization criteria, interactive polling, and breakout room discussions.

Key findings from the workshop:

- The top three criteria selected by participants to prioritize resiliency strategies included benefits to Environmental Justice or climate vulnerable populations, current conditions (which could include frequent flooding locations and aging infrastructure) and the level of adaptation and risk reduction provided
- Frequent themes of discussion during Breakout Room sessions included the importance of collaboration, need for funding and executive-level buy-in
- The top strategies that participants wished to implement included projects that prioritized environmental justice and vulnerable communities, increased collaboration and coordination, and proactive improvements.

Top themes identified by participants in LHMT Workshop #3



LHMT Workshop #3 Participants

1.2.3 Public Engagement

Equity Goals

Equitable engagement is a priority for this project. In an effort to strengthen existing social infrastructure and to support a more equitable and resilient future, the engagement team prioritized empowering stakeholders, residents, and community organizations early in the process. The project-specific equity goals include:

Being diligent and intentional about the composition of the LHMT so that it reflected the community in Boston City neighborhoods and community knowledge.

Evaluating whether the project's equity goals were met by 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 have been stressed by COVID-19. Respectfully and meaningfully asking for community input, addressing barriers to participation (including financial, technology, and language barriers), and compensating participation.

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.

Avoiding "planning fatigue" by building on previous and ongoing efforts, leveraging local expertise, and empowering residents, stakeholders, and partners to continue considering natural hazard preparedness beyond the duration of this project. The team also coordinated with related ongoing projects to find synergies between meetings and resources and avoid scheduling conflicts.

Developing accessible engagement materials by prioritizing visuals over text, using multilingual designs, using accessible language, and providing translation.

Street Team

The Street Team helped get the word out about the project; share project materials and engagement opportunities through their social media, newsletters, meetings, and other distribution channels; and represented community interests by participating in engagement activities such as the online survey.

The Street Team also advised the project team on appropriate activities to compensate participation, strategies to address the digital divide and increase the accessibility of virtual events, and methods to address additional barriers to participation, including language barriers.

What is a Street Team?

As part of the approach to equitable engagement, the project team sought to work with trusted community resources that were well connected and had established communication channels. To help reach as many residents as possible, the Street Team included a range of key partners such as:

- Age Strong Commission
- Department of Youth Engagement & Employment
- Disability Commission
- Language and Communications Access
- Mayor's Office of Immigrant Advancement
- Office of Neighborhood Services
- SPARK Boston
- Youth Homelessness Initiatives, Mayor's Office of Health and Human Services

A video shared online defining natural hazards

A facebook post advertising the first public meeting

Community Outreach

Due to the public health crisis surrounding COVID-19, the three required public meetings could not be conducted in person. As a solution, and to gather information from the public and educate the public on hazard mitigation, the City pursued the approach below.

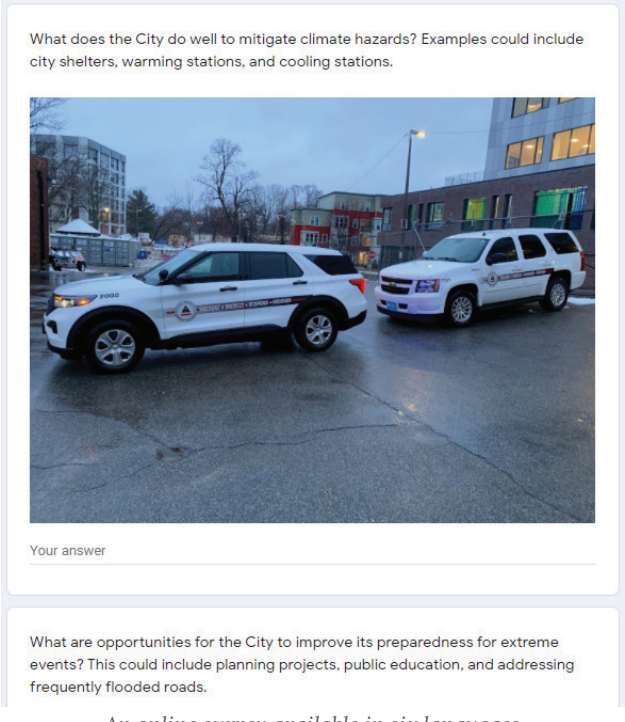
Fact Sheet & Survey

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. Both the fact sheet and the survey were translated into the City's top five languages, including:

- Spanish (Latin American)
- Simplified Chinese
- Haitian Creole
- Vietnamese
- Cabo Verdean Creole

These online materials allowed residents to engage with the project on their own time, and as their scheduled allowed. The online survey received 111 responses. The online materials were posted on the City of Boston's project webpage and advertised through social media posts and newsletters shared by the Street Team. These materials were also shared and promoted during meetings held by the Street Team, including:

- SPARK Chief Chat with OEM | March 31, 2021
- SPARK Meeting | April 5, 2021
- Disability Commission Meeting | March 31, 2021



An online survey available in six languages

A fact sheet translated into simplified Chinese

Community Meeting #1: Virtual Project Overview

The virtual meeting presented information related to the NHMP process, climate change in Boston, local strengths and vulnerabilities, examples of adaptation projects, and priority action items for future climate adaptation. The webinar also invited attendees to continue participating in the project by taking the online survey. Key findings from discussion and interactive polling with the forty-one participants included:

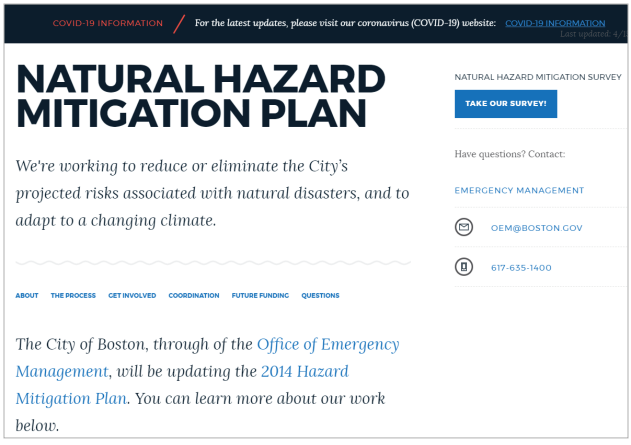
- The top three identified hazards of concern included flooding, winter weather, and extreme temperatures
- 61% of attendees had not been involved in a related previous planning process, such as Climate Ready Boston or the 2014 NHMP update
- The most frequently cited location for local flooding was Morrisey Boulevard
- The top three vulnerabilities of concern included power outage, public health impacts from extreme temperatures, and flooding of transportation infrastructure
- The top three considerations for prioritizing resiliency strategies were community benefits, environmental benefits, and feasibility (including technical feasibility, cost, and legal authority)
- Hazard mitigation strategies identified during a group brainstorm included public education and nature-based solutions and green infrastructure

A third of participants had heard about the public meeting through word of mouth, and a quarter had heard about the meeting through a newsletter or e-blast.

Community Meeting #2: Presentation of Draft Plan

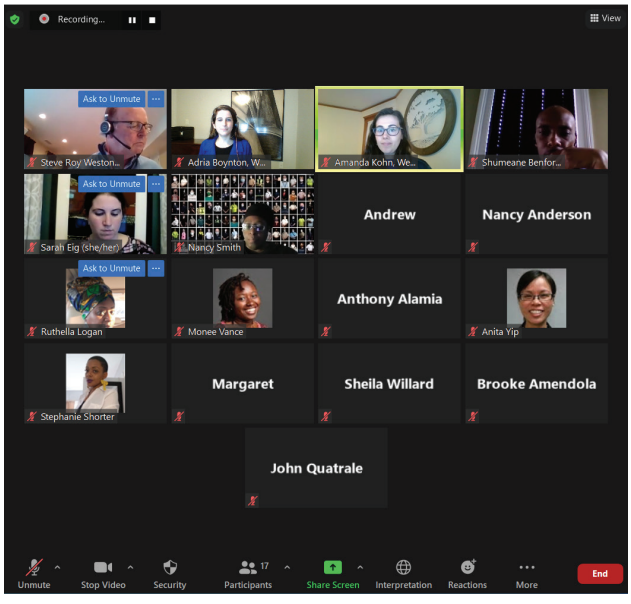
Description to be added.

More information about public engagement, including a summary of survey responses, is available in Appendix D.



A screenshot of the project webpage

Flood locations identified by participants in Public Meeting #1



Participants in Public Meeting #1

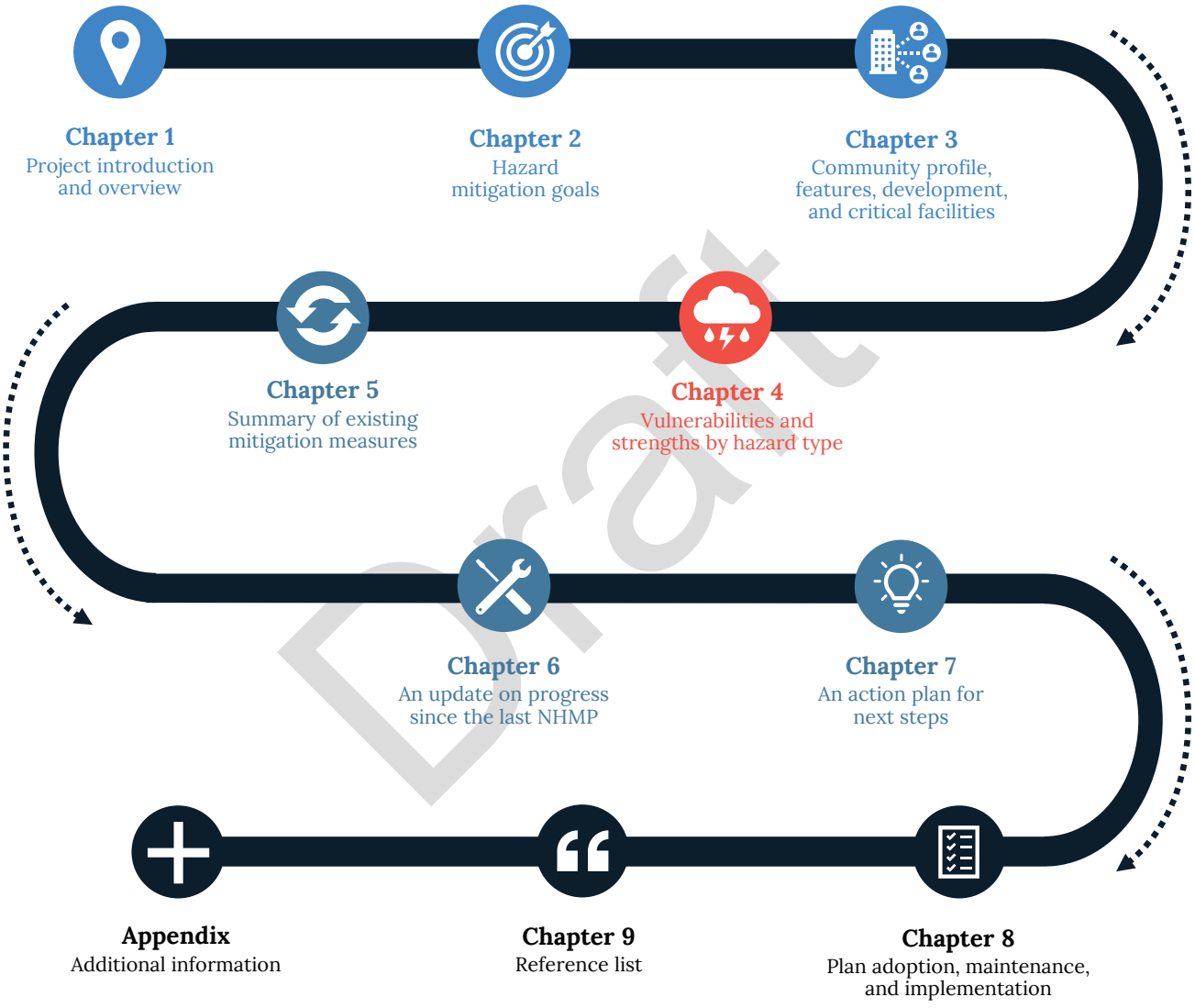
Addressing Challenges to Virtual Engagement

The project team planned each webinar to maximize participation and engagement. The team used equitable engagement modifiers to facilitate participation during meetings, including:

- Working closely with the LHMT and Street Team 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. Translating directions, contact information for tech support, an optional call-in number, local venue for free Wi-Fi, and and providing premeeting assistance for participants joining
- Scheduling meetings at times that allow working parents and adults with multiple jobs to attend
- Including giveaways for meeting attendees, such as gift cards
- The team also created a presentation that prioritized accessible language and graphically engaging visuals over text-heavy slides
- 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
- Providing translation services during meetings through collaboration with the City and project partners
- The staffing plan for the meeting included a main facilitator to present information and encourage discussion and additional facilitators to help field questions and moderate
- Translating project materials and deliverables through collaboration with the City and project partners

Looking for Something Specific?

The report presents the results of the planning process, which was informed by data review and analysis, and input received during ESC meetings, Local Hazard Mitigation Workshops, and Public engagement activities. This report is organized as visualized in the diagram below.



TWO: HAZARD MITIGATION GOALS

At its February 8, 2021 meeting, the Boston Hazard Mitigation Executive Steering Committee meeting established the goals and objectives for natural hazard mitigation planning in Boston. The committee reviewed and confirmed the goals at their subsequent meeting.

1 Equitably protect the health and safety of the public through awareness, preparedness, and connections.

- Provide programming to support educated, connected, empowered communities and individuals in pursuing operational preparedness, adaptation planning, and emergency response by coordination with Climate Ready Boston.
- Promote systems that encourage preparedness and that provide early warning communications prior to and during an emergency through Boston's Office of Emergency Management.
- Increase community engagement and outreach by providing support to organizations and agencies that provide services to vulnerable populations.
- Identify possible barriers to evacuating in an organized and efficient manner and develop systems and services for people that have limited ability to evacuate.

2 Invest in protecting properties and structures.

- Provide educational resources for residents, businesses, public officials, developers, and contractors on measures that can be taken to make buildings and properties more resilient to natural threats.
- Create a regulatory environment, financial incentives, services, and other approaches to integrate climate resilience and hazard mitigation into proposed and existing buildings and developments.
- Increase the number of buildings insured for flooding and other hazards through education and outreach.
- Increase the number of business owners and operators with business-continuity plans that incorporate a range of natural hazards and climate change.
- Encourage solutions that are innovative, protect neighborhood character, and protect the natural environment.
- Provide information to property owners and developers regarding natural hazards when planning for new development and significant redevelopment projects.

3 Increase resilience by protecting and enhancing natural resources.

- Identify and utilize the capacity of natural areas to buffer natural disasters.
- Encourage the use of green infrastructure and low-impact development approaches in new development and redevelopment and measure the performance of such infrastructure and approaches over time.
- Preserve and restore the functions of natural resource systems such as wetlands and tree canopy.
- Create a waterfront for all Bostonians that is climate-resilient and has the stewardship needed to thrive coming generations.
- Envision and create an accessible and equitable open space system for Boston's future.
- to promote livability and healthy environments.

4 Ensure that essential services and infrastructure will function during and after a hazard event and prepare essential services for projected climate change.

- Mitigate natural hazards posing risks to public health services and critical networks (such as sanitation, transportation, energy, water, wastewater, debris removal, digital systems, communications, hospitals, and emergency services) and provide redundancy.
- Assess and improve operational capacity to prepare, respond, and recover, including the availability and capacity of key service providers and employees.
- Minimize secondary impacts from hazard events, such as the release of pollutants, with a particular focus on fuel storage facilities, waste management sites, and stormwater infrastructure.
- Deepen coordination with regional, state, and federal authorities on public and private infrastructure activities through the Metro Mayors Climate Preparedness Taskforce and other relevant coordinating entities.
- Understand priorities and capabilities of state agencies, surrounding communities, and private entities to allow for resource sharing, mutual aid, and entering into agreements, like memoranda of understanding.
- Create redundancy in protection, response, and recovery by working at multiple scales, including with regional and state agencies, neighboring communities, and private entities.
- Integrate hazard mitigation and climate adaption into City initiatives and plans and streamline interdepartmental communication.

5 Implement hazard mitigation and climate adaptation projects that meet strategic priorities.

- Develop an asset management plan and condition inventory of existing mitigation structures, both public and private.
- Develop and practice an operations and deployment plan of public and private active hazard mitigation structures, like deployable barriers.
- Prioritize new hazard mitigation and climate adaptation structures with multiple co-benefits to society and mitigate the inequitable impacts of natural hazards.
- Invest in strategies that expedite preparedness, response, and recovery of socially vulnerable neighborhoods and local businesses.
- Give first consideration to nature-based strategies, while recognizing hard infrastructure improvements will need to be a part of the solution.
- Design hazard mitigation and climate adaptation structures that allow for adaption over time.
- Leverage hazard mitigation and climate adaptation as a tool for equitable economic development.
- Monitor and measure emerging risks across the City and how investments have reduced risk exposure over time.
- Incorporate community involvement in design and decision making in each phase of the emergency management cycle.
- Add hazard mitigation and climate adaptation projects into the Capital Investment Plans for City Departments represented on the Executive Steering Committee and advocate that other departments to do the same.
- Improve and centralize systems for documenting hazard impacts, necessary operational improvements, implementation of the NHMP, and other hazard mitigation metrics such as the costs of damage, number of insured properties, mitigation-related improvements to private property, and the impact of mitigation measures on health and safety.
- Create stable and reliable funding mechanisms to ensure implementation of hazard mitigation and climate adaptation.


BOSTON CITY HALL
POSTSEASON
DAMAGE

THREE: COMMUNITY PROFILE

City of Boston

On the eastern shore of Massachusetts in Suffolk County

48.28 square miles of land
41.2 square miles of water

Incorporated as a town in 1630, as a city in 1822

684,397 residents

26 neighborhoods

Mayor-Council form of government

City of Boston Office of Emergency Management's website

(BPDA, 2020*a*; BPDA, 2020*c*; *City of Boston*, 2015; ACS, 2019)

3.1 City Context

Abundant natural resources and well-connected waterways of the Boston area sustained the Massachusett people for thousands of years and support millions of people today. Since English settlers reached the shores of the Massachusetts Bay, the City of Boston's growth has been fueled by its position as a major harbor. As an expanding residential and commercial center, Boston's settlers filled in wetlands and waterbodies with the historic five hills and other sources to create hundreds of acres of new land (Brooks, 2011). This practice of reclaiming land by filling waterways has now made the city more vulnerable to natural hazards and climate change impacts, including flooding, sea level rise, and earthquakes.

Ever Wonder How Back Bay Got Its Name?

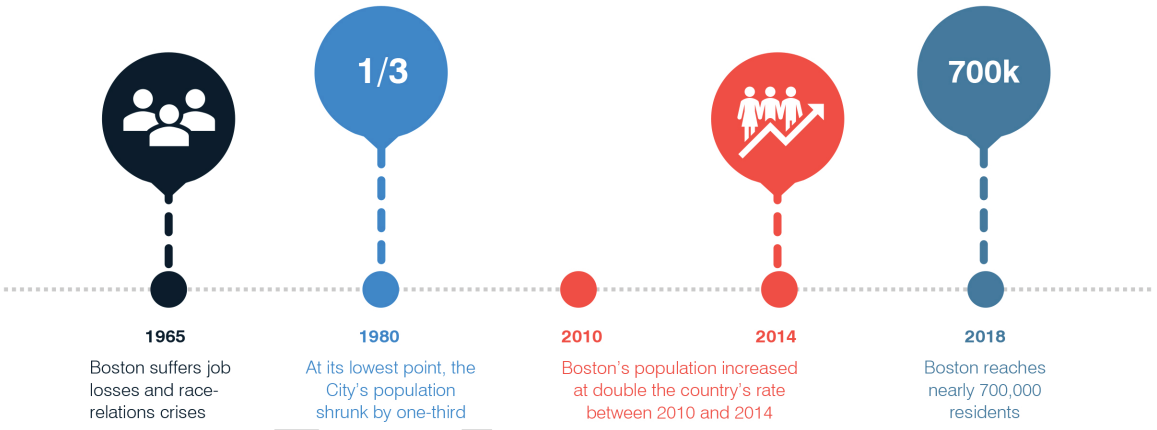
Originally tidal flats, this neighborhood was filled with trash, mud, sand, and gravel during the 1800s to create new land for development (Mason, 2017)

Old and New Boston Land Areas (Bacon, 1903)

(Climate Ready Boston, 2016)

Boston's physical and social history during recent centuries was also shaped by national policies and trends. The revolutionary and abolition movements were followed by industrial decline in the mid-20th century, racial discrimination and conflict over desegregation, and urban renewal policies.

In the first two decades of the new millennium, Boston has experienced a growing knowledge economy. This attracted young people and new technological industries, but we are still juggling the legacies of inequality, unaffordability, and environmental contamination. The City's features listed in this chapter serve as both strengths and vulnerabilities as the region faces climate change and natural hazards.



(Imagine Boston 2030, 2017)

3.2 Societal Features

TABLE 3-1. DEMOGRAPHICS

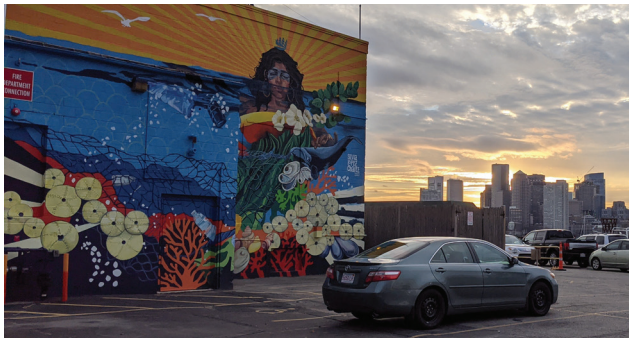
RACE OR ETHNICITY	BOSTON	MASSACHUSETTS
Native Hawaiian and Other Pacific Islander	0.1%	0%
Native American and Alaska Native	0.2%	0.3%
Other Race	0.8%	4.3%
Two or More Races	2.4%	3.6%
Asian	9.6%	6.9%
Black or African American	22.7%	7.9%
White	44.5%	77.0%
Hispanic or Latino	19.8%	12.4%

BOSTON		MASSACHUSETTS	
AGE			
15.8% Under Age 18	**11.5%** Over Age 65	**19.6%** Under Age 18	**17%** Over Age 65
EDUCATION			
49.7% Bachelor's degree or higher		**45.0%** Bachelor's degree or higher	
DISABILITIES			
11.9% With a disability		**11.5%** With a disability	
ENGLISH SPEAKING SKILLS			
17.4% Limited English-speaking skills		**9.2%** Limited English-speaking skills	
INCOME			
$71,115 Median household income	**18.9%** Poverty rate	**$85,843** Median household income	**9.4%** Poverty rate
HOUSING			
294,418 Housing units	**32.1%** Owner-occupancy rate	**2.9 M** Housing units	**62.2%** Owner-occupancy rate
40% Burdened by housing costs* (renter)	**16%** Burdened by housing costs* (mortgage)	**40%** Burdened by housing costs* (renter)	**15%** Burdened by housing costs* (mortgage)
TECHNOLOGY			
91.0% With a computer	**85.4%** With a broadband internet subscription	**93.5%** With a computer	**88.9%** With a broadband internet subscription

(US Census Bureau 2015-2019)

**Burdened by housing cost: if the monthly housing cost is 35% or more than the household income*

Percentages were rounded to the nearest integer



East Boston

The Rose Kennedy Greenway

Chinatown

Fort Point Channel

Boston's 26 neighborhoods represent a vibrant, international community that is served by world-class health and education institutions and a range of social services. Residents and visitors have access to transit, computer/internet service, and open space, but access varies by location and population.

Many Boston residents may not have the supplies, insurance coverage, and evacuation plans should an emergency arise. Few residents report that their neighborhoods or families are very prepared for the effects of climate change, and the numbers are even lower for Latinos/as, Blacks, and Asian Americans (Sustainable Solutions Lab, 2020).

A LEADER IN PUBLIC SERVICES

First large free municipal library in the United States

First community health center, established in 1965

First subway tunnel in North America in 1896

Certain populations in the City may need additional support before, during, and after an extreme event. These populations include children, the elderly, those with limited mobility, people at risk of isolation, residents with barriers to building personal resilience, and residents with limited English-proficiency (especially if emergency communication is not translated).

All stressors play a role in a community's resilience, so ongoing patterns of discrimination and legacies of racism also make some populations less resilient than others. Disparities in public health, safety, and economic opportunity among neighborhoods mean that statistics and policies at the city scale do not always reflect local conditions. For example, premature mortality in Dorchester is almost double West Roxbury rates (100 Resilient Cities, 2017). Increased exposure to environmental contaminants also puts some residents at a higher risk of health impacts from air pollution caused by dust and drought.

3.2.1 Social Vulnerability Mapping

Social vulnerability considers how different members of our community may be more vulnerable to hazards based on exposure, sensitivity, and adaptive capacity. Different demographic groups may be disproportionatly impacted due to historic and current inequities.

The Metropolitan Area Planning Council (MAPC) conducted a study of social vulnerability in Greater Boston (Flingai, Spence, and Guerrero, 2019) similar to Climate Ready Boston. Both analyzed US Census data across six categories related to social vulnerability: age, race, disability, English language proficiency, and income. Note that this differs from the State's Environmental Justice designation that focuses on race, income, and English isolation.

Using 2015-2019 American Community Survey date, Figure 3-1 captures a composite score of vulnerability. Each Census Tract was given a point if 25% or more residents identified with one of the six categories. The social vulnerability analysis was also compared to natural hazard impacts as reported in Chapter 4.

Neighborhoods with the **highest concentrations of climate vulnerable populations** included:

- Roslindale
- Roxbury
- Hyde Park
- Dorchester
- Mattapan
- East Boston
- Jamaica Plain
- Fenway

Boston is home to incredible examples of community resilience. Visit the Climate Ready Story Project for more information on how residents have helped each other through times of crisis.

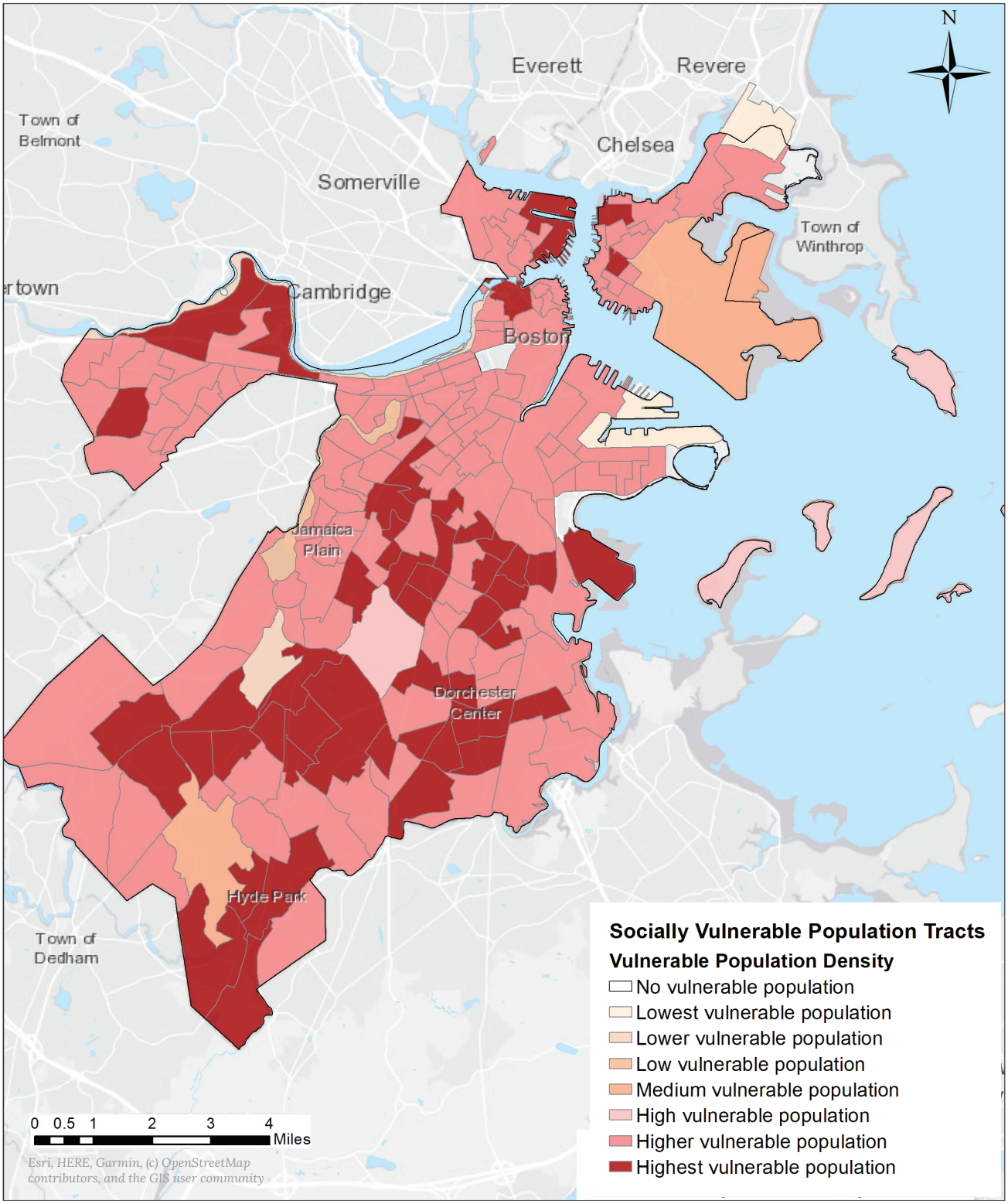


Figure 3-1. Map of Socially Vulnerable Population Census Tracts. "No vulnerable population" indicates that there are no vulnerable populations in those Census Blocks. "Highest vulnerable population" indicates that the proportion of vulnerable populations are highest in those Census Blocks.

Strengths

- A growing and increasingly diverse community. Most Boston residents are people of color, and more than 1 in 4 were born outside of the US. (City of Boston, 2017b)
- **140** Languages spoken in Boston
- High rates of broadband and computer access
- Highest population of millennials (ages 20-34) of any US city (BPDA, 2013; Boston Indicators, 2017)
- A growing economy
- Neighborhood-level climate adaptation planning
- Dozens of museums and libraries
- 29 colleges and universities
- Critical employees are able to rely on the MBTA
- Most hospitals are equipped to island during an extreme event
- The Greater Boston Food Bank is connected to agencies across the State and can help with regional recovery efforts. Boston is connected to Feed America, and local food banks provide strength
- Cultural institutions and collections have emergency operation departments and plans
- Community organizations support residents, communications, and response
- City provided laptops to students. Local programs are available to provide devices and training to lower income households and seniors
- Boston uses a mass communications system that translates into 5 languages
- Assessment and modelling completed through the Climate Ready Boston initiative

3.2.2 Spotlight on Strengths

In 2016, the City initiated Climate Ready Boston to prepare for the long-term impacts of climate change. This process deepened Boston's understanding of climate adaptation and hazard mitigation risk, and identified priority actions to build a more resilient community.

The discussion, coordination, and momentum of this process led to numerous assessments, climate modeling efforts, and the incorporation of climate change resilience and hazard mitigation into the City's planning and regulatory framework. Action items from the 2014 HMP were reflected in the final Climate Ready Boston report. Similarly, this plan reflects findings of the Climate Ready Boston initiative.

Vulnerabilities

- Existing urban heat island effect. Up to a 15°F overall temperature difference in the City (Museum of Science, 2019)
- Large population of low-income residents
- Racial educational achievement and income gaps
- Housing unaffordability and displacement
- Disparities in health status (e.g. asthma) and mortality rates by neighborhood
- Disproportionate exposure to hazardous sites by communities of color (Faber and Krieg, 2005)
- The high number of non-English speaking residents, or those with limited English fluency, can be vulnerable in emergencies due to communication barriers
- A legacy of residential segregation (100 Resilient Cities, 2017)
- Accessible community health centers are not equipped to island
- Evacuation routes are currently in draft form and will need to be promoted widely and practiced
- Internet is not accessible to all communities and is dependent on electricity, affordability of Wi-Fi, access to devices, and knowledge of how to use devices
- Residents experiencing homelessness are vulnerable to natural hazards
- Disruptions in the food chain from natural hazards exacerbates food insecurity. Transportation connections may make accessing food, sheltering in place, and evacuation difficult for some residents
- Health staff may struggle to reach hospitals during hazard events
- Elderly residents face transportation and mobility challenges that result in lack of access to medical services and possible isolation
- Emergency response personnel face access and staffing issues
- Public housing stock is outdated and many elderly and disabled residents are at risk of isolation and in need of additional assistance and support
- Boston has an unstable rental housing stock and most residents have no access to emergency funds and may require public assistance
- Density of development in some older parts of the City may lead to evacuation and emergency response systems being overwhelmed
- There is a need to bring community organizations and non-traditional cultural institutions into mitigation and response planning more

3.2.3 Economic Features

Home to state government, federal facilities, high tech companies, major universities, hospitals, and financial institutions, Boston is an economic hub for the state and the New England region (City of Boston, 2016c). The City's waterfront serves a significant regional role in providing jobs related to cargo transport and ship repair, but these activities are decreasing (City of Boston, 2016b). The City's tax base is also restricted, since half of the properties in Boston are tax-exempt uses (public, institutional, or open space; BPDA 2020a).

Growth can increase revenues that support schools and services, increase job and business opportunity, and increase housing affordability by increasing supply. Growth can also cause demand pressures that can lead to increased housing costs, costs of living, and increased business rents and prices, which may drive some small business out. Imagine Boston 2030 recommends directing growth to existing neighborhoods and the commercial core to provide significant amounts of new housing and spaces to work. Growth in these areas alone will not accommodate all of Boston's demand for housing and commercial spaces, and development will be needed in new areas of the city to keep up.

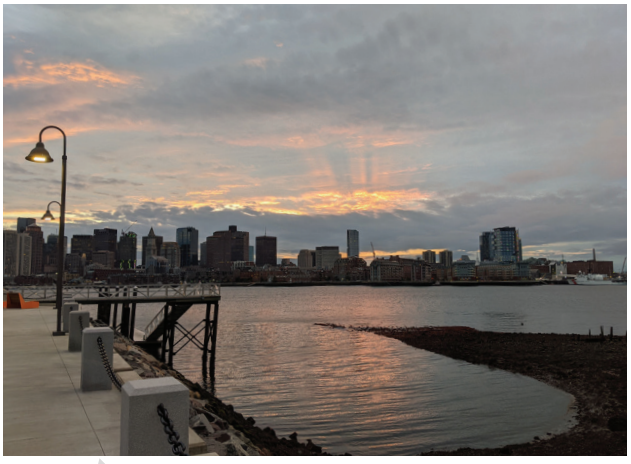
The regional economy moves – literally - through the Greater Boston area. While 229,600 people travel into the city for work, 98,000 residents commute to jobs outside the county (City of Boston, 2017a). However, the City's economic growth has largely benefited non-Boston residents who commute into the City. Boston residents have lower incomes than nonresidents. The City's poverty rate is more than double the State's average at 19%, and unemployment affects communities of color most (100 Resilient Cities, 2017).

> "The benefits of growth have not been shared by all"
>
> – 100 Resilient Cities, "Resilient Boston," 2017, page 18

The effects of the COVID-19 pandemic in 2020-2021 on the City's economy have not been fully quantified, but reduced tax revenue and changes in development and land use patterns are likely to follow. The City has experienced widespread loss of life, impacts on the healthcare and educational systems, and disruptions to income, tourism, commuting, small businesses (Sharifi and Khavarian-Garmsird, 2020).

City Hall Plaza, with a view of Faneuil Hall Marketplace

Tufts Medical Center



A view of Boston Harbor from East Boston

ECONOMIC HIGHLIGHTS

409,573
Residents employed
(US Census Bureau, 2019)

Boston is
24%
of the State's economy
(Boston, 2016c)

Boston is
10%
of New England's economy (Boston, 2016c)

Boston's economic growth exceeded the State and Nation for
4 YEARS
pre-COVID
(BPDA, 2020b)

MARITIME INDUSTRY

the Port is the state's
6TH
largest employer
(Boston, 2016b)

the Port creates approximately
50,000
total jobs
(Boston, 2016b)

total weight of goods imported decreased
20%
from 2010 to 2016
(Boston, 2016b)

maritime employment decreased by
24%
from 2001 to 2015
(Boston, 2016b)

Boston's Port has a
$4.6-billion impact
(Boston, 2016b)

contributes **$136 million** in state and local tax revenues (Boston, 2016b)

more than **1,600 businesses** use the port (Boston, 2016b)

OTHER MAJOR EMPLOYERS

State and Federal agencies
Healthcare
Education
Finance
Small businesses

PRIMARY ECONOMIC CENTERS

Financial District
Colleges & Universities
Longwood Medical Area
Community Facilties
Economic Development Area
Boston Harbor
South Boston Waterfront
Main Street Districts

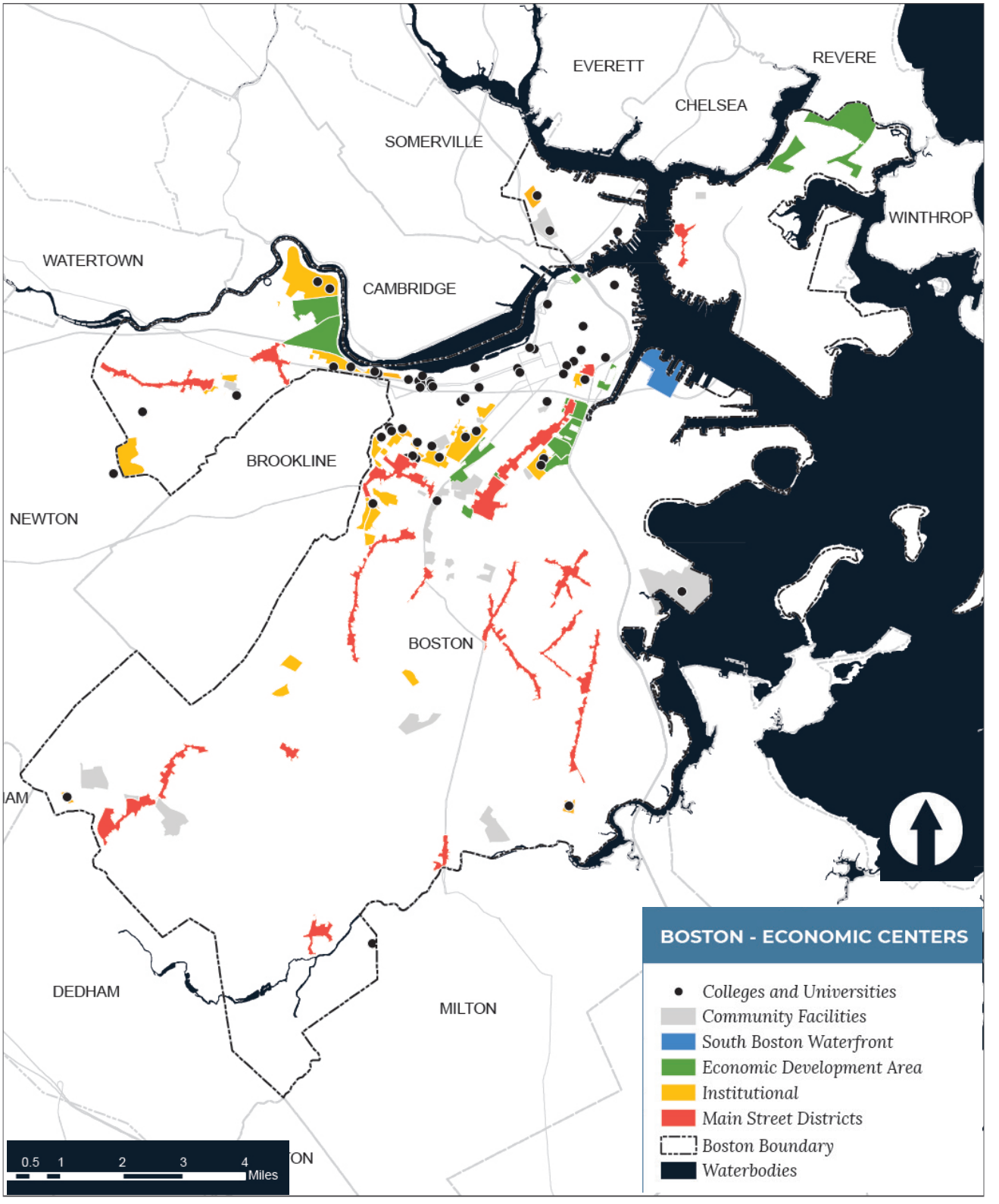


Figure 3-2. Economic Centers in Boston

3.3 Infrastructure Features

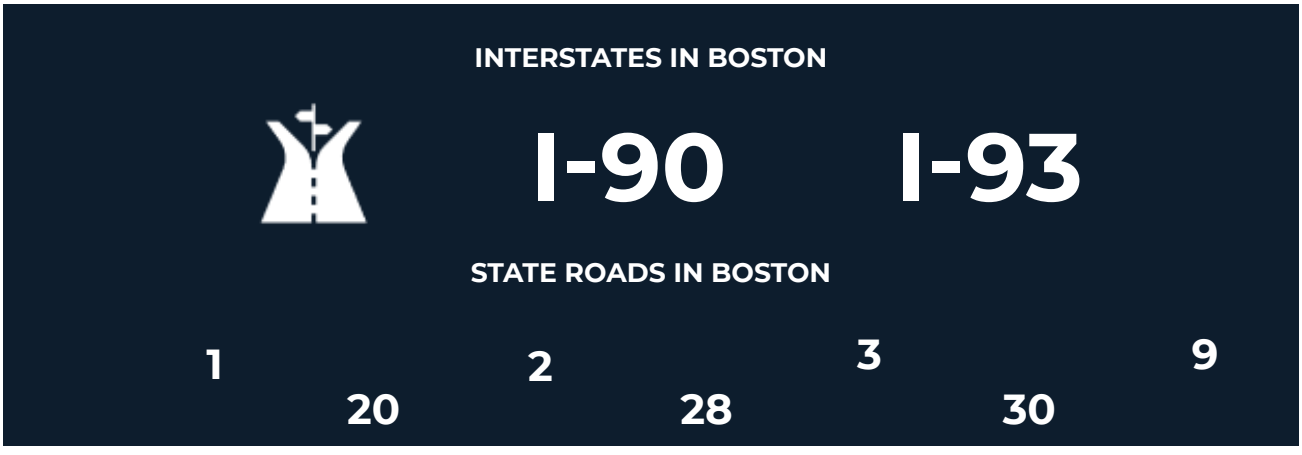
3.3.1 Transportation

Boston is New England's transportation hub, home to a regional commuter rail, regional Amtrak stations, the Boston Harbor, subway lines, buses, ferries, and Logan International Airport. The largest transportation center in the region, Logan International welcomed over 40 million passengers in 2018. The airport and the seaport are also transportation hubs for hundreds of millions of pounds of freight. The Massachusetts Port Authority (Massport) that operates Logan International also manages critical facilities including the Port of Boston, Conley Terminal, Cruiseport, the Boston Autoport, and real estate in South Boston and East Boston (Massport, 2019). See Section 3.5 for more information on regional vulnerabilities.

Boston is a very walkable city, with 15% of people walking to work and walking forming an essential component of most transit trips (City of Boston, 2017a). More than half of all commutes are done by transit, walking, or biking.

Many major employment centers are connected to Downtown Boston by MBTA services (the T), but new business districts leave some commuters with long and complex daily routes. Capacity is also strained on many lines, and some haven't been substantially replaced in almost 50 years (MBTA, 2019). Because 36% of commuters entering Boston do so by transit, regional transit reliability affects a significant proportion of commuters. The T has been shut down by flooding, heavy snows and by extremely hot days. Most notably, flooding has shut down both the green line (D line from Kenmore to Longwood) and the blue line (at Aquarium). Walking and biking will be affected by extreme weather conditions, too, but are less likely to be affected by power outages. Ridership on ferries has grown to over 1.3 million people a year, and this mode of travel is particularly vulnerable to coastal storms.

Forty-six percent of Bostonians drive to work. Many people commute from outside the city and rely on regional highways and bridges to get between home and work. Also, nearly 90% of Massachusetts goods are moved by freight truck, contributing to, and affected by congestion in the highway network (ABC, 2013). A 2019 study ranked Boston as having the worst traffic congestion in the United States (Gerst, 2019). However, the dramatic decrease in traffic enabled by remote work during the COVID-19 pandemic has reinvigorated support for improved public transportation and more pedestrian-friendly streets (Seay, 2020). Several roadways are at risk of flooding and are identified in Chapter 4. Throughout the public and stakeholder engagement, Morrissey Boulevard was continuously named as the area where flooding frequently occurs and is of top concern.



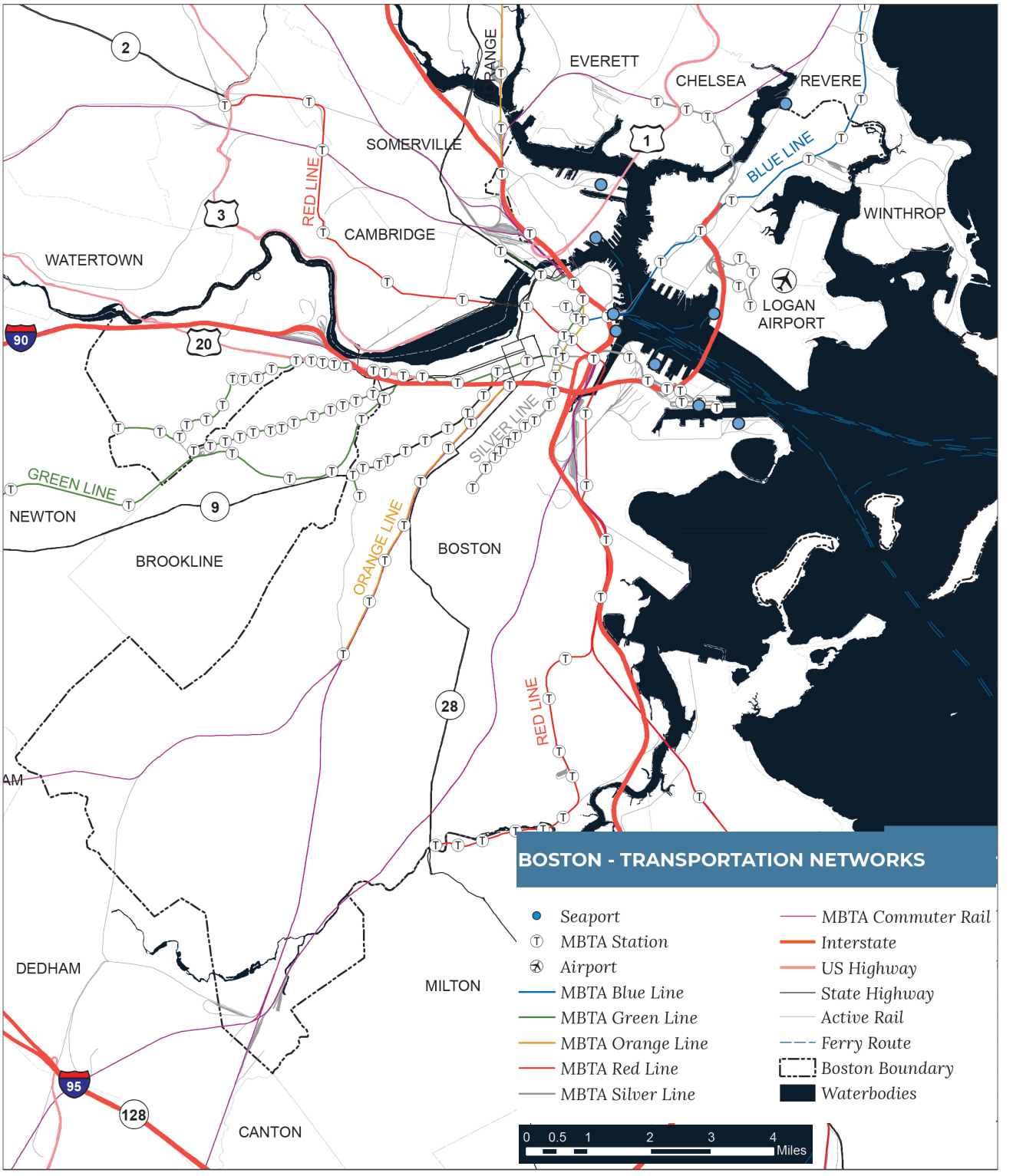


Figure 3-3. Transportation Networks in Boston

Boston's aging transportation infrastructure, particularly bridges, can be vulnerable to earthquakes. A recent study found that more than 10% of the City's bridges are either closed or "functionally deficient" (ABC, 2016). Small earthquakes happen regularly in Boston, but are often of small magnitude and go unnoticed. However, larger earthquakes can occur as evidenced by the 6.2 earthquake off of Cape Ann in 1755. Please see Chapter 4 for more information on the potential impact of earthquakes and other natural hazards on the City's aging infrastructure.

3.3.2 Waterfront

Boston is among the top four most vulnerable cities in the United States to flooding, but almost 600 acres of the waterfront is designated for water-dependent industrial uses (City of Boston, 2016b). The City is actively working to address climate risks to the waterfront in recognition of how important this space is for critical infrastructure, jobs, and public outdoor space. See the "Economic Features" section for more information on the economic impact of the waterfront, and Chapter 4 for more information on historic and future climate risks there.

3.3.3 Neighborhoods, Buildings, and History

Boston is home to 26 vibrant neighborhoods: Allston, Back Bay, Bay Village, Beacon Hill, Brighton, Charlestown, Chinatown, Dorchester, Downtown, East Boston, Fenway, Harbor Islands, Hyde Park, Jamaica Plain, Leather District, the Longwood Medical Area, Mattapan, Mission Hill, North End, Roslindale, Roxbury, South Boston, South Boston Waterfront, South End, West End, and West Roxbury (BPDA, 2020c). Many important events in the City's rich history are memorialized by sites and buildings including the Paul Revere House, Old North Church, Old State House, USS Constitution, and the Granary Burying Ground. In addition, 34 islands and peninsulas are preserved as the Boston Harbor Islands National and State Park.

Portions of Dorchester, Roxbury, and Hyde Park neighborhoods are federally designated Empowerment Zone and Enterprise Communities, eligible for federal assistance because of poverty levels and economic distress.

East Boston

Chinatown

The "Wicked Hot Boston" project identified temperature disparities in the City, including increased urban heat islands in the South End, East Boston, the Seaport, the North End, and Dorchester. The highest temperature was recorded in Dorchester at over 102°F (Museum of Science, 2019). Please see Chapter 4 for more information on the impact of extreme heat on vulnerable populations.

As of 2018, Boston had 114.4 million square feet of commercial office space and more development underway. There are almost 275,000 occupied housing units in Boston, but planned residential development is not sufficient to house the City's estimated 2030 population of close to 760,000 residents (BPDA, 2020b). Commercial office buildings make up 18 percent of Boston's built square footage, but only two percent of the total number. Small residential buildings are 93% of buildings in the City, and most were built before 1950 and the advent of building codes (Hatchadorian et al., 2019).

What is Stormwater?

Stormwater is rain or snow melt that soaks into the soil and recharges groundwater, naturally drains into waterbodies, or is conveyed through a series of pipes until it is discharged into a nearby waterbody. Stormwater runoff, if not properly treated, can carry pollutants into waterbodies such as the Harbor, and can be harmful to public health and safety. Boston largely manages stormwater through an extensive system of pipes, culverts, outfalls and drains to quickly convey runoff to nearby waterbodies. In areas where the stormwater system becomes overwhelmed, flooding can occur. With rainfall events becoming increasingly intense due to climate change, some of the stormwater infrastructure designed decades ago is now undersized, which can also cause stormwater flooding. Refer to Chapter 4 for more information on inland stormwater flooding.

3.3.4 Power Supply

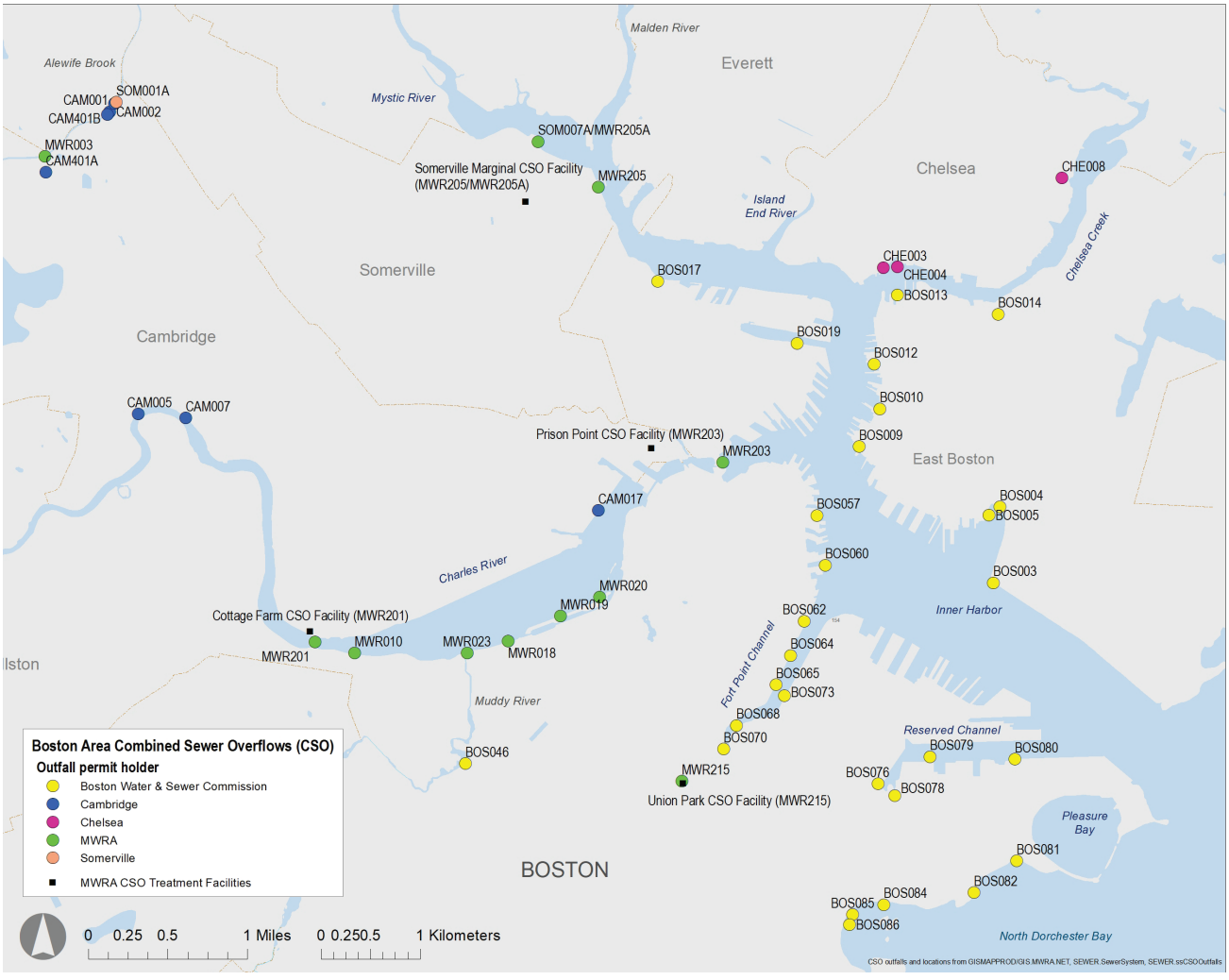
The City of Boston relies on natural gas and the electric grid for power. Boston launched the Community Choice Electricity Program in February 2021 to provide affordable, renewable electricity to residents and is the largest such program in the State. Constellation NewEnergy Inc. is the supplier for the program (City of Boston, 2021a). In certain areas of the City, the powerlines are underground and are less susceptible to damages from wind and winter weather. However, in many other residential areas, powerlines are above ground and are at greater risk.

3.3.5 Water, Wastewater, and Stormwater Systems

The Massachusetts Water Resources Authority (MWRA) and the Boston Water and Sewer Commission (BWSC) provide water and sewer service for the City. Drinking water is sourced from the Wachusett and Quabbin Reservoirs, located 90 miles west of the City of Boston. The BWSC purchases and distributes water from the MWRA and takes 36% of the MWRA water supply. Water is treated at a treatment plant in Marlborough before its distribution through 29 delivery points. BWSC's distribution pipes range in age from 18 to 147 years old and are made of a variety of iron and cement (lined and unlined) materials (BWSC, 2019; City of Boston, 2015). The water supply storage in the Wachsett/Quabbin system is able to withstand short- and medium-term droughts (MWRA, 2021).

The City's wastewater treatment plant at Deer Island, managed by MWRA, processes much of the sewage for the city and is the second largest plant in the U.S (ABC, 2016). Both the MWRA and BWSC maintain wastewater infrastructure in the City, including several combined-sewer systems. Combined sewers collect both wastewater and stormwater and convey it to Deer Island for treatment. On average, rain and snow runoff accounts for more than 60 percent of water treated at Deer Island. During large rain events, combined sewers may reach capacity and the untreated wastewater is diverted to combined sewer overflows (CSOs) that flow directly into local

bodies of water. This relief measure can prevent sewage backups into homes and businesses. Sewer system improvements by MWRA and BWSC (replacing combined systems) have reduced stormwater inflow into the system treatment plant, decreased CSOs, and eliminated dry weather overflows into local waterways. As part of its role in managing stormwater, BWSC also implements pollution abatement programs and stormwater management measures to improve the water quality of discharges to local waters. Both the MWRA and the BWSC have conducted multi-hazard risk and resilience assessments.



(MWRA, 2021)

3.3.6 Dams

There are five dams in Boston. One is classified as a High Hazard dam, and two are classified as Significant Hazard dams (ODS, 2019). The Charles River Dam is vulnerable to sea level rise and storm surge and could cause inundation throughout the City (BWSC, 2020). A 2019 study by the Associated Press identified 39 high hazard dams in Massachusetts in poor or unsatisfactory conditions (Casey, 2019). Regional dams that fail could potentially impact Boston. Please refer to Chapter 4 for more information on the possible effect of dam failure.

3.3.7 Waste Management

Eighty percent of City households (1.27 million) receive trash/recycling services. Boston generates almost 900,000 tons of trash and 410,000 tons of recycling each year (BWSC, 2020).

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@AlertBoston

3.3.8 Emergency Services

The City's Office of Emergency Management (OEM) educates the public and prepares for emergencies across the city. Having managed many past storms and catastrophic events, the OEM will continue to play a central role in responding to and preparing for climate and other natural hazards. OEM has regularly received grant funding to improve emergency response, including the Urban Area Security Initiative program to improve capabilities for handling acts of terrorism.

In addition to 73 fire stations and 23 police stations, the City has designated emergency shelters in every neighborhood. An AlertBoston system is available for all residents, businesses, and visitors to receive timely emergency communications. The Emergency Operations Center coordinates emergency response, and the department coordinates with Boston's EMS, Fire, Police, and Public Health Commission, and the Massachusetts Emergency Management Agency (City of Boston, 2021b).

To ensure the City's readiness now and in the face of climate change, OEM is leading this update of the City's Natural Hazard Mitigation Plan.

Strengths

- Extensive transit system
- Recent transportation system improvements
- Abundant water supply
- 26 vibrant neighborhoods
- Public buildings provide meeting places, evacuation spaces, cooling and warming sites, and space to assist residents who are displaced by natural hazard events
- Timely emergency communications through AlertBoston
- The existing communications system has some redundancies, and contingency planning is underway
- Dedicated leadership that supports hazard mitigation planning
- Regional watershed groups that support cross-boundary issues

Vulnerabilities

- High commute times and reliance on an aging transit system
- Extensive filled land vulnerable to hazards
- Old housing pre-dates building codes and buildings on wooden piers
- Impervious surfaces and stormwater flooding, approximately 54% of Boston's land has an impervious surface
- Aging infrastructure deficiences can compound impacts of natural hazards
- Waterfront development that may be subject to future sea level rise and coastal storms
- Narrow streets and congestions may impede evacuation or movement of needed materials
- Many critical equipment rooms in public buildings are in basements and vulnerable to flooding
- Some of the public housing stock is outdated and faces problems with drainage, heat, power outages, urban flooding and earthquakes
- Emergency response's ability to operate from contingency locations. Some existing emergency stations are in low lying areas
- Some public buildings do not have air conditioning and are in need of repair
- High winds can cause property damage and electric outages
- Fire hydrants get buried during winter storms, complicating access. Older hydrants need replacing
- Low lying roads flood often. Other roads face issues with flooding, snow, earthquakes, geohazards and wind
- Many bridges are underbuilt or need maintenance, and some are critical for reaching vulnerable populations
- MWRA has experienced water main breaks that led to water advisories. There is also a risk of cyberattack
- There are opportunities to improve communication infrastructure. For example, addressing the reliance on service providers for 911
- Electrical infrastructure is vulnerable to weather and other disruptions and supports other essential services
- Data servers are vulnerable to natural hazards
- Some wastewater pump stations are vulnerable to flooding and service large areas

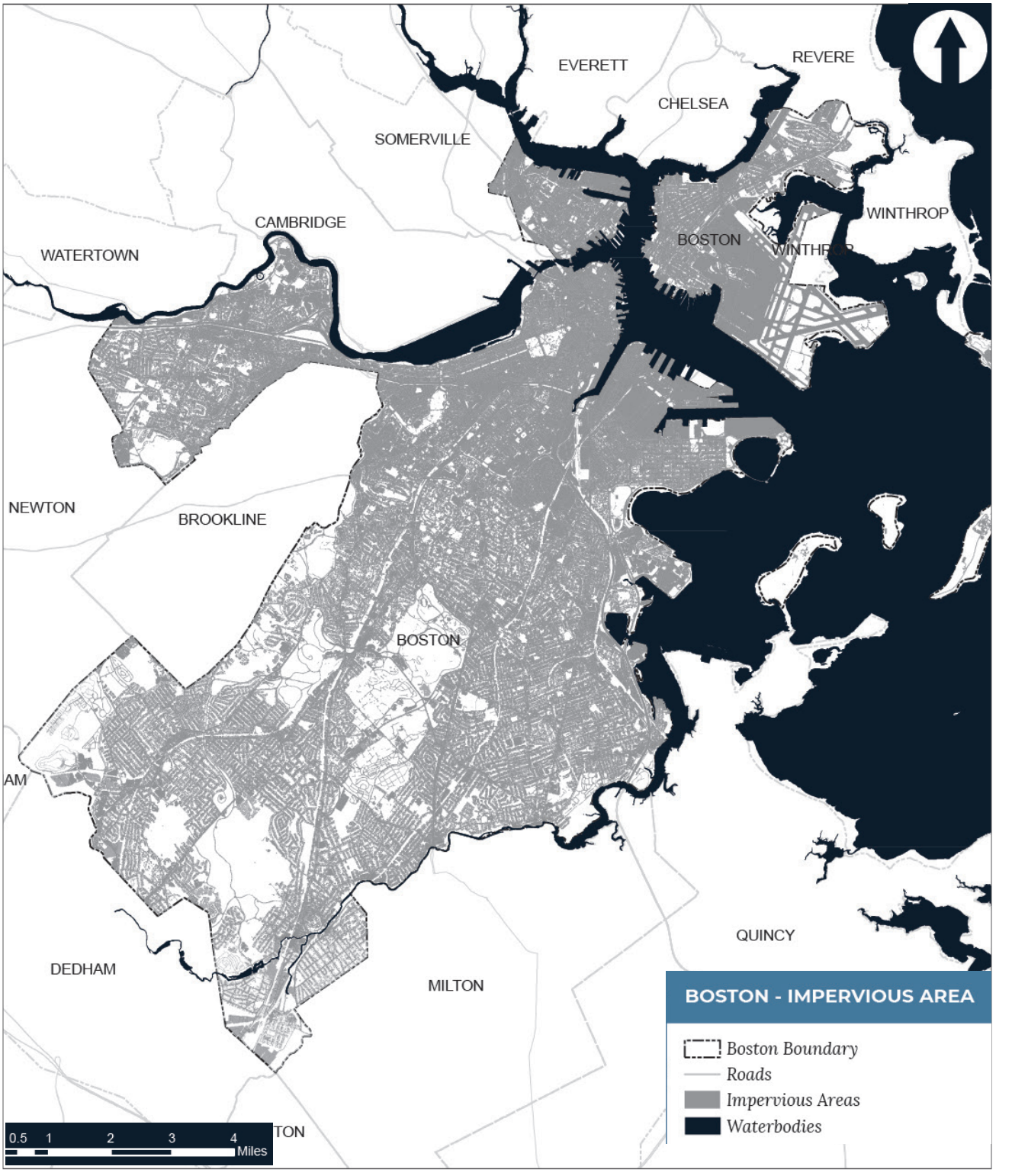


Figure 3-4. Impervious Surfaces in Boston

3.4 Environmental Features

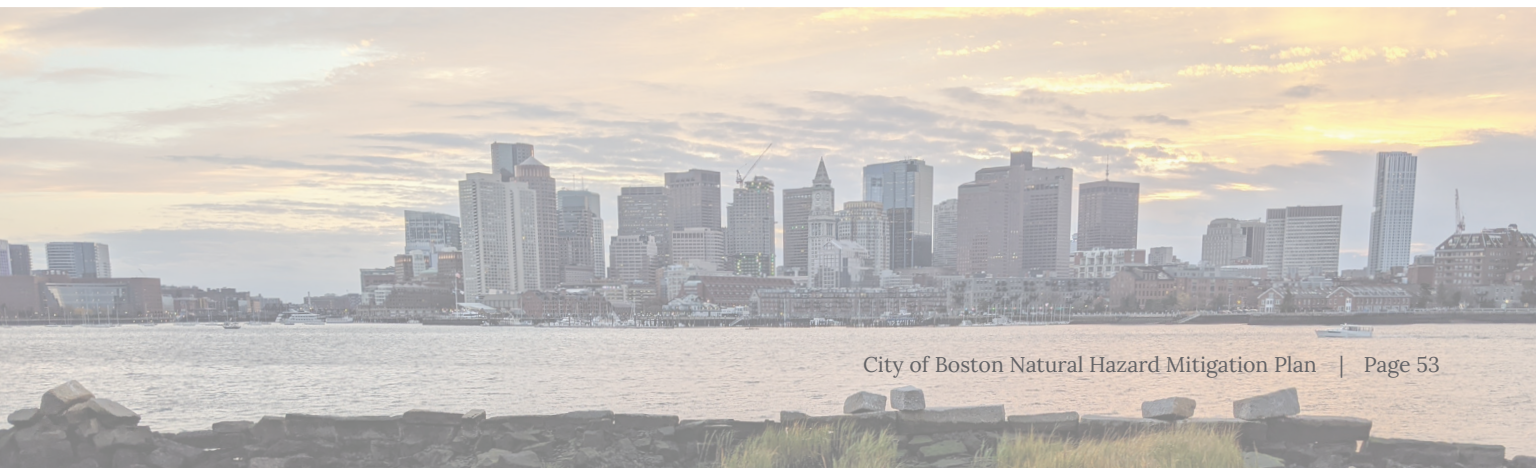
3.4.1 Natural Resources

Boston is part of both the Charles River Watershed and the Boston Harbor Watershed, which includes the northern Mystic River sub-watershed and the southern Neponset River sub-watershed. Boston's natural resources include the ocean, rivers, wetlands, islands, and varied uplands. The City includes "noteworthy landscapes" classified by the Department of Conservation and Recreation (City of Boston, 2015). The "noteworthy" designation is one of three classifications included as part of the State's Scenic Areas identified in 1982 (MassGIS, 2012). These are regionally important places for the Commonwealth. Much of the City is covered my impervoius surfaces, such as roads, sidewalks, and buildings that are in areas that were previously wet: tidal marshes, floodplains, bays, harbors and swamps. Impervious surfaces do not allow stormwater to readily infiltrate into the ground. Conversly, well-drained soils occur in the low hills and uplands in Mattapan, Hyde Park, and Roslindale (City of Boston, 2015).

3.4.2 Environmental Contaminants

A history of industry has left many neighborhoods with hazardous sites and environmental health issues. Several brownfield cleanup projects are underway in Boston, some in Empowerment Zone and Enterprise Communities, as defined by the U.S. Department of Housing & Urban Development. In the Dorchester, Roxbury, and Hyde Park neighborhoods, these cleanup efforts also dovetailed with the creation of a community center, Dudley Square revitalization, and Neponset River revitalization (EPA, 2008).

Boston began Harbor cleanup efforts in 1985, which led to nearly $4 billion of wastewater treatment improvements at Deer Island. The MWRA has also worked to improve sewer lines and reduce combined sewer overflows to better protect natural resources during heavy precipitation events. Collaborations with neighboring communities, regional organizations, and the State can help address environmental justice issues and the existing stressors that vulnerable populations face across geographic boundaries.



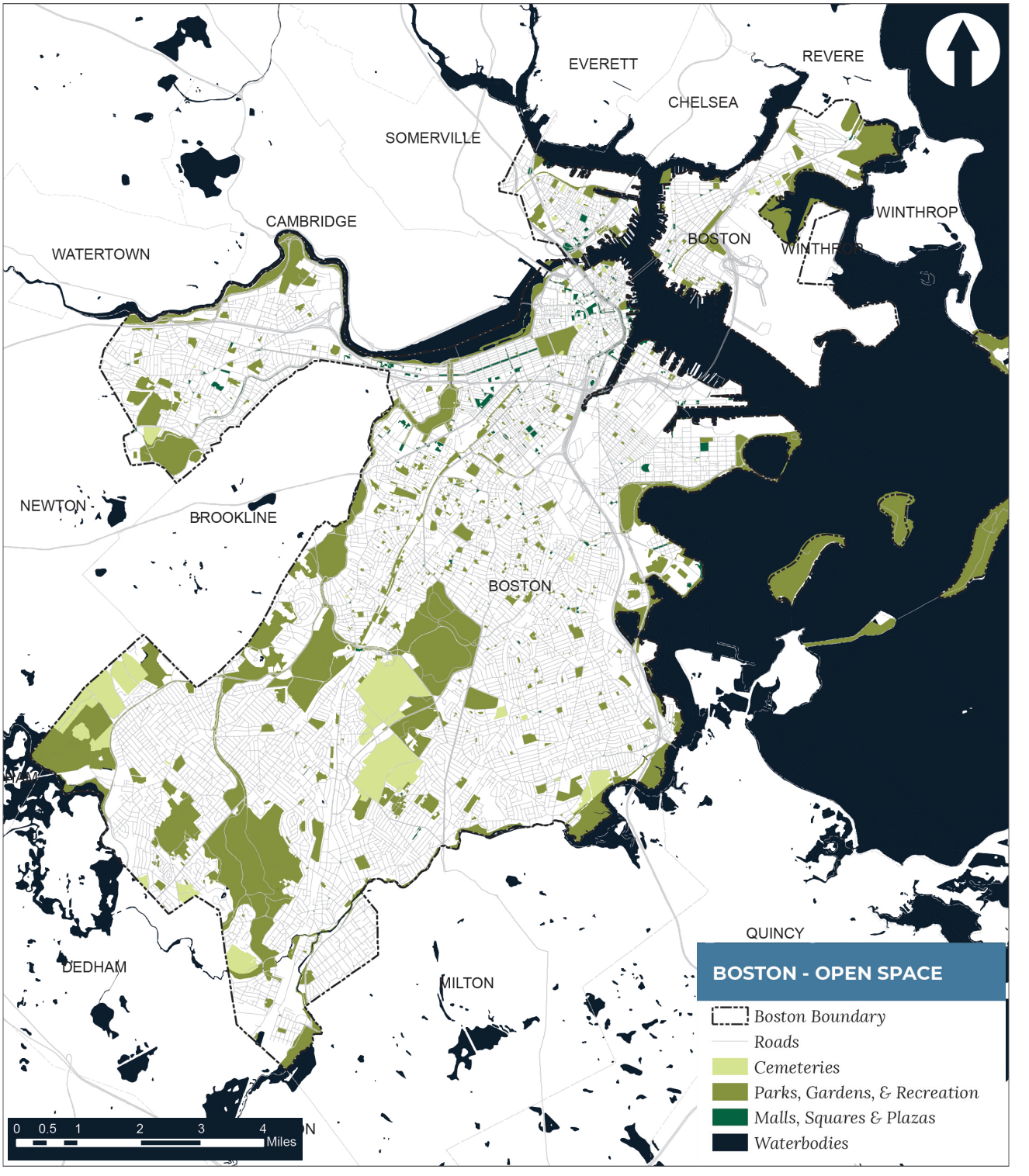


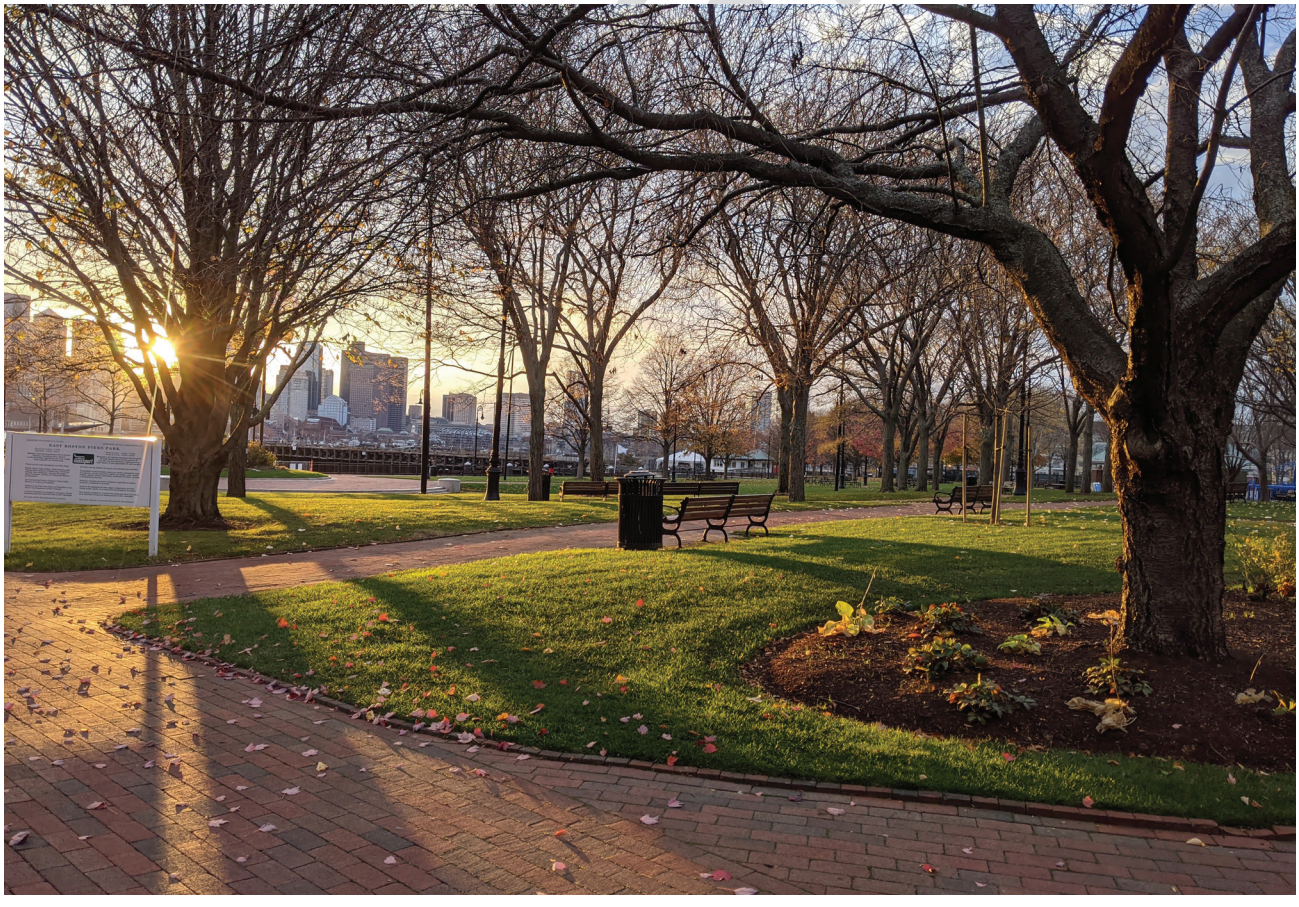
Figure 3-5. Open Space in Boston

Strengths

- Pedestrian access to open spaces, although outdoor spaces vary in number and quality across neighborhoods (City of Boston, 2015)
- New waterfront park projects such as Langone & Puopolo, Moakley Park, and Piers Park
- Parks help address the urban heat island effect

Vulnerabilities

- Inequitable access to open space (Faber and Krieg, 2005)
- Groundwater table



Piers Park in East Boston

3.5 Regional Vulnerability, Interdependencies, and Capacity

3.5.1 Regional Vulnerability

The City of Boston includes infrastructure that could adversely affect the surrounding region if crippled by an extreme event. For example, aging infrastructure such as bridges may be particularly vulnerable to hazards such as earthquakes, hindering shipping, commuting, or evacuation efforts. The I-95 Tunnel to East Boston and the airport could be flooded in the future due to sea level rise or from extreme weather events.

Regional infrastructure in Boston also includes:

- The Amelia Earhart Dam
- Medical centers, including:
  - Massachusetts General Hospital
  - Boston Children's Hospital
  - Brigham and Women's Hospital
  - Beth Israel Deaconess Medical Center (BIDMC)
  - Boston Medical Center
  - Spaulding Rehabilitation Hospital
- Waterfront infrastructure, including the Conley Container Terminal
- Transportation infrastructure, including:
  - MBTA buses, subways, commuter rail, bridges, and ferries
  - Logan International Airport

Please refer to Chapter 4 for more information on possible impacts of natural hazards on regional infrastructure, including a HAZUS analysis of potential earthquake damage (City of Boston, 2016a; Massport, 2019; ABC, 2013).

What is..?

Regional Vulnerability

Vulnerability is a function of exposure, sensitivity, and adaptive capacity. Regional vulnerability refers to the potential for an extreme event in Boston to adversely affect the surrounding area.

Exposure

The extent to which something can be impacted by natural hazards or climate change. Exposure is often determined by examining the number of people or assets that lie within a geographic area affected by a hazard, or by determining the magnitude of a climate change impact.

Sensitivity

The impact on a system, service, or asset when exposed to a hazard. The level of sensitivity indicates how much the hazard would disrupt the ability of the system, service, or asset to continue normal operation.

Interdependencies

The extent to which systems or assets are linked. Interdependencies can lead to cascading failures.

Cascading Failures

Failure is defined as the inability of a system, service, or asset to continue normal operation. Cascading failures occur when interdependent systems are crippled by a hazard.

3.5.2 Interdependencies and Cascading Failures

Many City systems are linked, and these interdependencies can become vulnerabilities during extreme events. For example, the Central Artery/Tunnel (CA/T) is at risk from sea level rise (City of Boston, 2016a) and if flooded could complicate emergency response and evacuation efforts. Similarly, flooding impacting the Sumner Tunnel could cut off access to East Boston. Hazard mitigation planning must consider interdependencies as part of developing strategies to address vulnerability. Please refer to Chapter 4 for more information on the potential impacts of natural hazards and Chapter 7 for priority action items to improve resilience.

Cascading failures occur when interdependent systems are impacted by an extreme event and unable to continue normal operation. For example, the COVID-19 crisis has exposed the potential for hospitals to become overloaded with patients and dangerously low on supplies because of supply chain disruptions. Similarly, when extreme weather causes power outages, vulnerabilities in the transportation system could lead to fuel shortages.

The 2015 winter weather events known as "Snowmageddon" provide a recent example of cascading hazard impacts in the Boston area. Within a 1-month period between late January and February, Boston experienced nearly 95 inches of snow, half of which resulted from Winter Storm Juno and Winter Storm Marcus. The record-breaking winter temperatures and snowfall led to disruptions to the MBTA commuter rain, subway, and buses, which disproportionately impacted the mobility of the City's' more vulnerable residents. Transportation disruptions also impacted the City's economy and the ability of health care providers and patients to reach hospitals (Flynn, 2017). If a similar event occurred today, critical systems that have already been stressed by the COVID-19 pandemic could be more severely impacted by an extreme event than if the natural hazard occurred during a non-pandemic period.

Adaptive Capacity

The ability of a system, service, or asset to adapt or prepare for an anticipated hazard or climate impact. Adaption is defined as an action that seeks to reduce vulnerability and risk to an anticipated hazard or climate impact.

Residual Risk

The level of acceptable risk. For example, a system that is prepared for the 500-year flood event may still experience the 1,000-year flood event.

Risk

According to the 2018 State Hazard Mitigation and Climate Adaptation Plan (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."

3.5.3 Adaptive Capacity

Mitigation actions can both reduce natural hazard and climate vulnerability and support adaptation to current and future conditions. The impacts of climate and other natural hazards on the City's population, infrastructure, environment, and economy can be mitigated by our ability to moderate potential damages, take advantage of opportunities, or cope with consequences. This is called "adaptive capacity" (IPCC, 2007). The analysis conducted of potential natural hazard and climate change impacts and strategies for response, and incorporating the information into planning and land use decisions, will increase Boston's adaptive capacity to extreme events.

The City's ongoing efforts to monitor and reduce greenhouse gas emissions indicate a moderate level of adaptive capacity to climate change. Redesigning buildings and rethinking water supplies are just two areas where the City is actively increasing its adaptive capacity. The City can continue to improve the adaptive capacity by educating residents about natural hazards and climate risks and household-level adaptation opportunities. The City should also assess the local economy and local ecosystem's capacities to adapt to extreme events. Lastly, encouraging strong social networks that can provide decentralized emergency response and support can provide Bostonians another tool for resilience.

3.5.4 Residual Risk

All hazard mitigation actions and adaptation projects have an associated residual risk. Time horizons, natural hazard scenarios, and climate change projections are chosen to help guide planning efforts and design projects. However, a system that is prepared for the 100-year storm event may still experience the impacts of a 500-year storm event. Therefore, resiliency strategies should ideally be multi-faceted, layered approaches across scales. Increased redundancy leads to increased resilience. Please refer to Chapter 7 for more information on priority action items to improve resilience.

Clippership Wharf in East Boston, designed for sea level rise

3.6 Critical Facilities, Areas of Interest, and Community Lifelines

The following summary shows a sample of critical facilities related to community lifelines and infrastructure. This information is presented as an example of critical facilities rather than as a comprehensive list.

73 fire stations

16 electric substations

21 hospitals

219 schools

372 religious centers

148 public libraries

54 community health centers

162 T stations

250+ child care centers

23 police stations

105 museums, historical sites, and similar institutions

3.7 Land Use and Development

Land use and development play a critical role in the resilience of a city. Developmental regulations determine where and how development can occur. Many of Boston's land use and development regulations are further explained in Chapter 5. For example, large development or redevelopment projects that have coastal vulnerability are required to meet BPDA's Coastal Resiliency Design Standards and Guidelines, which ensures that resiliency is being built into the fabric of the community outside of the public right of way. In Boston, the BPDA, Conservation Commission, and Zoning Commission play a critical role in regulating development. Boston's current land use is broken down in Figure 3-6 and displayed in greater detail in Figure 3-7.

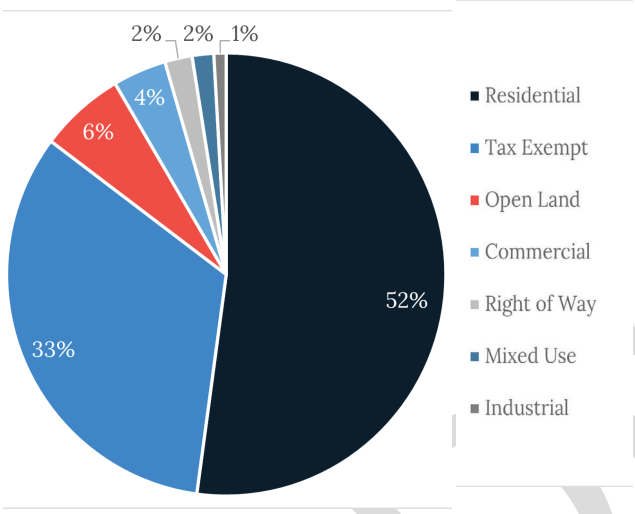
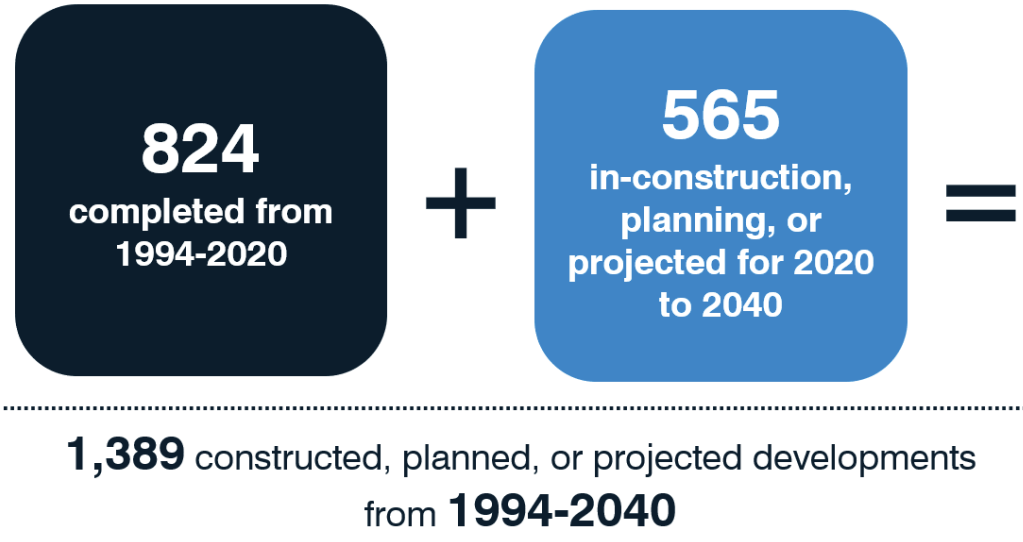


Figure 3-6. Land Use in Boston

Recent and Potential Development

The Metropolitan Area Planning Council (MAPC) tracks both past and planned development within the region through MassBuilds. The dataset is not comprehensive, but it can show trends in development. The following figures provide information for a range of constructed to projected developments from 1994-2040 and will be used to assess the vulnerability of recent and future development in Chapter 4. This dataset was also compared to data available from BPDA for all developments that would require Article 80 review. MassBuilds was found to be inclusive of the BPDA data and more wide-ranging.



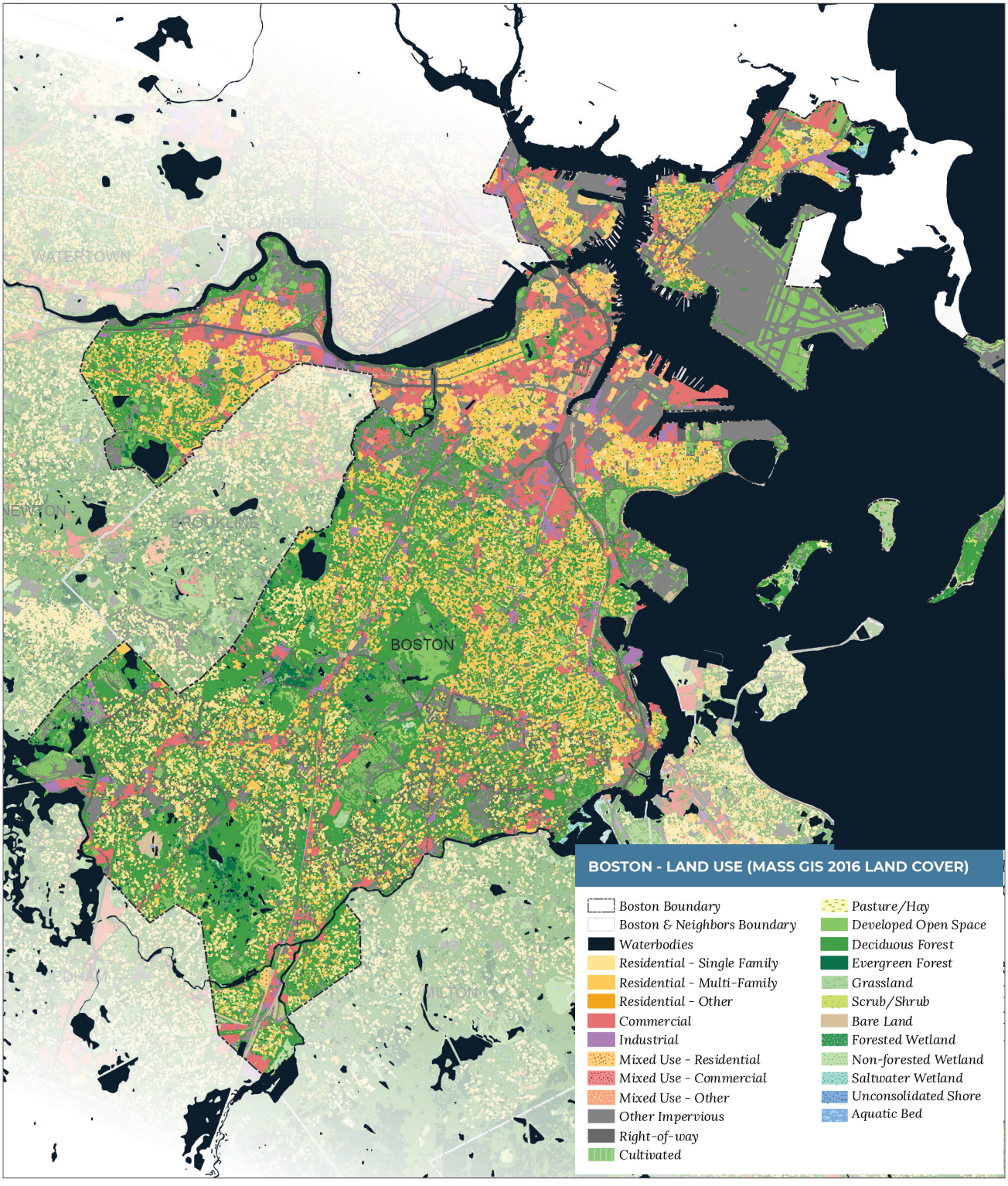


Figure 3-7. Land Use in Boston

The South Boston, Dorchester and Roxbury areas have the greatest amount of both completed and proposed and planned developments. Gentrification with displacement is a concern for upholding the social fabric of these neighborhoods. South Boston's Waterfront, East Boston, and Downtown also received large investment during the last 25 years. These areas will be subject to sea level rise. Dense, historic districts like the Bay Village and Beacon Hill had less development planned (MAPC, 2020).

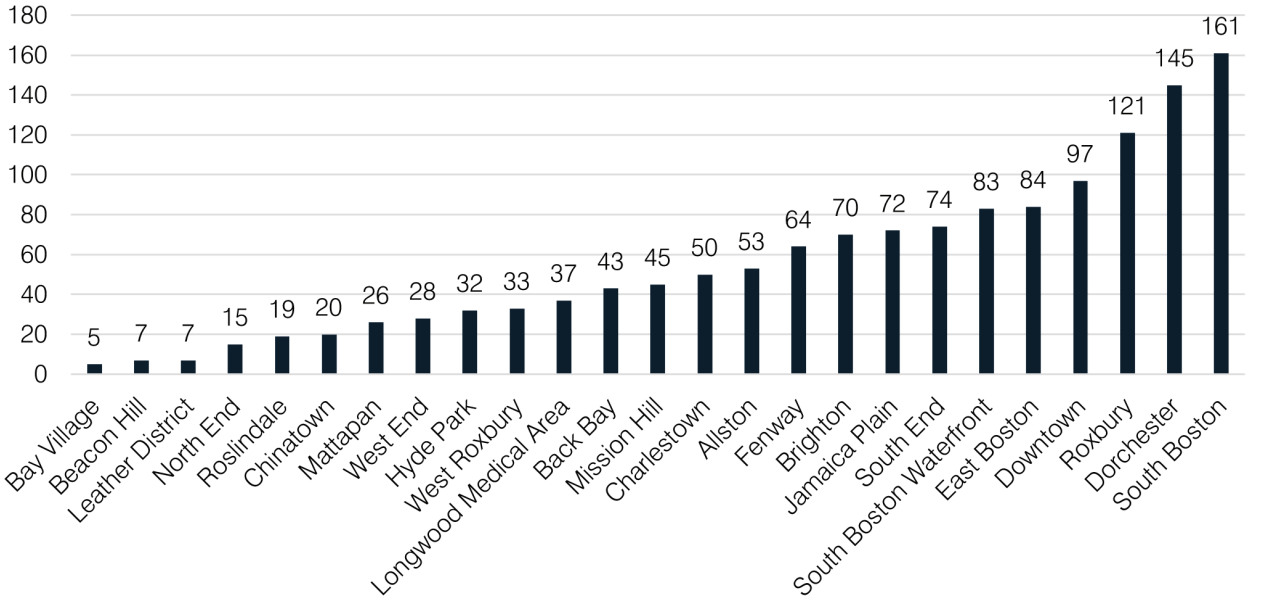


Figure 3-8. Completed and Planned Developments

Surprisingly, new development in the City outweighs redevelopment even in a dense city like Boston. Out of the recent completed and planned development, 67% is new development. Known future planned and projected building projects indicate this trend will continue. Two known projects were cancelled and not included in the graph below (MAPC, 2020).

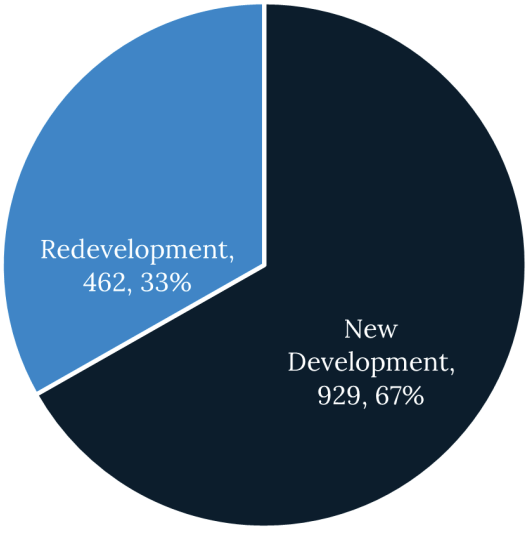


Figure 3-9. A Comparison of Redevelopment and New Development

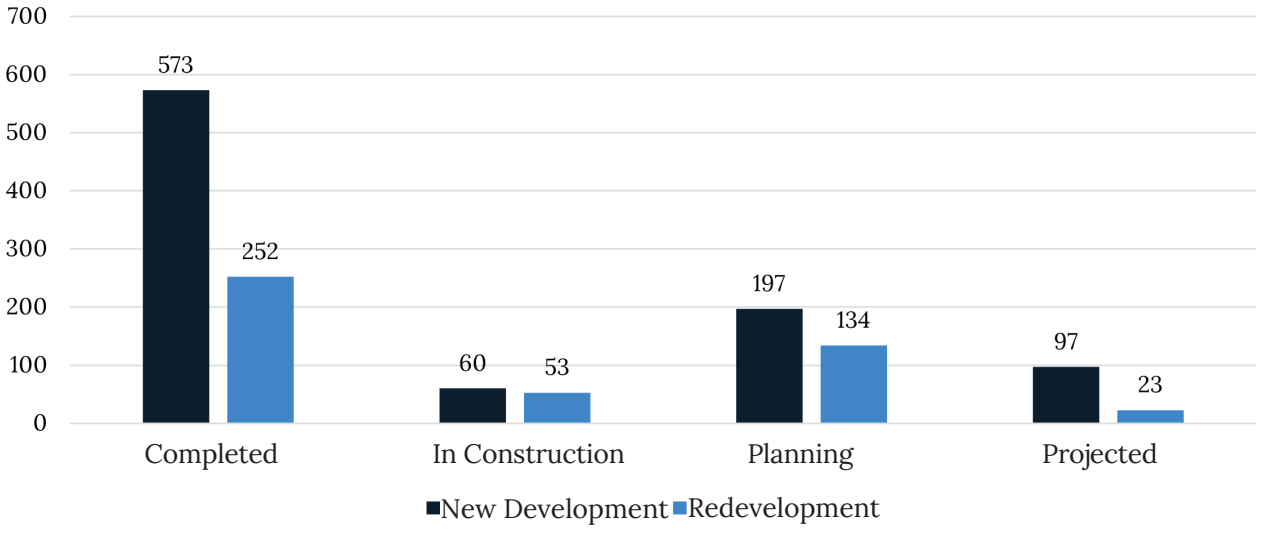


Figure 3-10. A Comparison of New Development and Redevelopment by Phase

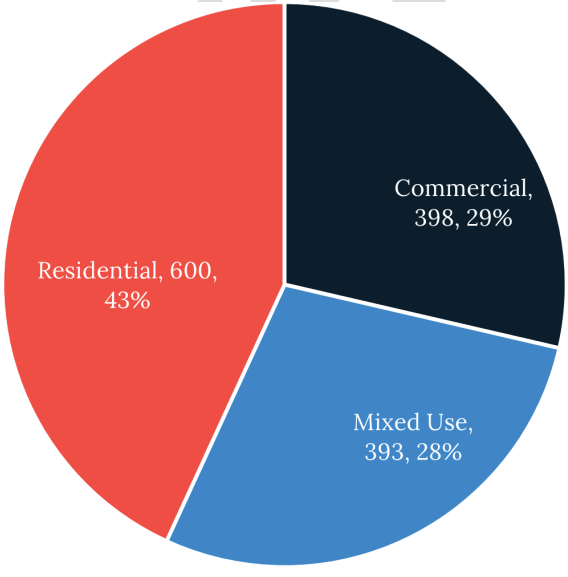


Figure 3-11. A Comparison of Development Types

Residential development outweighed mixed use and commercial development overall, with nearly double the number of constructed projects. However, this trend is not present in the planned and projected projects.

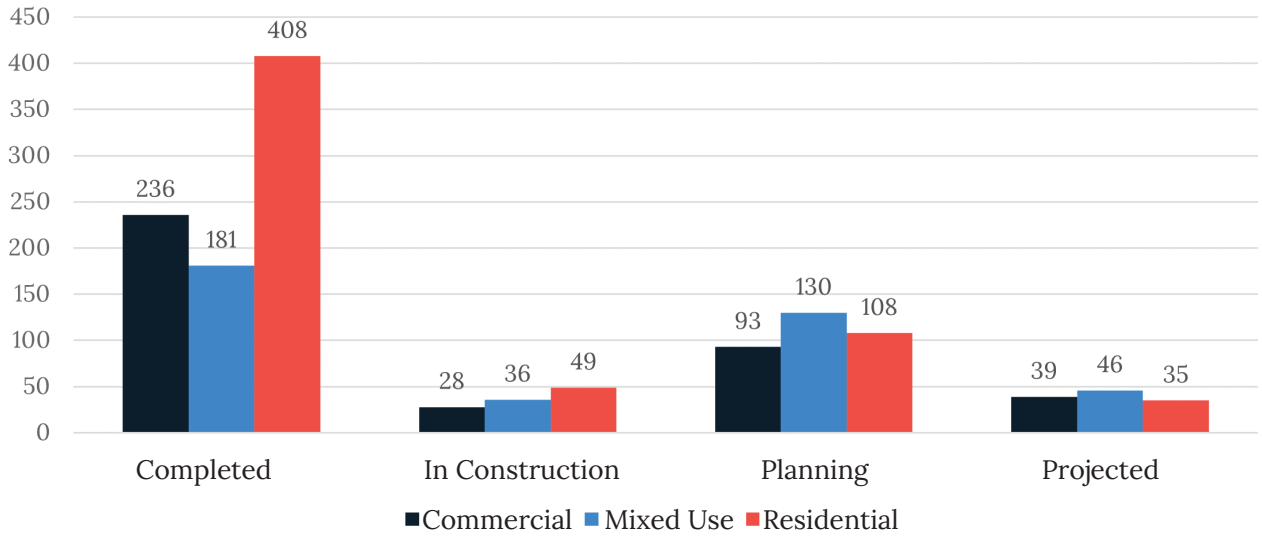


Figure 3-12. A Comparison of Development Types by Phase


Cabbages
Cabbages
PRODUCE KOUNTRY
PRODUCE KOUNTRY

FOUR: HAZARD PROFILES, RISK ASSESSMENT & VULNERABILITIES

4.1 Hazard Profiles

Each natural hazard that can occur in Boston has a varied risk based on the severity, extent of the impact, probability, and the vulnerability of the assets within the social, natural, and the built environment. a hazard profile was developed hazard. These hazard profiles present information useful in determining risk, which is further explained in this section of the chapter. Each profile is structured the same to make information easy to locate within the plan. In some cases, more data is readily available or documented for some hazards than others. Because of that, some profiles are more robust than others. Whenever possible, the hazard profiles were updated with information from:

- Local, State, and National Hazard Mitigation and Climate Adaptation Resources
- Local and National Hazard and Weather Event Databases
- Workshop and Survey Results
- Geographic Information System (GIS) Assessments
- HAZUS Software Analysis

2019 Snowstorm

4.1.1 Description

Using the 2018 State Hazard Mitigation and Climate Adaptation Plan (EEA and EOPSS), the 2014 Natural Hazard Mitigation Plan (NHMP) (City of Boston, 2016c), and Climate Ready Boston (City of Boston, 2016a) as a guide for the types of hazards that can occur in the state, we have included the following hazards:

Flooding Hazards

- Riverine
- Inland/Stormwater
- Coastal
- Tidal

Geological Hazards

- Earthquakes
- Landslides

Dam Hazards

- Dam Failure

Fire Hazards

- Brushfires
- Urban Conflagrations

Wind-Related Hazards

- Severe Storms and Thunderstorms
- Hurricanes and Tropical Storms
- Tornados
- Nor'easters

Extreme Temperature Hazards

- Extreme Heat
- Extreme Cold

Winter Storm Hazards

- Heavy Snow and Blizzards
- Ice Storms

Drought Hazards

- Drought

4.1.2 Severity

The severity of the hazard is synonymous with the magnitude, or how serious the hazard event is. Where possible, the severity of a hazard can be measured using an established indicator like the Richter Scale for earthquakes. Severity is described as the duration or force of an event. In other cases, severity is ranked by the consequence or risk. For example, a catastrophic event may have widespread infrastructural damage and loss of life, whereas a minor event may have minimal infrastructure damage and no loss of life.

4.1.3 Probability

Probability is the likelihood, or the estimated potential, for a natural hazard to occur within a specific time period. Probabilities often need to account for severity. For example, small rain events have a high probability of occurring each year. However, there are large rain events that are only likely to occur every fifty years.

4.1.4 Location

Some hazards, such as drought, are equally likely to occur across the entire geographic extent of Boston. However, some hazards are more likely to occur in specific areas, and therefore these geographic locations are considered more vulnerable, such as a floodplain.

4.1.5 Historic Occurrences

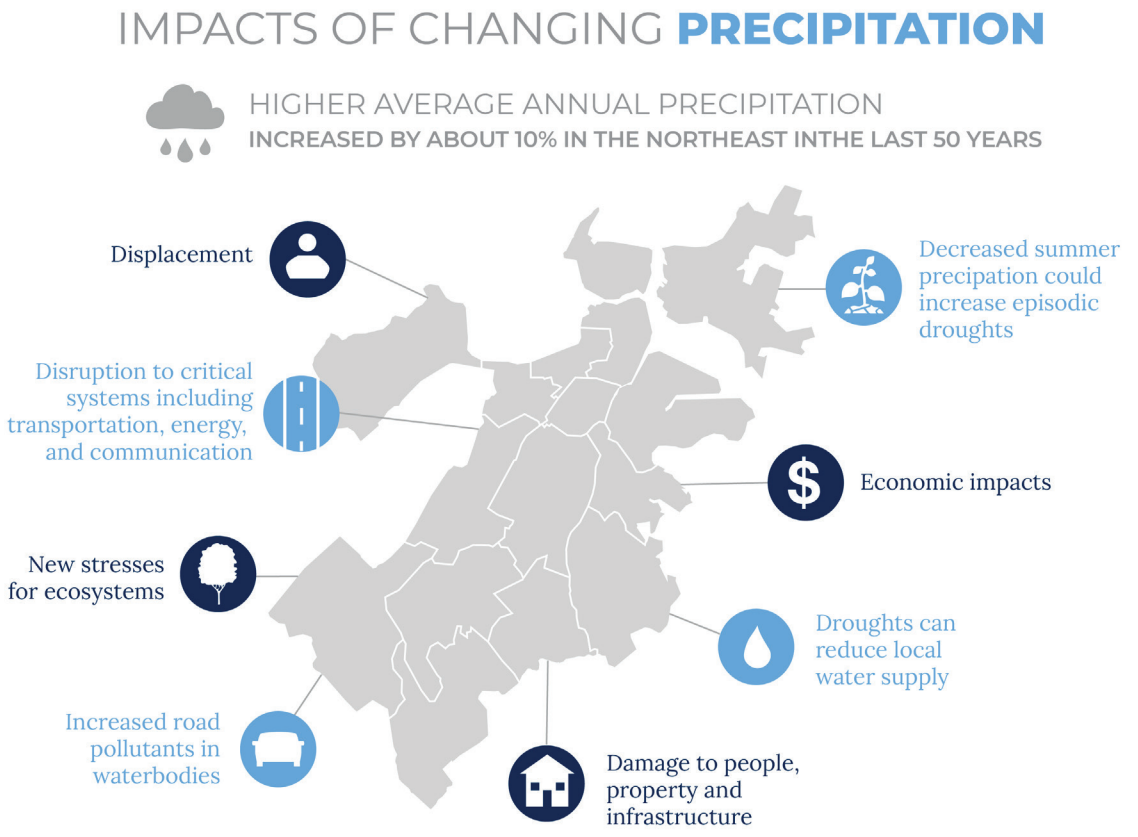
Tracking historical occurrences of hazards and federally declared disasters that occur in Boston or Suffolk County helps planners understand the possible severity, frequency, and geographic extent of hazards.

Since 2000, there have been ten federal disaster declarations in Suffolk County.

Within this chapter, the National Oceanic and Atmospheric Association's (NOAA) National Centers for Environmental Information (NCEI) Storm Events Database (NOAA, 2020a) was used as the primary source for historical occurrences of hazard events. The definitions for the event types can be found online under the Storm Data Preparation documentation (NOAA, 2018a). Throughout the hazard profiles, record information has been provided from this database. Record information is not always synonymous with a single storm event but rather recorded occurrences of an event. For example, if a storm causes flooding over four days, the database may return four records for a single event. This information, although incomplete, is the only information readily available on historical records over the last twenty years that is not institutional or local knowledge-based. Data for the date range of 2000-2020 has been provided in most circumstances; however, at the time of data collection, the database was only updated to reflect events through October 2020. Some hazard profiles provided additional historical information beyond this time frame when it was available.

4.1.6 Impacts of Climate Change

The City of Boston is one of the most vulnerable cities in the United States to climate change and sea level rise. Many of the hazards that Boston commonly experiences are projected to occur more frequently and with more intensity due to climate change. This includes projections for a six-foot rise in sea levels, increased temperatures, erosion caused by increased precipitation volume and velocity, among many others. Information about the projected changes that typically correspond to future planning horizons or timeframes is provided in each hazard profile. Although this plan is required to be updated every five years, continued progress towards long-term goals and expected changes are necessary when designing infrastructure and regulating development and land use that will be functional for decades to come. Among Boston's approaches to address the issues faced due to climate change, the City may update provisions and use of open space to accommodate temporary inundations during flood events, changes to planting plans, and modified times for recreational activities. These updates may mitigate climate change impacts, while other may change the way recreation is experienced in these areas (City of Boston, 2015). Please see Section 1.2.1 for a diagram of the City's historic and ongoing projects and initiatives related to climate change adaptation.



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

Figure 4-1. Impact of Climate Change and Changing Precipitation

4.1.7 Vulnerability and Risk

To understand risk, one must first understand vulnerability. Vulnerability is determined by the amount of exposure, sensitivity, and adaptative capacity of an asset in the social, natural, and built environment and is the predisposition to being negatively affected by a natural hazard. The amount of exposure is influenced by the location of the asset and the severity of the event. Sensitivity refers to the impact of a natural hazard due to the existing conditions or characteristics of the assets. For example, a building with an older roof may be more sensitive to wind damage and may lose its ability to function or keep rain out of the building. Adaptive capacity is the ability of a system, service, or asset to adapt or prepare for an anticipated hazard or climate impact (as further explained in Chapter 3).

Risk, or the possible adverse outcome, is determined through the consideration of vulnerability, the severity of an event, and the probability of that event occurring. In some instances, risk can be calculated in dollar amount or other metrics. In other cases, risk can be conveyed through the consequence and follow-on impacts. The consequence may be the amount of damage, length of service disruption, and the loss of life or number of injuries. Follow-on impacts could include public health concerns and environmental damage.

Vulnerability = Exposure x Sensitivity x Adaptative Capacity

Risk = Probability x Severity x Vulnerability

2021 snowstorm


GIFT SHOP
GIFT SHOP
BOSTON
SEWER

4.2 Flood-Related Hazards

Flooding occurs when water overflows onto land that does not normally hold water. Damage can occur from flooding of just a few inches to a few feet. Flash floods happen quickly and leave those impacted with little time to respond, while other floods could occur over a longer period of time and may last for days or weeks (NOAA, 2020c). Flooding can be caused by various weather events including hurricanes, extreme precipitation, thunderstorms, nor'easters, storm surge, and winter storms. Flooding is potential threat along Boston's entire shoreline and within dense areas of the City with undersized drainage. Boston experiences four types of flooding: riverine flooding, stormwater flooding, coastal flooding, and tidal flooding, which are described in detail in the sections below. While a single type of flooding event may pose a threat to society, infrastructure, and the natural environment, these types of flooding events often occur simultaneously, resulting in compounded impacts to the City.

QUOTES FROM PUBLIC SURVEY

"I am concerned about the flooding of newly developed areas and the impact that climate change will have on the City's vulnerable populations."

"Heavy rain greatly affects the community. I remember driving down Morton Street and large portions of the road were flooded and Walk Hill by the cemetery was even worse. I only imagine the problem getting worse if nothing is done about this."

"We have had flooding in our buildings due to the 100 year storms that happened within a few months of each other."

4.2.1 Riverine Flooding

4.2.1.1 Description

Riverine flooding occurs when the volume of water in a waterbody exceeds the capacity and overflows the banks. Most waterbodies have the potential to experience riverine flooding, but many have flood control systems that mitigate the possibility of major damage. Boston has two major watersheds, the Charles River watershed and the Boston Harbor watershed (comprised of sections of the Neponset River and the Mystic River subbasins). The Open Space and Recreation Plan (City of Boston, 2015) provides thorough descriptions of these waterbodies in addition to the following:

- Muddy River
- Chelsea Creek
- Stony Brook
- Canterbury Brook
- Mother Brook
- Bussey Brook
- Sawmill Brook
- Dana Brook
- Jamaica Pond
- Leverett Pond
- Turtle Pond
- Chestnut Hill Reservoir
- Cow Island Pond
- Public Garden Lagoon
- Mill Pond
- Chandler Pond
- Scarborough Pond

For the purposes of this plan, flooding caused by undersized culverts is discussed under stormwater flooding. Flash floods or rapid rises of water that occur within minutes that may last for multiple hours may be either stormwater or riverine floods. Flash floods may occur due to undersized stormwater infrastructure during high intensity events or because of blockages caused by debris.

4.2.1.2 Severity

Riverine flooding in Boston is highly variable and can range from a few inches in depth to a few feet. Isolated flooding can leave one neighborhood inaccessible, while an adjacent neighborhood remains safe due to elevation or proximity to the waterbody. Flooding severity is dependent on the duration of the flooding event and the ability of the flood water to recede. Flash flooding typically occurs as a result of short-term, heavy precipitation.

2019 Flooding

4.2.1.3 Probability

Based on historic occurrences riverine/riparian flooding events in Boston have been classified as a high frequency event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard occurs more frequently than once in five years or greater than 20% per year (MEMA and DCR, 2013).

4.2.1.4 Location

Riverine flooding in Boston occurs most frequently along the Muddy River and Mother Brook (City of Boston, 2016c). Flooding of the Muddy River causes damage to residences, businesses, academic and medical institutions, cultural institutions, and the public transit system (City of Boston, 2015). Survey responses expressed concerns around flooding throughout the greenway and around the Mystic River.

Repetitive loss sites are also likely to be areas prone to riverine flooding, but the exact locations of these properties are not publicly available due to privacy concerns. An aggregated summary of number of repetitive loss properties is provided in the Historic Occurrences section below.

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) (FEMA, n.d.-a). 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. Zones related to coastal inundation areas start with V and account for additional storm wave action. Read more in the Coastal Flooding hazard profile for details.

The Zone A areas listed in the 2014 NHMP (City of Boston, 2016c), which relied on FEMA FIRMs from 2010, are very similar to the areas indicated as Zones A in the updated FEMA FIRMs from 2016, listed below. S

- Coastline near Deer Island and on some of the Harbor Islands
- In East Boston, Belle Isle Marsh, Constitution Beach and the Wood Island Bay Marsh area
- In Charlestown, portions of piers and land in the Navy Yard area, along the Little Mystic Channel and along the Mystic River
- Most of the wharves from the Charlestown Bridge to the Northern Avenue Bridge
- In South Boston, the Massport Marine Terminal area and portions of other piers along Boston Harbor; land on the southern side of the Reserved Channel; some land between A Street and the Fort Point Channel; Castle Island; the Conley Terminal; and the coast along Dorchester Bay extending to Columbus Park and including William J. Day Boulevard
- In Dorchester, land around the Bayside Exposition Center, land along the southern coast of Columbia Point, the coast around Savin Hill including Morrissey Boulevard, the Victory Road Park and Tenean Beach area including land west of I-93, the Port Norfolk area, and land along the Neponset River including the Neponset River Reservation
- In Roslindale, land within the Stony Brook Reservation

Boston Flood Insurance Rate Map (FIRM)

- In Hyde Park and Mattapan, land along the Neponset River including the Neponset River Reservation, land along Mill Pond and Mother Brook
- Land along the Charles River
- Land along the Muddy River from the Charles River to Jamaica Pond
- In West Roxbury, land along the Charles River including land between the river and the VFW Parkway near Bridge Street and along Millennium Park

> Nationally one in three insurance claims occur in areas in moderate- to low- risk areas.
>
> – FEMA FloodSmart

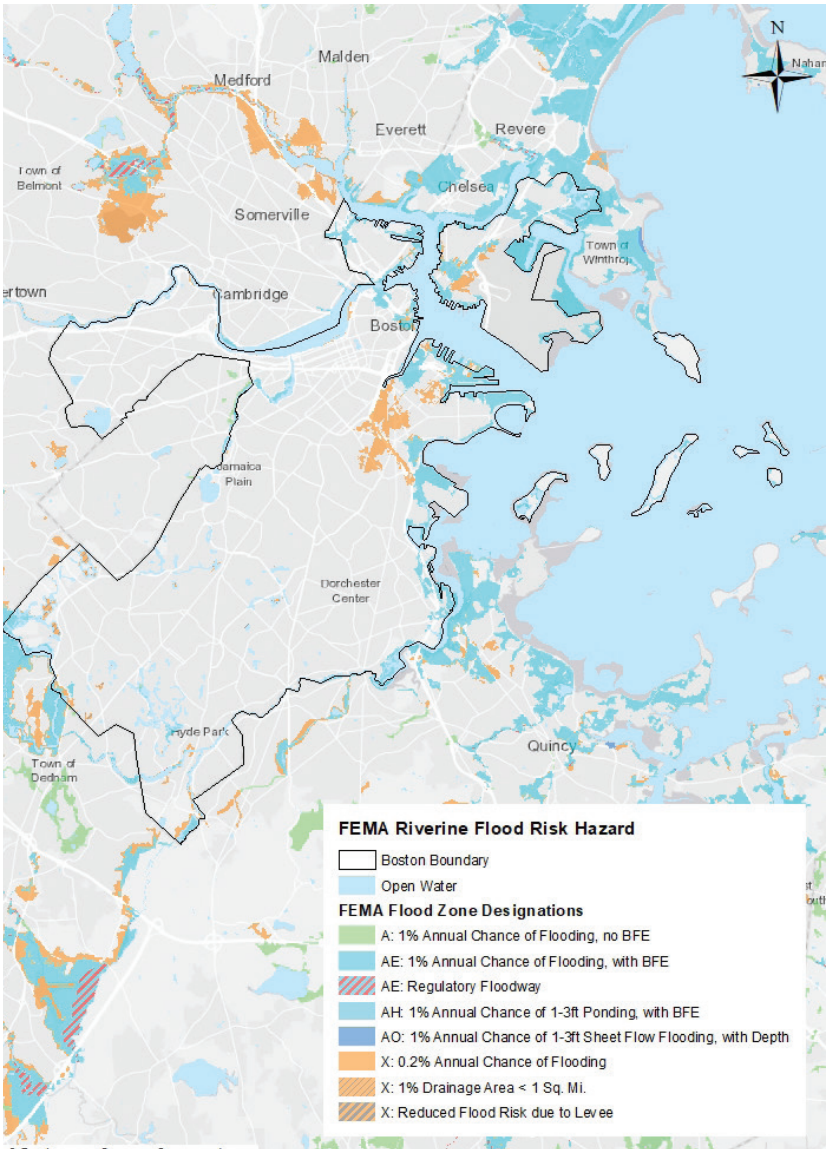


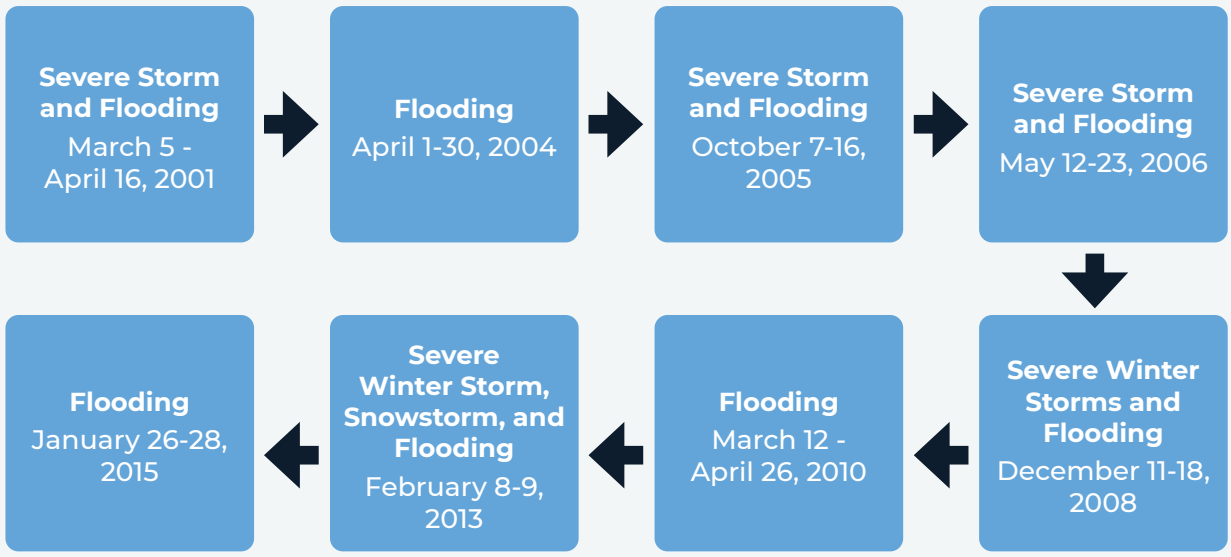
Figure 4-2. FEMA Riverine Flood Risk Map

Table 4-1. FEMA Riverine Flood Zones

ZONE	RISK	FLOODPLAIN	ANNUAL CHANCE OF OCCURRENCE
Zone A	High	100-year	1%
Zone X, B, C	Moderate/Low	500-year	0.2%

Previous Federal Disaster Declarations – Flooding

Suffolk County had 8 federally declared disasters related to flooding between 2000-2020.



(FEMA, 2021)

4.2.1.5 Historic Occurrences

Between 2000 and 2020, 20 flood events, specific to Boston or reported as a county-wide event, were recorded in the NOAA Storm Events Database (NOAA, 2020a) with an additional nine flash flood events. One heavy rain event was recorded, and the description mentioned brief flooding. (Note this does not include all flood events in Suffolk County, such as events that were specifically recorded for Chelsea, Winthrop, and Revere). Five out of the eight federally declared flood disasters were not reported in the Storm Event Database indicating the data is not always comprehensive. With federally declared disasters and Storm Event Database records combined, there were at least 35 flood events between 2000-2020. There were no deaths or injuries reported resulting from any of these events.

Repetitive Loss Sites

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 since 1978 (FEMA, 2019a). 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 receive any aid from FEMA,

$605,000
damage from flash floods

$25,808,000
in property damage from flood events

$15,000,000
of damage in Suffolk County in **March 2001** flood event

$25,808,000
of damage in Suffolk County in **March 2010** flood event

MBTA Stations Vulnerable to Flooding

- Green Line (Boylston Street Station and Kenmore to Longwood)
- Red Line (Alewife Station, JFK/UMass, and Fields Corner Mass Transit Station)
- Orange Line (Sullivan Square)
- Blue Line (Aquarium, Maverick, Airport)
- Silver Line (Along the South Boston Waterfront)

Reported Flood Areas

- Brookline Ave near Riverway
- Boynton Street
- Ceylon Street
- Child Street
- Clayton Street
- Columbia Road
- Condor Street and Putnam Street
- Corey Road
- Freeport Street near UMass
- Gallivan Boulevard
- Logan Airport Terminal B Access Road
- Hamilton Street
- Harvard Street
- Heath Street
- Lewis Street
- Malcolm X Boulevard
- Marginal Street
- Morton Street
- McClellan Highway
- Morrissey Boulevard
- Orient Heights
- Park Street
- Quincy Street
- Route 1
- Sargent Street
- Storrow Drive
- Stuart Street
- Southern Avenue
- Talbot Street
- Ted Williams Tunnel
- Tremont Street
- Woodrow Ave Railroad Bridge underpass

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 the MA Department of Conservation and Recreation (DCR, 2020a), with the exception of the land use type, which was provided by FEMA. The identified repetitive loss properties have received an aggregated total of $650,283 for damages from FEMA for losses. The number of NFIP policies currently in force also indicate the potential future risk of flooding and the amount of paid loss indicates the historic losses since 1978.

4,872 policies in force
$1.35 billion in coverage
$4.03 million in annual premiums

319 paid losses since 1978
$3.29 million total paid losses since 1978

27 REPETITIVE LOSS BUILDINGS IN BOSTON		
## are residential ## are non-residential	8 are located within the Zone A 19 are located within the Zone X	5 are insured 22 are uninsured
60 REPETITIVE LOSS CLAIMS IN BOSTON		
## are residential ## are non-residential	23 are located in Zone A 37 located in Zone X	12 are insured 48 are uninsured

4.2.1.6 Climate Change

Extreme rain and snow events are becoming increasingly common and severe, particularly in the Northeast region of the country (Figure 4-3). Severe rain or snow events that historically happened once a year in the middle of the 20th century now occur approximately every nine months. It is predicted that between the 2030s and 2050s, the 10-year, 24-hour rainfall depth in Boston will increase to 5.6 inches, and by the 2070s it will increase to 6.0 inches (City of Boston, 2016a). With this projected increase in rainfall, waterbodies in and around the City will be increasingly likely to top their banks and cause localized flooding. As frequency and severity of rain events continues to increase, it will become more difficult for the system to convey collected stormwater with no associated flooding.

4.2.1.7 Vulnerability and Risk

The impacts of flooding can include injury or death, property damage, and traffic disruption. Flood hazards can also cause erosion, which can compromise water quality, slope stability, and the stability of building foundations. Erosion, both inland and coastal, puts current and future structures and populations located near steep embankments or the coast, at risk. Erosion can also undercut streambeds and scour around stream crossings, creating a serious risk to roadways and bridges.

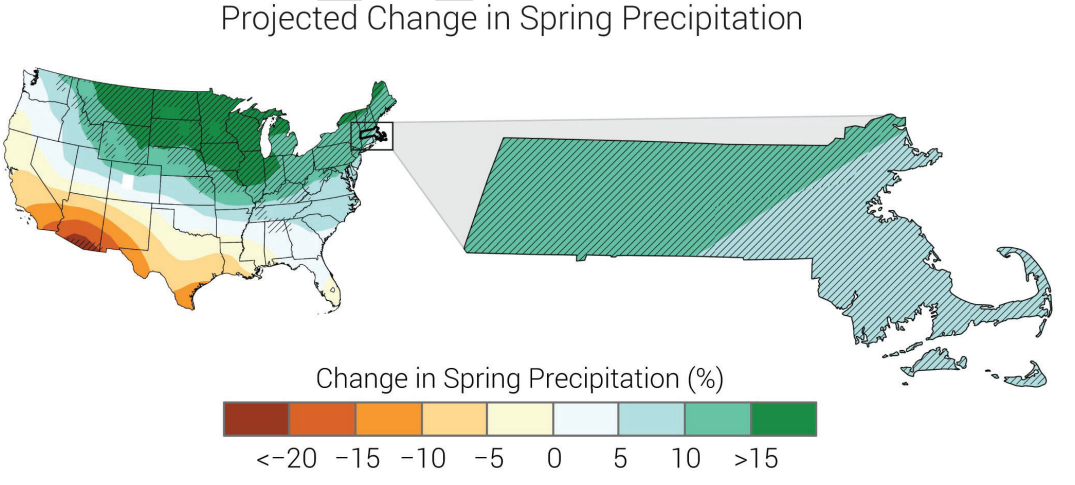


Figure 4-3. Projected Change in Spring Precipitation by the Middle of the 21st Century Relative to the Late 20th Century, Under a Higher Emissions Pathway
**Hatching represents areas where the model indicates a statistically significant change* (NOAA, 2017)

Much of the infrastructure in Boston, include bridges, tunnels, and the subway system, were designed for historic flooding scenarios. Since the design and construction of this infrastructure, the City has experienced flood events that have surpassed historic norms that have put this vital infrastructure at risk. These events disrupt critical infrastructure systems, putting the City at risk. Bostonians rely on the public transportation networks and roadways to get from place to place, and damage to any of these systems will impact thousands of people.

Critical Facilities Riverine Flood Vulnerability Analysis

Hazard location and extent of riverine flooding was determined using the FEMA FIRM for Zone A and Zone X. A flood exposure analysis was conducted for critical facilities and vulnerable populations throughout the municipality utilizing MassGIS data, FEMA flood maps, and information gathered from the City. In total, 179 of Boston's critical facilities are located within the FEMA flood zone.

Development and Flood Vulnerability Analysis

The Metropolitan Area Planning Council (MAPC) tracks both past and planned development within the City (see Chapter 3 for more details). MAPC's MassBuilds data was overlaid with FEMA riverine flood hazards to determine flood vulnerability on recent and planned development. The analysis found that recent and planned development in South Boston is most vulnerable to flooding. Seventy-five recently completed developments and twenty-seven planned and projected developments are located in the FEMA riverine flood zone. Overall the change in vulnerability from development is complex. Development continues to occur in vulnerable areas, but the City has instituted stronger regulations to require resiliency measures.

Social Vulnerability and Flooding

Using the social vulnerability mapping introduced in Chapter 3, it was found that 45 highly vulnerable tracts are located in FEMA riverine flood zone and half of the highly vulnerable tracts are located in the 2070 flood zones.

4.2.2 Stormwater Flooding

4.2.2.1 Description

Stormwater flooding occurs during a short-term, high intensity precipitation event where the rate of rainfall is greater than the capacity of the stormwater management system. This may be due to an undersized culvert, poor drainage, topography, high amounts of impervious surfaces, debris that causes the stormwater system to function below its design standard, or a combination of these issues. In these cases, the stormwater management system becomes overwhelmed, causing water to inundate roadways and properties. Coastal surge can magnify these impacts as the stormwater outfalls can become blocked by high tides, or wind and wave action. The winter and spring thaw can also present flooding challenges for the City by way of clogged catch basins, which create a bottleneck and cause water to back up in the river and overtop the banks.

In the 2014 NHMP, stormwater flooding also accounted for groundwater flooding, which can cause things like basement flooding. Groundwater flooding can cause property damage and public health concerns, such as mold growth. Groundwater is difficult to manage and high water tables are necessary in some parts of the City, such as the Back Bay, where building foundations rest on wooden piers sunk deep into the ground. These piers rely on a highwater table to prevent rotting. This complicates groundwater flooding

issues further, due to the delicate balance between maintaining these building foundations while preventing flooding in other buildings nearby.

4.2.2.2 Severity

Stormwater flooding is primarily a nuisance that will dissipate within a few hours, but under some circumstances it can cause serious property damage and put people at risk. Stormwater flooding is typically shorter in duration and more localized than riverine flooding. When stormwater flooding occurs the flood waters can range from a few inches to a few feet in depth.

> One inch of flood water can cause over $25,000 in damage
>
> – NFIP's Urban Flood Campaign

4.2.2.3 Probability

Based on historic occurrences, stormwater flooding is considered a high frequency event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard may occur more frequently than once in five years or greater than 20% a year (MEMA and DCR, 2013). On average stormwater flooding in Boston occurs at least once every 3 years, but less often than once a year (City of Boston, 2016c).

4.2.2.4 Location

Stormwater flooding can theoretically occur anywhere in the City (City of Boston, 2016c), but is most likely to occur near stormwater collection sites that are undersized or at locations of blockages in the stormwater system. Stormwater flooding may also be caused by high water at stormwater outfall sites, causing backflow to

2019 Flooding

occur. The Climate Ready Boston Map Explorer (City of Boston, 2020) features spatial data from Climate Ready Boston, including locations around the City that are vulnerable to stormwater flooding. Stormwater flooding is a City-wide hazard for Boston, with some known areas of undersized drainage being more susceptible, as mapped by Climate Ready Boston. Survey responses showed a general concern around roadway flooding in Allston, East Boston, Downtown, and the South End, often caused by riverine or coastal flooding and made worse by undersized drainage.

4.2.2.5 Historic Occurrences

People who live and work in Boston rely on the T to get around. As both frequency and intensity of rain events increases, low-lying MBTA stations around the City are becoming increasing vulnerable to flooding. Stakeholders recalled occasions in the past where T stations flooded and were inaccessible to commuters. There are also narrow, low-lying roads and tunnels throughout the City that have experienced flooding, as water funnels into these areas with insufficient drainage to handle high intensity storm events. These events greatly impact commuters, residents, and emergency personnel trying to around the City. These occurrences are only expected to worsen in coming years and climate change increases the frequency and intensity of storms.

4.2.2.6 Climate Change

Boston's current 10-year, 24-hour rainfall is 5.24 inches, while the stormwater drainage system is only designed to handle 4.8 inches of rain in 24 hours (City of Boston, 2016a). This results in the system being overwhelmed fairly frequently by rain events. Most stormwater systems in Massachusetts are aging and have been designed with rainfall data that is no longer accurate. Figure 4-4 shows how anticipated rainfall during design storms has increased from 1961 to 2015, especially for the larger 24-hour, 100-year event. With climate change, the intensity and duration of rainfall is projected to increase, which will further stress the current system. This combination of issue will likely result in an increase of stormwater flooding events within the City, as noted in Section 4.2.1.6 Riverine Flooding Climate Change.

Climate Ready Boston's Map Explorer contains near-term, medium-term, and long-term stormwater flooding locations. This data represents the stormwater flooding extent from a 10-year, 24-hour rainfall event for various climate change scenarios with the City's current drainage infrastructure. Green infrastructure or low impact development improvements can help reduce demand on the existing stormwater system by increasing infiltration on-site. Rain gardens and pervious pavement are two examples of possible strategies. Upsizing culverts with new rainfall data can also mitigate flooding by allowing a greater volume of water to pass through the system.

4.2.2.7 Vulnerability and Risk

The risks associated with stormwater flooding is relatively similar to those of riverine flooding, noted in Section 4.2.1.7. Property damage and public health and safety are primary concerns. Stormwater flooding is often concentrated to smaller areas including parking lots and roadways, leaving communities isolated. With increasing frequency and severity of storm events, stormwater flooding will become an increased vulnerability for the City to manage.

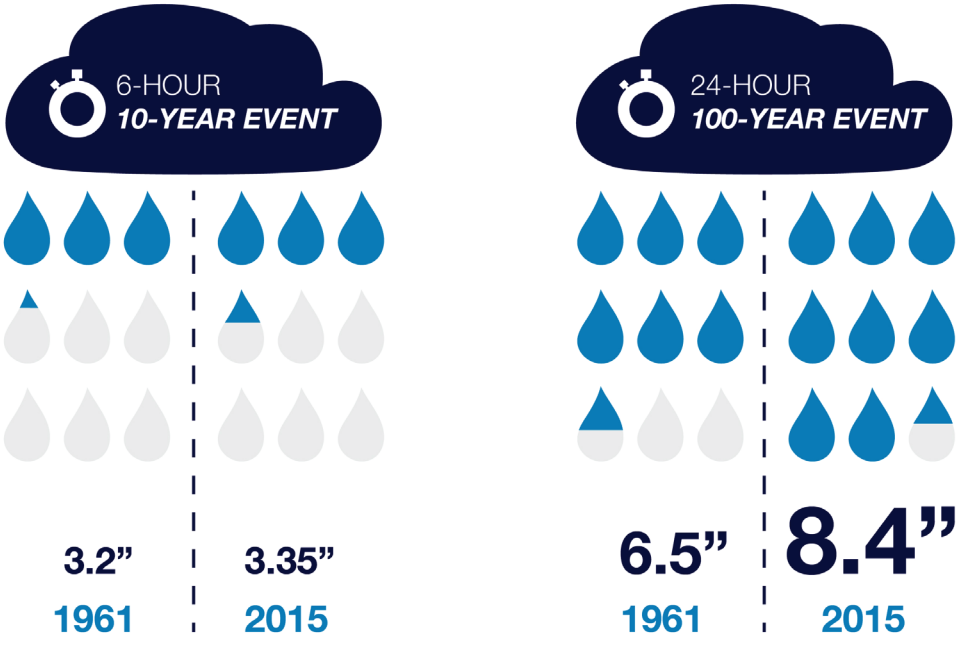


Figure 4-4. Stormwater Design Standards (NOAA TP 40, 1961 and NOAA, 2015)

Without improvements to the stormwater system, over **11,000 structures** and **85,000 people** will be directly exposed to frequent stormwater flooding as soon as the 2070s.

-Climate Ready Boston (City of Boston, 2016a)

4.2.3 Coastal Flooding

4.2.3.1 Description

Coastal flooding is caused by sea level rise, seasonal high tides, and storm surge. Storm surge is a rise in sea level that occurs during a tropical storm, caused by strong winds pushing the water towards the shore. Coastal flooding is often the result of a storm surge that accompanies a storm event, sometimes magnified by accompanying season high tides.

Boston has 47 miles of coastal shoreline. Coastal flooding impacts the entire coastline differently. Sections of the coast are protected by seawalls and breakwaters, aiding in keeping flood waters away from infrastructure. Guided by initiatives such as Climate Ready Boston, the City continues to pursue ongoing work to protect coastal infrastructure from flooding, such as by installing green and grey infrastructure solutions that capture, hold, divert, or block coastal flood waters. However, as sea levels continue to rise and intense storms become more frequent, these flood management systems are not always sufficient, resulting in flooding of low-lying areas such as roadways and buildings.

4.2.3.2 Severity

Boston's coast is highly developed, leaving many structures and populations vulnerable to coastal flooding. As of 2017, if a storm surge of 5 feet coincided with the high tide, approximately 132 miles of roadway could be flooded (City of Boston, 2017a). An event like this would leave drivers stranded, and would affect pedestrians, bicyclists, and public transportation users. It would impact communications, emergency response, and energy. Coastal flooding in Boston can impact the City as well as the entire region that relies on Boston as an economic hub. It is anticipated that this scenario will worsen with sea level rise and increasing storm events.

4.2.3.3 Probability

Based on historic occurrences, coastal flooding in Boston is considered a high frequency event. As defined by the Massachusetts State Hazard Mitigation Plan, this hazard may occur more frequently than once in five years, or greater than 20% chance per year.

4.2.3.4 Location

It is estimated that 88% of the population living along the northeast coast is living on developed coastal landforms, that have a very limited ability to adapt to rising sea levels (NCA, 2018). Coastal flooding is predicted to extend inward as sea level rise increases. In the near term, between 2030 and 2050, coastal flooding in Boston is predicted to primarily affect South Boston, East Boston, Charlestown, and Downtown. Between 2050 and 2100, this flooding is predicted to extend in these areas and begin to significantly impact Dorchester. The 2015 Open Space and Recreation Plan noted that flood hazard that overlap with development are usually found along coastal areas, including the Downtown, East Boston, Charlestown, South Boston, and Dorchester waterfronts (City of Boston, 2015). The City as a whole, and particularly

As of 2017, if a storm surge of **5 feet** coincided with the high tide, approximately **132 miles** of roadway could be flooded

these neighborhoods, are protected by seawalls and other shoreline structures; however, these structures are designed to withstand historical events and are not sufficient to protect against coastal flooding with sea level rise. Additionally, only 58% of the Boston Harbor shoreline is protected with private or public structures leaving much of the Harbor shoreline unprotected and increasingly vulnerable (CEC, 2015).

Flooding in East Boston is very common along the waterfront; however, this is being addressed by the Climate Ready Boston's resilient planning efforts. Stakeholders and residents of Boston recall many times when Morrissey Boulevard was impassible due to coastal flooding. Landowners and residents in the North End voiced concerns about the extent of coastal flooding their building can withstand. Sea level rise in the Downtown and South End is also an area of concern among stakeholders. Underground tunnels such as O'Neill, Sumner, and Callahan are at risk from coastal flooding, sea level rise, and storm surge. The thin-walled tunnels rely on electricity to function, and vulnerable populations rely on the tunnels, roadways, and public transportation travel through these areas to move around the City. Vulnerable populations would also rely on these transportation networks during an evacuation, leaving them increasingly vulnerable if the infrastructure were to fail due to a storm event.

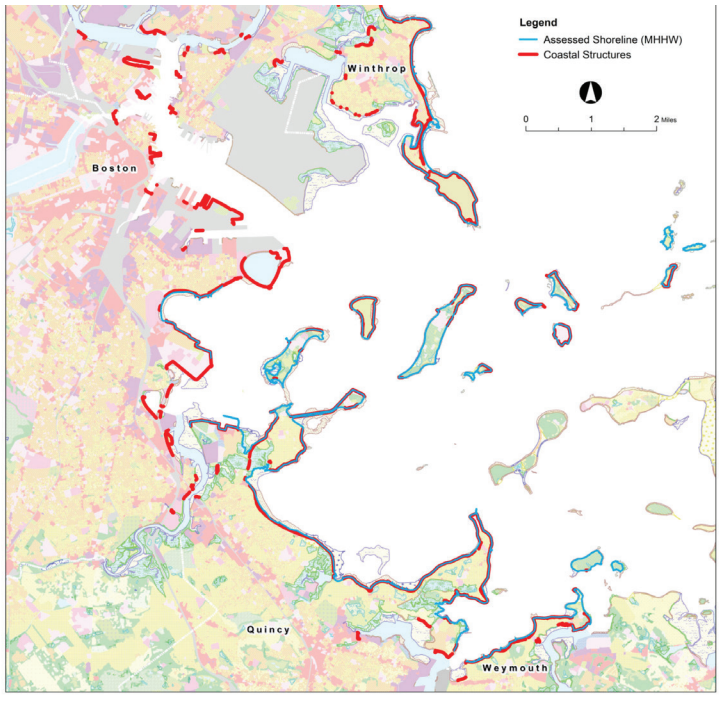


Figure 4-5. Map of Assessed Shoreline (blue) and Coastal Engineering Structures (red) for Winthrop, Boston, Quincy, and Weymouth in the Boston Harbor Region

Map created by MA Coastal Erosion Commission for the 2015 "Report of the Massachusetts Coastal Erosion Commission Volume 1: Findings and Recommendations."

Many of the areas in Boston prone to flooding are coastal, and therefore are further susceptible to storm surge and wave action. Much of the coastline of Boston is shown as a high-risk coastal area (Zone VE)

Flood Insurance Rate Map Zone Definitions

Zone V (1% annual chance): Zone V is the flood insurance rate zone corresponding to the coastal 100-year floodplain, with additional hazards associated with storm-induced waves. Because detailed hydraulic analyses have not been performed, no Base Flood Elevations or flood depths are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone VE and V1-30 (1% annual chance): Zones VE and V1-30 are the flood insurance zones that correspond to the 100-year floodplain with additional hazards due to storm-induced velocity wave action. Base Flood Elevations derived from detailed hydraulic analysis are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Source: (FEMA, 2019b) https://www.fema.gov/flood-zones

on the 2016 FEMA FIRMs, seen as the purple layer in Figure 4-6. Repetitive loss sites are also likely to be areas prone to coastal flooding. The exact locations of these properties are not publicly available due to privacy concerns, but summaries are provided in the *Riverine Flooding Historic Occurrence* Section 4.2.1.5.

As part of the Massachusetts Coastal Inventory and Assessment Project, the publicly owned coastal protection structures of the City were assessed for their ability to provide adequate protection from major storms. These structures do not typically erode but can be damaged by coastal hazards. Due to the fact that more than half of Boston's coastline is protected by man-made structures, it is important to understand the condition of them. A summary of the results of the project is provided in Table 4-2.

Within the City, there are 103 structures of public or unknown ownership which provide significant coastal protection. There were 18 structures in East Boston, 16 in Charlestown, 6 in Downtown, 36 in South Boston, and 27 in Dorchester. In the City of

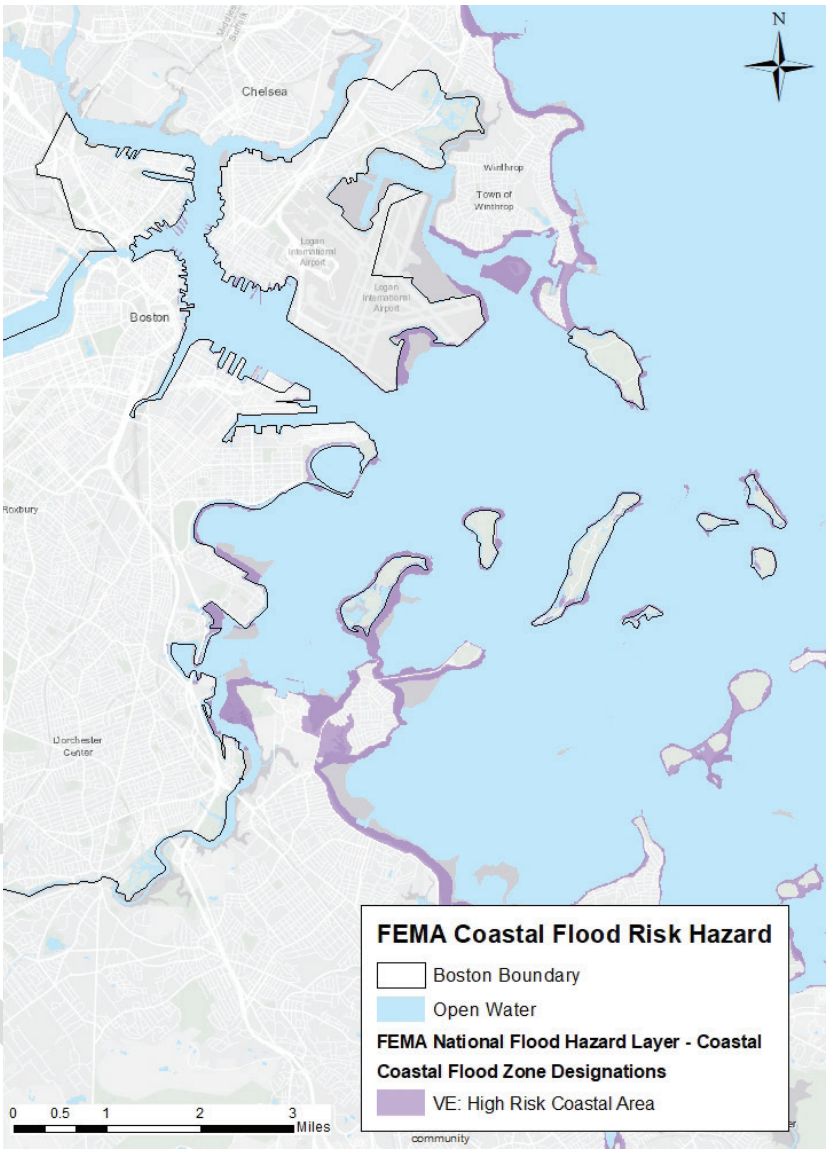


Figure 4-6. Boston Coastal FEMA Flood Zones

Table 4-2. Coastal Structure Type and Condition Rating

PRIMARY STRUCTURE	TOTAL STRUCTURES	STRUCTURE CONDITION RATING					TOTAL LENGTH
		A	B	C	D	F	
Bulkhead/Seawall	56	6	25	13	8	4	36,304
Revetment	36	3	21	10	3	-	31,054
Coastal Dune	1	-	1	-	-	-	849
Coastal Beach	10	-	9	1	-	-	14,674
Total	**103**	**9**	**56**	**24**	**11**	**4**	**82,881**

Boston there are 95 structures which would require approximately $81 million to bring all the coastal structure to an "A" rating (DCR, 2009). Boston does not have any breakwater or groin/jetty structures in place with a condition rating.

4.2.3.5 Historic Occurrences

According to NOAA's Storm Event Database there were 32 occurrences of coastal flooding in Suffolk County between 2000 to 2020. These events did not result in any injuries or deaths but did produce $3.63 million in damages.

Several of these events indicated direct impacts in Boston:

- January 2, 2010
- March 14, 2010
- December 27, 2010
- November 23, 2011
- June 3-4, 2012
- October 29, 2012
- March 7, 2013
- January 2-3, 2014
- August 13, 2014
- October 23, 2014
- October 28, 2015
- January 4, 2018
- January 30, 2018
- March 2, 2018
- October 27, 2018
- November 25, 2018
- January 20, 2019
- October 28, 2019
- April 9, 2020
- September 22, 2020

2015 Boston Harbor Flood Risk Model (BH-FRM)

The Massachusetts Department of Transportation – Highway Division (MassDOT), partnered with the Federal Highway Administration (FHWA) to conduct a vulnerability assessment and develop the BH-FRM as a direct output from the Central Artery/ Tunnel (CA/T) Vulnerability and Adaptation Assessment. The BH-FRM was developed to identify risk and depth of water resulting from storm surge induced coastal flooding under current and future sea levels. The BH-FRM is considered a "bathtub model" that assumes the ocean stays perfectly flat. This project resulted in the creation of Coastal Flood Exceedance Probability Maps and Estimated Flood Depth Maps for the 2013, 2030, and 2070/2100 climate scenarios. Much of the planning work for Climate Ready Boston used the results of this model for assessing future flood risks to Boston's neighborhoods.

2020 Massachusetts Coast Flood Risk Model (MC-FRM)

Massachusetts DOT funded the MC-FRM following the success of the BH-FRM to create a model for the entire Massachusetts coast and islands. The MC-FRM is a more accurate representation of flooding risk because it is a dynamic model that includes the critical processes associated with storm induced flooding (winds, waves, wave-setup, storm surge, wave run-up, and overtopping). The MC-FRM is calibrated to historical storm events that impacted Massachusetts with observed high water data and measurements, which improved the model resolution enough to capture flood pathways in complex urban topographies. The scenarios are simulated for 2030, 2050, and 2070. Compared to Boston Harbor Flood Risk Model, the MC-FRM predicts the extent of flooding by 2070 to a much farther extent inland (see in Figure 4-8).

BWSC Two-Dimensional (2-D) Inundation Model

BWSC has developed 2-D drainage model using PCSWMM software to predict the extent and duration of flood inundation for a variety of wet weather events. The model could be used by the City of Boston agencies and departments and other entities to identify land area, buildings, transportation infrastructure, and other facilities that will likely be impacted by major precipitation and flooding events, as well as for evacuation, adaptation, and resiliency planning. The model's predictive results are available through an online viewer.

Table 4-3. Boston Sea Level Rise Exposure BH-FRM

VULNERABILITY ASSESSMENT SLR (above current sea level)	LIKELY YEARS OF INITIAL OCCURRENCE		
	Major Emissions Reduction	Moderate Emissions Reduction	Business as Usual
9 inches	2030s – 2050s	2030s – 2050s	2030s – 2050s
21 inches	2060s – 2100s	2060s – 2090s	2050s – 2080s
36 inches	2090s or later	2080s or later	2070s or later

All of the events with direct impacts to Boston indicated that Morrisey Boulevard closed due to various levels of inundation. In addition to these coastal flood events, NOAA's Storm Event Database identified eight instances of storm surge in Suffolk County. No injuries or deaths were recorded and damages in the amount of $410,000 were sustained.

4.2.3.6 Climate Change

Climate change data is evolving regularly. The text box below captures a high-level summary of three existing models. The BH-FRM was used during the Climate Ready Boston planning process but has since been updated through the MC-FRM. The BWSC has also developed a model that incorporates stormwater. As of the publication of this plan, the City is undergoing conversations on possibly selecting a model to use across departments. For this plan, the BH-FRM and MC-FRM were predominately used to provide a reference point of risk. As sea levels continue to rise over the next few decades, the occurrence of severely damaging floods will increase from a rare occurrence to happening monthly. It is expected that by 2050,

Table 4-4. Boston Sea Level Rise Exposure BH-FRM

		LAND AREA EXPOSED (ACRES)			PERCENT OF NEIGHBORHOOD EXPOSED		
Neighborhoods	**Total Land Area (Acres)**	**9" SLR 1% annual chance**	**21" SLR 1% annual chance**	**36" SLR 1% annual chance**	**9" SLR 1% annual chance**	**21" SLR 1% annual chance**	**36" SLR 1% annual chance**
I. GREATEST EXPOSURE & INCREASING THROUGHOUT CENTURY							
Charlestown	870	120	310	460	14%	36%	54%
Downtown	779	110	240	350	14%	31%	45%
East Boston	3,340	540	1,040	1,680	16%	30%	49%
Harbor Islands	820	200	230	260	25%	28%	32%
South Boston	1,940	470	930	1,220	24%	48%	63%
II. LOWER EXPOSURE TODAY, BUT SIGNIFICANT JUMP LATE CENTURY							
Allston/Brighton	2,940	30	70	240	1%	2%	7%
Back Bay/ Beacon Hill	460	<10	<10	80	<1%	1%	17%
Roxbury	2,770	<10	<10	130	<1%	<1%	5%
Dorchester	3,780	240	430	750	6%	11%	20%
South End	640	<10	20	450	<1%	3%	71%
III. OTHER NEIGHBORHOODS							
Fenway/Kenmore	620	<10	<10	<10	<1%	<1%	<1%
Hyde Park	3,260	0	0	0	0	0	0
Jamaica Plain	2,260	0	0	0	0	0	0
Mattapan	1,560	0	0	0	0	0	0
Roslindale	2,250	0	0	0	0	0	0
West Roxbury	3,350	0	0	0	0	0	0
Boston Total	**31,720**	**1,720**	**3.280**	**5,630**	**8%**	**10%**	**18%**

sea levels in Boston will rise by nine inches regardless of the reduction of emissions, and by 2100 that number will increase to twenty-one inches (City of Boston, 2016a). Municipal harbor plans and studies are in development to ensure that development is resilient to increased flooding due to climate change and that the development does not harm the environment.

In the late century, it is predicted that a significant area of Boston's current land will be inundated every month. The model also predicts exposure of each sea level rise scenario in different neighborhoods of Boston (City of Boston, 2016a). As can be seen in Table 4-4, the neighborhoods with the greatest exposure and increasing are the most coastal neighborhoods of Charlestown, Downtown, East Boston, Harbor

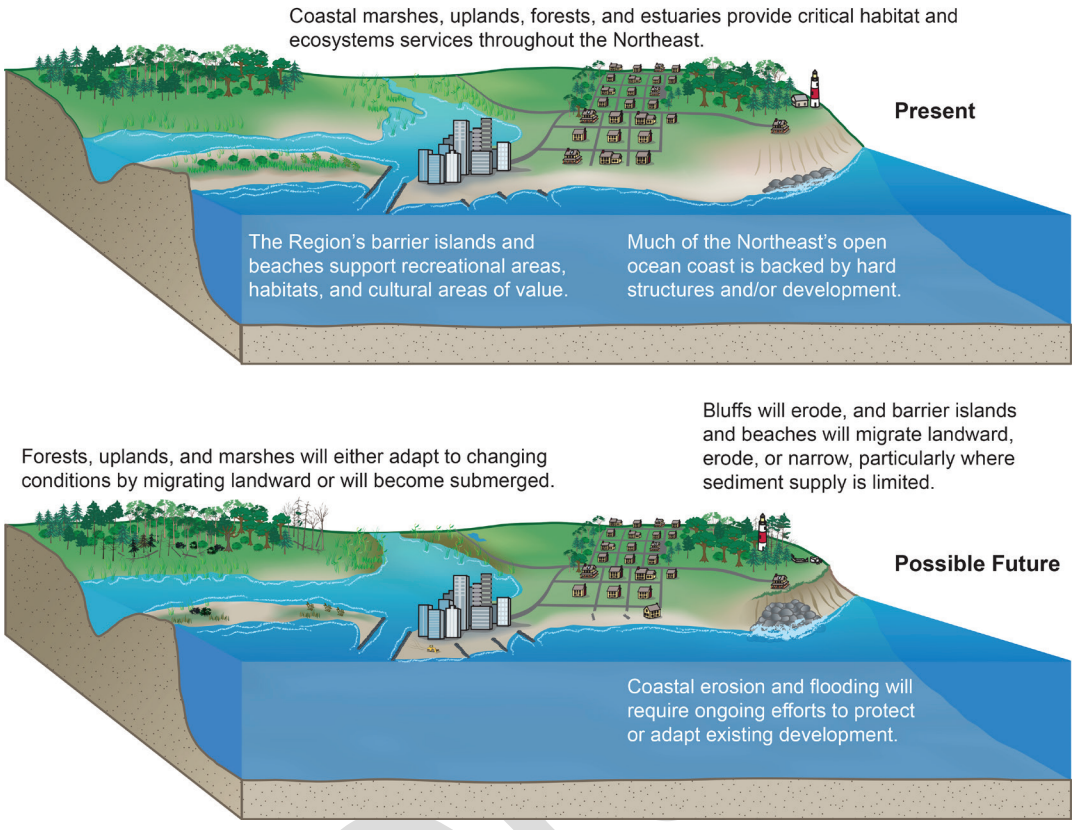


Figure 4-7. Coastal Impacts of Climate Change (USGS, 2018)

Island, and South Boston. However, as the scenarios progress even the more inland neighborhoods will begin to be affected. Inland neighborhoods like the South End and neighborhoods along the Charles River will have a new and increased exposure to coastal flooding. From the 2050s to the 2070s, over three times more land area will be exposed to inundation from a lower probability flood event.

4.2.3.7 Vulnerability and Risk

Coastal flooding can impact the City's infrastructure, economy, and the well-being of the community. Many of the same vulnerabilities exist for coastal flooding as riverine flooding, as described in Section 4.1.2.7. As sea level rise and other climate change impacts continue, this infrastructure will be at an even greater risk. A major storm surge has the potential to inundate multiple modes of transportation, rendering the systems unusable for days at a time as they are repaired. Erosion, both inland and coastal, puts current and future structures and populations located near steep embankments or the coast at risk.

Critical Facilities Coastal Flooding Vulnerability Analysis

Hazard location and extent of coastal flooding was determined using the FEMA FIRM for Zone VE, the 100-year coastal flood zone. A flood exposure analysis was conducted for critical facilities and vulnerable populations throughout the municipality utilizing these flood maps and models in addition to data provided by the City. This analysis found that only one facility was located in the FEMA Zone VE. By running an overlay analysis of the BH-FRM flooding extents and Boston's critical facilities, it is possible to estimate the impact of flooding on this important infrastructure in the future. It is estimated that 291 of the 6,737

critical facilities in Boston would be impacted by the 1% flood in 2030, and by 2070 that number would increase to 823 facilities. In the MC-FRM 2030 scenario, 436 of Boston's 6,737 mapped critical facilities are located within the coastal flood zone. According to the MC-FRM, 695 facilities will be within the flood zone boundaries by 2050 and by 2070 that number will increase to 1,402 facilities.

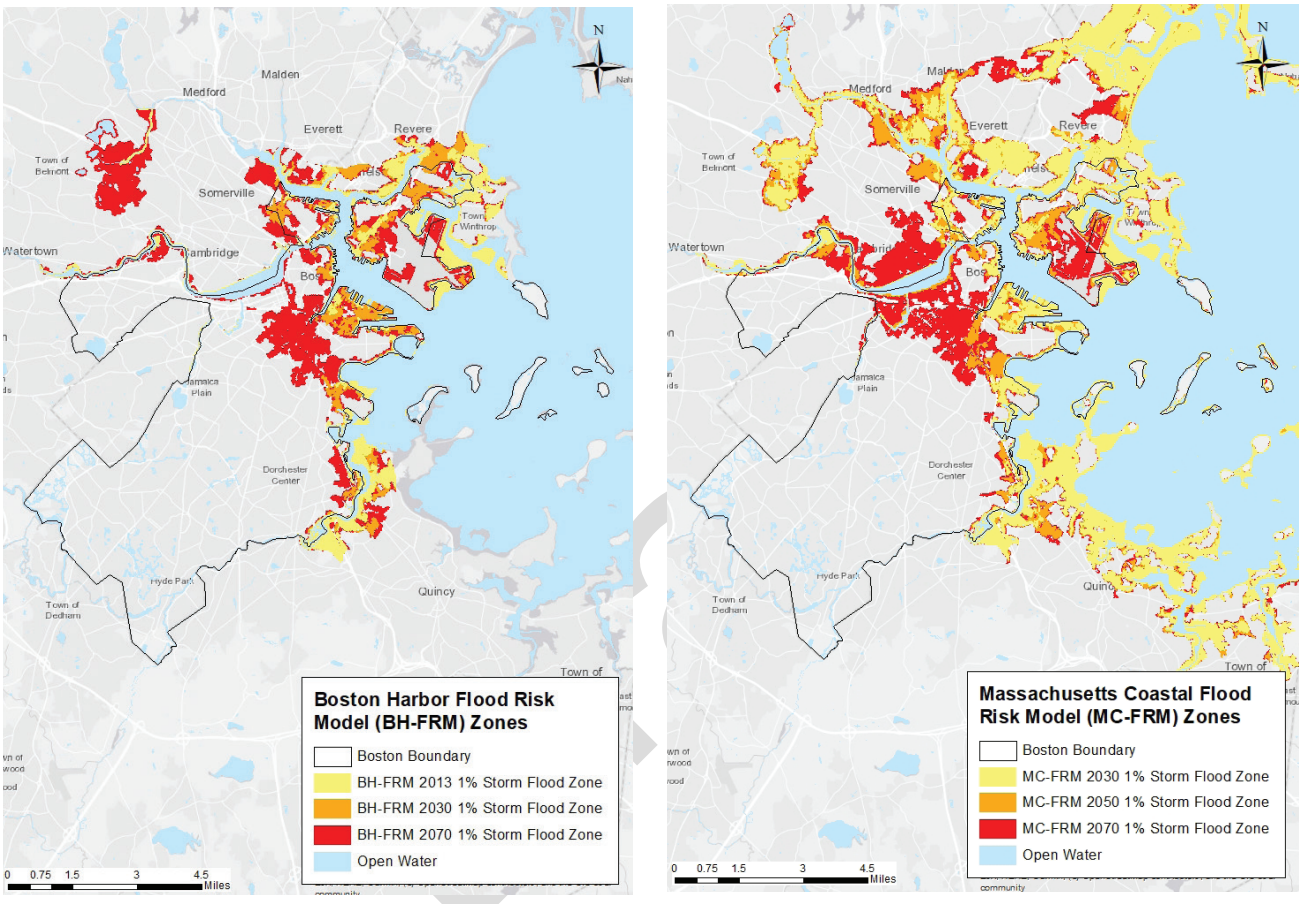


Figure 4-8. Boston Harbor Flood Risk Model (left), Massachusetts Coastal Flood Risk Model (right)

Development and Flood Vulnerability Analysis

The development data tracked by MAPC was compared against the FEMA coastal flood zone. Four proposed and one completed development are within the 100-year coastal flood zone. It can also be noted that sixteen projected and planned developments provided by MAPC MassBuilds are located within the present day BH-FRM 100-year flood zone, and thirty-three recently or soon-to-be completed developments are within the 100-year BH-FRM 100-year flood zone. By 2070, 232 developments (currently completed, planned, and projected) will be within the BH-FRM flood zone.

Additionally, many recently, planned, and projected developments are within the MC-FRM flood zone. Seventy-four developments are within the 2030 flood zone, and that number increases to 262 in the 2070 flood zone. This equates to nearly 19% of recent and future developments in the MC-FRM 2070 flood zone. Overall the change in vulnerability from development is complex. Development continues to occur in vulnerable areas, but the City has instituted stronger regulations to require resiliency measures.

- **Nearly 10%** of the new and proposed developments are located within the 2030 flood elevation zone for MC-FRMand BH-FRM
- **20%** of new developments and 15% of proposed developments are within both the MC-FRM and BH-FRM 2070 flood zone

Social Vulnerability and Coastal Flooding

Using the social vulnerability mapping introduced in Chapter 3, 16 of the 170 highly vulnerable tracts are located in FEMA VE zone. Nearly a third of the highly vulnerable tracts are located in the MC-FRM and BH-FRM 2030 zones.

4.2.4 Tidal Flooding

4.2.4.1 Description

Tidal flooding is caused by regular fluctuations in the tide cycle. This is linked to the lunar cycle, and can happen at any time, regardless of weather conditions. Twice a month, during "spring tides" the daily high tides are at the highest due to the alignment of the earth, sun, and moon. As sea level rise increases, these high tide events will become more and more destructive as they get higher. Additionally, when storm surge coincides with a high tide, the City will experience a "storm tide".

4.2.4.2 Severity

The tidal flooding currently experienced in Boston is not severe and does not pose a significant threat to major infrastructure. Due to the cyclical nature of tidal flooding, these events do not have a long duration, as they are subject to regular tidal fluctuations. Tidal flooding is most likely to occur when a high tide cycle coincides with an intense rainfall event. This combination of hazard events is exacerbated by the

2019 Flooding

impacts of climate change, which can increase the intensity and severity of the rain event, causing an already potentially damaging high tide to pose even more of a threat to the City's infrastructure.

4.2.4.3 Probability

Under current circumstances, normal high tides do not pose a significant threat to Boston. It is during above average high tides or when a high tide coincides with a significant rain event, that tidal flooding poses a threat to the City. Twice a year, during a new or full moon, Boston experiences what is referred to as a King Tide or a spring tide. According to NOAA a King Tide is a popular, non-scientific term that is often used to describe exceptionally high tides (NOAA 2021b). With the anticipated effects of sea level rise, it is expected that high tide events, especially those of King Tides, will pose an increasing threat to the City. As the level of the sea rises, so will the level of high tide events, causing an increased amount of tidal flooding.

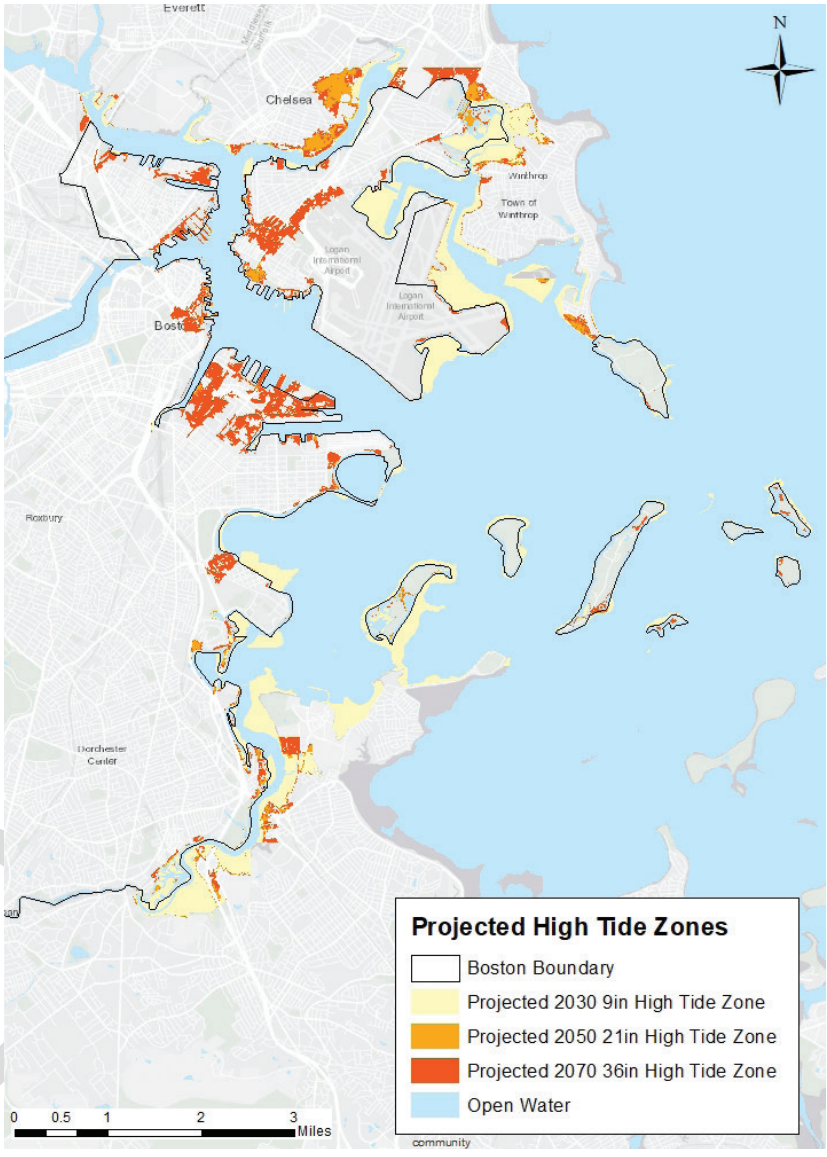


Figure 4-9. Climate Ready Boston Projected High Tide Zones

Tidal flooding is considered a high frequency hazard event. As defined by the Massachusetts State Hazard Mitigation Plan, this hazard may occur more frequently than once in five years, or greater than 20% chance per year.

4.2.4.4 Location

Tidal flooding is currently experienced in low-lying areas of the City, as well as areas that do not have sufficient protection, such as those described in Table 4-2 in Section 4.2.3.4. Areas with low lying stormwater infrastructure also experience tidal flooding through the drainage system. As sea level rise occurs, it is anticipated that additional areas of the City will experience tidal flooding. Long Wharf, Rowes/India Wharf, areas of the Seaport, and Morrissey Boulevard currently experience flooding during typical high tide events on a regular basis, despite the lack of an accompanying rain event.

Climate Ready Boston assessed multiple high tide scenarios to understand the extent that Boston will be impacted by flooding. The dataset included nine-inch (2030), twenty-one inch (2050), and thirty-six inch

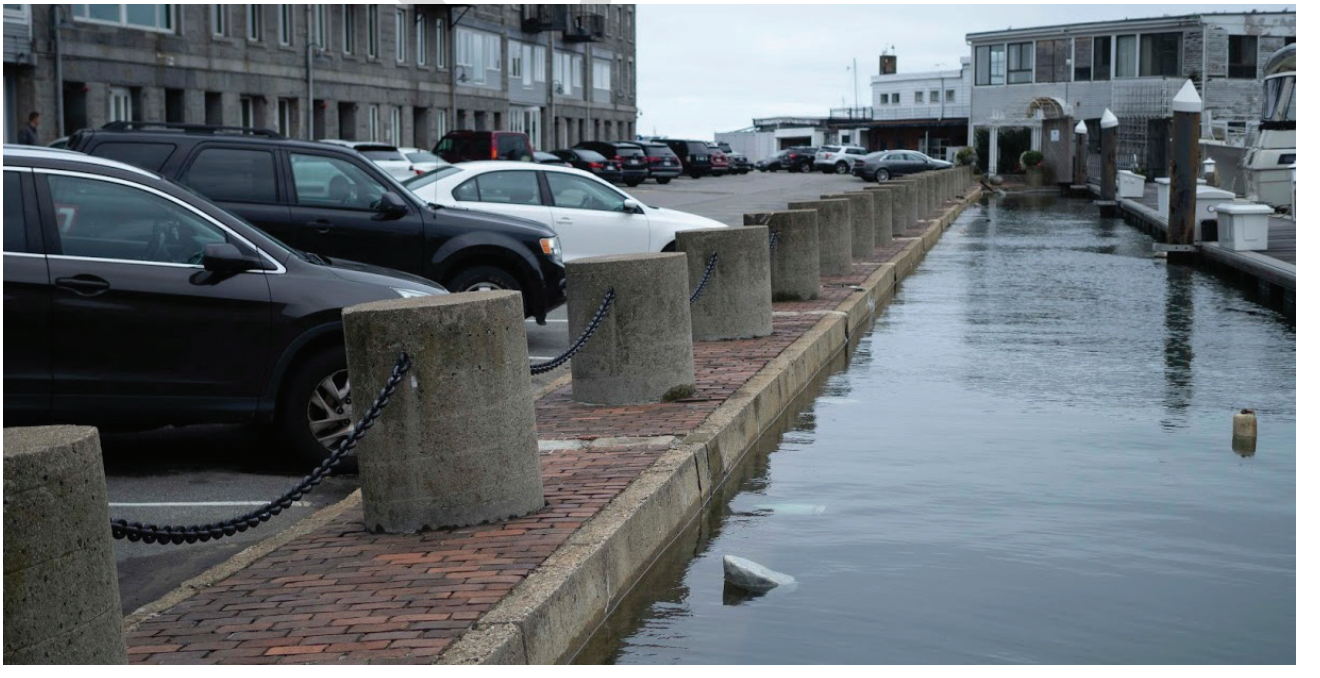
(2070) high tides (City of Boston, 2020). To understand present day tidal impacts on the City, Figure 4-9 demonstrates the impact that may be seen in Boston during each of these scenarios.

4.2.4.5 Historic Occurrences

Between 2000 and 2020, eight events categorized as Storm Surge/Tidal events, specific to Boston or reported as a county-wide event, were recorded in the NOAA Storm Events Database (NOAA, 2020a). None of these events overlapped with the reports the 2014 NHMP, which documents several occurrences of where high tides exacerbated coastal flooding as follows:

- **February 25-26, 2010** – northeast winds built up seas along the east-facing coastline and combined with astronomical high tides to produce moderate coastal flooding.
- **November 23, 2011** – High astronomical tides combined with weak wave action and produced minor coastal flooding along the east-facing shore of Massachusetts. Minor coastal flooding during high tide closed Morrissey Boulevard.
- **June 4, 2012** - Boston experienced high spring astronomical high tides. . Coastal flooding lasted through several high tide cycles with heavy rainfall. Morrissey Boulevard was closed with minor coastal inundation. Restaurants on Long Wharf flooded with 14 to 16 inches of water.
- **January 2, 2014** – After the City declared a Snow Emergency, Morrissey Boulevard was closed to traffic due to tidal flooding

In 2017, Boston had a record number of events meeting NOAA's high tide flood threshold with 22 events occurring in a single year. For comparison, only five events occurred in 2019 (NOAA, 2020g). In 2018 astronomical high tides during a bomb cyclone flooded Aquarium Station and many streets along the coast. Sunny day high tide flooding closed Morrissey Boulevard on Nov 16, 2020 during the King Tide. Portions of Long Wharf and the Seaport flood during nearly every king tide event.



4.2.4.6 Climate Change

As relative sea level increases, it will no longer take a strong storm or rain event to cause tidal flooding. Smaller precipitation events will create the same amount of flooding that a powerful storm would have created in the past when the sea level was lower. According to NOAA high tide flooding has increased in the U.S. on average by about 50 percent since 20 years ago and 100 percent since 30 years ago (NOAA, 2021c). It is expected that the effects of rising sea levels will intensify high tide flooding impacts in Boston's coastal areas.

Without factoring in storm conditions, five percent of Boston's land area will be inundated at high tide once a month or more. It is expected that coastal flooding from high tides will become a chronic hazard, flooding low-lying neighborhoods along the waterfront monthly (City of Boston, 2016a).

> As sea levels continue to rise, severely damaging floods will shift from a rare occurrence to a monthly reality.
>
> *(City of Boston, 2016a).*

4.2.4.7 Vulnerability and Risk

The current risk of severe tidal flooding during dry times in Boston is low. However, the City is beginning to consider "blue sky" condition – meaning flood hazards from high tides and sea level rise alone – when assessing vulnerability and risk. Boston is a low-lying City with a large tidal range, and as sea levels continue to rise the frequency of a blue-sky flooding event will become more frequent. Currently, the risks of tidal flooding are of greater concern when high tides are paired with other hazard events and projected future sea level rise. Using the social vulnerability mapping introduced in Chapter 3, 27 of the highly vulnerable tracts are located in 9" high tide zone and 35 of the highly vulnerable tracts are located in the 36" high tide zone.

2019 Flooding

4.3 Dam Failure

4.3.1 Description

Dam failure is defined as a collapse of an impounding structure resulting in an uncontrolled release of impounded water from a dam (DCR, 2017a). Dam overtopping occurs when floods exceed the capacity of the dam, which can be due to inadequate spillway design or other outside factors such as settlement of the dam crest or back of spillways. Thirty-four percent of all dam failures that occur in the United States are a result of overtopping (EEA and EOPSS, 2018). Many dam failures in the United States have been the secondary result of another hazard or event that has occurred. The prominent causes include earthquakes, landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, and sabotage (MEMA and DCR, 2013).

There are five dams located within the City limits of Boston. In addition, there are several regional dams that could impact Boston if they were to fail (DCR, 2019). Table 4-5 provides information on dams located in Boston, as well as those of regional significance to the City.

Charles River

Table 4-5. Boston Sea Level Rise Exposure

DAM NAME	PRIMARY OWNER	HAZARD CLASS	IMPOUNDED WATER
Old Charles River Dam*	DCR	N/A	Charles River
New Charles River Dam*	DCR	Significant	Charles River
Watertown Dam	DCR	Significant	Charles River
Chestnut Hill Reservoir Dam*	DCR	High	Chestnut Hill Reservoir
Southwest Campus Dam*	City of Boston	N/A	Sawmill Brook
Westinghouse Dam*	DCR	Significant	Mother Brook
Amelia Earhart Dam	DCR	Low	Mystic River
Upper Mystic Lake Dam	DCR	Significant	Mystic River
Baker Chocolate Dam/ Lower Mills Dam	DCR	Significant	Neponset
Neponset River Dam	DCR	Significant	Neponset

*Table Note: Dams marked with asterisk * are located in Boston (DCR, 2019)*

4.3.2 Severity

There are two types of dam failures that can occur. Catastrophic failure occurs when there is a sudden, rapid, uncontrolled release of impounded water. The second type is design failure, which occurs as a result of minor overflow events. DCR categorizes dams according to the potential extent of the hazard in the event of dam failure. Below is a description of dam hazard classification.

High Hazard: Dams located where failure or mis-operation will likely cause loss of life and serious damage to homes(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).

Significant Hazard: Dams located where failure or mis-operation may cause loss of life and damage home(s), industrial or commercial facilities, secondary highway(s) or railroad(s) or cause interruption of use or service of relatively important facilities.

Low Hazard: Dams located where failure or mis-operation may cause minimal property damage to others. Loss of life is not expected.

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

4.3.3 Probability

Many of the dams in Massachusetts were constructed in the 19th century (MEMA and DCR, 2013). Given this, DCR's Office of Dam Safety maintains records of dams located state-wide ensuring compliance with acceptable practices pertaining to dam inspection, maintenance, operation, and repair. Due in part to this proactive dam safety program, dam failure is classified as a very low frequency event in the City. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, a very low frequency hazard may occur less frequently than once in 100 years (less than a 1% chance per year).

4.3.4 Location

A total of ten dams, as indicated in Table 4-5 above have the potential to impact the City of Boston, five of which are located in Boston. The other five dams are located upstream of Boston and could impact the City if they were overtopped.

4.3.5 Historic Occurrences

In August 1955, the Neponset River Dam failed after two hurricanes occurred within five days of one another (City of Boston, 2016c). These two storms also caused 200 dams throughout New England to suffer partial or complete failures. The first storm, Hurricane Connie, produced 4-6 inches of rainfall over August 11 and 12 saturating the ground and elevating water levels in the river. Between August 17-19, Hurricane Diane brought 20 inches of rain causing the dam to breach. The greatest impact was the release of soil contaminated with polychlorinated biphenyls (PCBs) from Mother Brook into the Neponset River estuary. Contaminated soil continues to be a concern in Mother and Meadow Brook and would be a concern if the dams on the Neponset were to fail today.

4.3.6 Climate Change

Climate change may indirectly affect dam breaches for a variety of reasons. Dams are typically designed based on historic water flows and known hydrology. Climate change projections indicate that the frequency, intensity, and amount of precipitation will increase in New England. This anticipated increase in precipitation may push dams over capacity, placing additional stress on dam infrastructure. The Charles River Dam is a known entry point for coastal flooding, If the New Charles River Dam was flanked, flooding would extend into the Charles River basin and low-lying land immediately east of Sullivan Square.

Twenty-one includes of sea level rise is predicted between the 2050s and 2100s. If the Charles river was protected against the one percent annual chance flood in this scenario, the City could avoid an economic loss of $543 million in a single event. Therefore, continuing and enhancing dam monitoring and protection will be crucial to maintaining safe dam conditions as precipitation and sea levels continue to increase in the future.

There are several mechanisms in place to manage increased volume in water bodies, such as slowly releasing impounded water at scheduled intervals. It is advised that these controlled events are monitored closely as they can add additional stress on the dam infrastructure.

4.3.7 Vulnerability and Risk

A dam failure could result in catastrophic impacts to both Boston and the surrounding areas that rely so heavily on the City. Buildings would be destroyed, homes lost, roads washed out, and stream banks eroded. These impacts can be at least partially mitigated through advance warning to communities impacted by a dam failure. Updating the dam and protection around the dam for future seal level rise and flooding scenarios could save both money and lives.

Charles River

4.4 Wind Related Hazards

High winds occur during a variety of weather events, most notably during hurricanes, tropical storms, tornadoes, nor'easters, and thunderstorms. Boston's typical wind speed ranges from approximately 11 to 14 miles per hour but can gust of up to 40 miles per hour independently from storm events (City of Boston, 2016c). As seen in Figure 4-11, Boston is located within the Wind Zone II where shelters should be designed to withstand up to 160 mph (FEMA, n.d.-b).

QUOTES FROM PUBLIC SURVEY

"Nor'easters (winter) and large wind events have frequently caused downed trees and power lines in my community, thus making local travel difficult plus risking day to day life due to no power at home"

"This year we've had a few major wind storms. branches/trees down causing property damage and electric lines."

"A wind storm ripped the roof off my apartment, caused flooding & car damage"

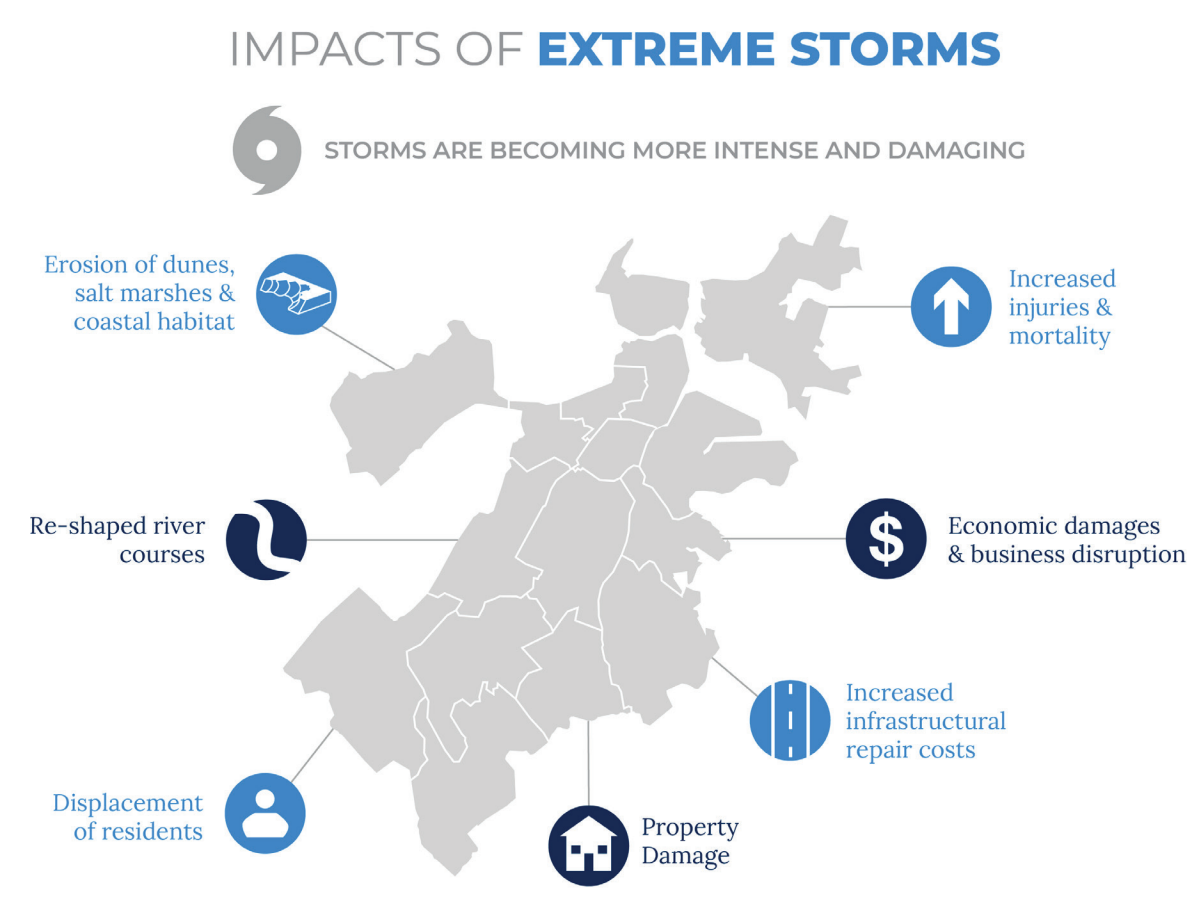
4.4.1 Severe Thunderstorms

4.4.1.1 Description

According to NOAA's National Severe Storms Laboratory a severe thunderstorm is a rain event, accompanied by thunder and one or more of the following: hail one inch or greater, winds gusting in excess of 50 knots (57.5 mph), or a tornado (NOAA, 2020c). Tornadoes are discussed in Section 4.4.2. Thunderstorms are most likely to occur in spring and summer during the afternoon or evening hours, but can occur at all hours in every season. Hail is solid ice that forms inside thunderstorms.

4.4.1.2 Severity

Thunderstorms are typically less severe than other wind related hazard events in Boston. The average thunderstorm will last for 30-60 minutes, but may last longer if there are multiple weather cells or supercells (NOAA, 2020c). Severe storm fronts can range in width from a mile to hundreds of miles in width.



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

Figure 4-10. Impacts of Extreme Events and Stronger Storms

Hail is usually reported by making comparisons to known objects.

- Pea = 1/4 inch diameter
- Mothball = 1/2 inch diameter
- Penny = 3/4 inch diameter
- Nickel = 7/8 inch
- Quarter = 1 inch*
- Ping-Pong Ball = 1 1/2 inch
- Golf Ball = 1 3/4 inches
- Tennis Ball = 2 1/2 inches
- Baseball = 2 3/4 inches
- Tea cup = 3 inches
- Softball = 4 inches
- Grapefruit = 4 1/2 inches

*hail quarter size or larger is considered severe

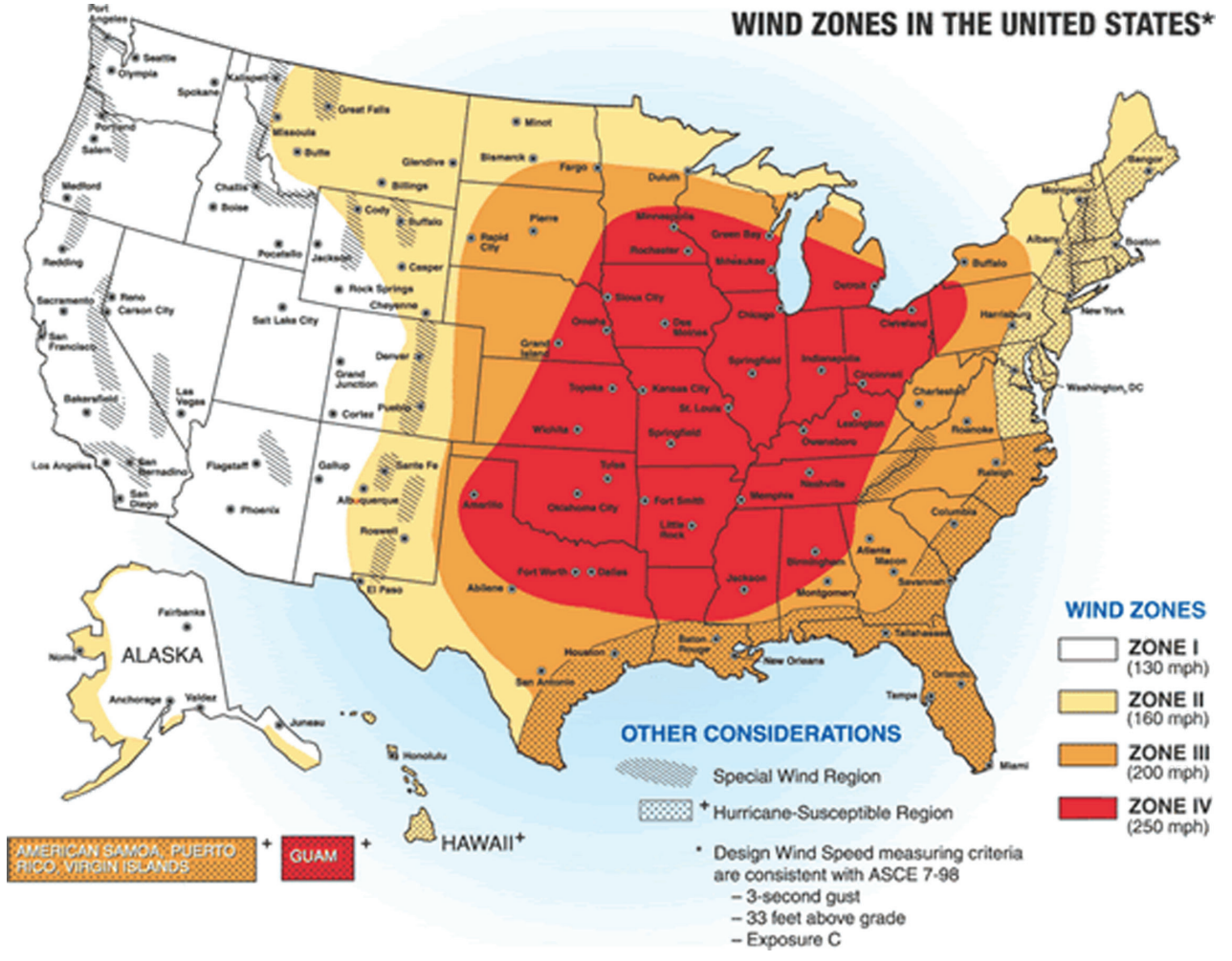


Figure 4-11. US Wind Zones Map (FEMA, n.d.-b)

4.4.1.3 Probability

NOAA's Storm Event Database collects data related to thunderstorm wind events. In all instances winds from the recorded thunderstorm events were recorded at 45 knots or more. From 2000 to 2020, 75 thunderstorm wind events, on 45 different days, were recorded in Suffolk County. These events produced one injury, no deaths, and $666,700 in damages. Based on historic occurrences, severe thunderstorms are considered high frequency events in Boston (MEMA and DCR, 2013). As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard may occur more frequently than once in 5 (a greater than 20% chance per year).

4.4.1.4 Location

Thunderstorms can cause local damage and are a city-wide risk in Boston. The entire city is equally susceptible to impacts from thunderstorms, which can include lightning, strong winds, heavy rain, hail, and sometimes tornados.

BETWEEN 2000 AND 2021

40

THUNDERSTORM EVENTS CAUSED

$666,700

PROPERTY DAMAGES
IN SUFFOLK COUNTY

BETWEEN 2000 AND SEPT 2020

149

WIND EVENTS CAUSED

$5,035,700

PROPERTY DAMAGES
IN SUFFOLK COUNTY

4.4.1.5 Historic Occurrences

NOAA's National Centers for Environmental Information offers thunderstorm and hail data for Suffolk County (NOAA, 2020a). Between 2000 and 2021, 40 thunderstorm events caused $666,700 in property damages in Suffolk County. One injury and no deaths were reported. The major thunderstorm events that affected Boston caused downed trees, branches, and powerlines, leading to roadblocks and power outages in parts of the City. Survey responses showed that many residents of Boston have experienced power outages and downed trees due to heavy wind events, often making local travel difficult or even impossible.

NOAA's National Centers for Environmental Information offers thunderstorm wind, high wind, and strong wind data for Suffolk County. Between 2000 and Sept. 2020, 149 wind entries were uploaded into the database. Other wind events were related to low pressure cells, rains, and other hazard events. During this time period, there were no deaths, four injuries, and a total of $5,035,700 worth of damages from strong, high, and thunderstorm wind events in Suffolk County. Winds ranged from 27 to 68 miles per hour.

Many of these thunderstorm events were also accompanied by hail. Between 2000 and 2021, there were 18 hail events, but no property damage, deaths or injuries were reported. The size of hail ranged from 0.75" up to 2" (NOAA, 2020a).

4.4.1.6 Climate Change

There is evidence that rising temperatures will increase convective available potential energy (CAPE) which is one of the two ingredients needed for severe thunderstorms. The other is strong wind shear, which is a difference in wind speed or wind direction within a short distance. It is projected that by warming the surface and putting more evaporation in the air CAPE will increase providing more raw fuel to produce rain and hail, and vertical wind shear, resulting in an increased amount of severe thunderstorm events (NASA, 2013).

4.4.1.7 Risk and Vulnerability

Winds associated with thunderstorms can knock down trees, resulting in power outages and blocked evacuation and transportation routes. Trees with insufficient planting space and soil volumes, trees weakened by invasive species, and softwoods, are more vulnerable. Extreme rain during thunderstorms can cause coastal flooding, riverine flooding around waterbodies, and stormwater flooding due to surcharged drainage systems. During periods of drought, lightning from thunderstorm cells can result in fire ignition (EEA and EOPSS, 2018).

2021 powerline repairs Allston

4.4.2 Tornados

4.4.2.1 Description

A tornado is a narrow, rotating column of air that extends from the base of a cloud to the ground. According to the 2018 SHMCAP, the following are common factors in tornado formation:

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

4.4.2.2 Severity

Tornadoes are the most violent of all atmospheric storms (EEA and EOPSS, 2018). They can be spawned by tropical cyclones or the remnants thereof, and weak tornadoes can even form from little more than a rain shower if air is converging and spinning upward. Tornados can cause fatalities and devastate a neighborhood in seconds. The winds of a tornado may reach 300 miles per hour with damage paths in excess of one mile wide and 50 miles long (NWS, n.d.-a).The Fujita Tornado Scale measures tornado severity through estimated wind speed and damage. The National Weather Service began using the Enhanced Fujita-scale (EF-scale) in 2007, which led to increasingly accurate estimates of tornado severity Table 4-6 provides more detailed information on the EF Scale.

Table 4-6. Enhanced Fujita Scale

FUJITA SCALE			DERIVED		OPERATIONAL EF SCALE	
F NUMBER	FASTEST ¼ MILE (MPH)	3-SECOND GUST (MPH)	EF NUMBER	3-SECOND GUST (MPH)	EF NUMBER	3-SECOND GUST (MPH)
0	40 – 72	45 – 78	0	65 – 85	0	65 – 85
1	73 – 112	79 – 117	1	86 – 109	1	86 – 110
2	113 – 157	118 – 161	2	110 – 137	2	111 – 135
3	158 – 207	162 – 209	3	138 – 167	3	136 – 165
4	208 – 260	210 – 261	4	168 – 199	4	166 – 200
5	261– 318	262 – 317	5	200 – 234	5	Over 200

(MEMA and DCR, 2013)

4.4.2.3 Probability

Based on historical occurrences, tornado events in Boston are considered a very low frequency event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard may occur less than once in 100 years (a less-than 1% chance per year).

4.4.2.4 Location

Because tornados are typically generated by strong thunderstorms, the entire City is equally susceptible, and tornadoes are considered a City-wide hazard.

4.4.2.5 Historic Occurrences

Although no tornadoes have been reported to have touched down within the City of Boston, Massachusetts experiences an average of 1.7 tornadoes per year. The most tornado-prone areas of the State are the central counties. Tornadoes are rare in eastern Massachusetts, although Suffolk County is considered an at-risk location (EEA and EOPSS, 2018). There has been one recorded tornado in Suffolk County since 1950 (NOAA, 2020a). In 2014, there was an EF2 tornado that touched down in Chelsea and then moved through Revere, causing extensive damage. Sixty-four structures sustained damage, ranging from torn off siding to roofs being lifted off the structure and blown away. Thirteen of these structures were deemed uninhabitable following the tornado. Four injuries were reported, and City officials estimated that City-owned buildings alone sustained upward of 1.5 to 2 million dollars of damage.

ONE
EF2 TORNADO IN SUFFOLK COUNTY SINCE 1950

1.5 to 2 MILLION DOLLARS
DAMAGE TO CITY-OWNED BUILDINGS

4
INJURIES

The most common months for tornadoes to occur are June, July, and August. There are exceptions: The 1995 Great Barrington, Massachusetts tornado occurred in May; and the 1979 Windsor Locks, Connecticut tornado occurred in October (EEA and EOPSS, 2018).

4.4.2.6 Climate Change

Tornadoes are typically spawned by strong thunderstorms. As thunderstorms increase in frequency and severity due to climate change, so does the chance that a tornado will occur. Tornados are difficult to simulate well in climate models because of their small size, but because they are generated by storm events that have been modeled to increase, it is predicted that the frequency of tornados in eastern Massachusetts will also rise in the future due to climate change.

4.4.2.7 Risk and Vulnerability

During a tornado, debris become windborne and can cause extensive damage on people and property. If a tornado were to occur in Boston, there is the potential for extensive damage. Damages would depend on the track of the tornado and would be most likely be high due to the prevalence of older construction and the density of development that exists. Structures built before current building codes may be more vulnerable. Evacuation, sheltering, debris clearance, distribution of food and other supplies, search and rescue, and emergency fire and medical services may be required as part of an 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 outages.

4.4.3 Hurricanes and Tropical Storms

4.4.3.1 Description

Tropical cyclones (including tropical depressions, tropical storms, and hurricanes) form over the warm waters of the Atlantic, Caribbean, and Gulf of Mexico. A tropical storm is defined as having sustained winds from 39 to 73 mph. If sustained winds exceed 73 mph, it is categorized a hurricane. The official hurricane season runs from June 1 to November 30. However, storms are more likely to occur in New England during August, September, and October (MEMA and DCR, 2013).

4.4.3.2 Severity

The Saffir-Simpson scale ranks hurricanes based on sustained wind speeds from Category 1 (74 to 95 mph) to Category 5 (156 mph or more). Category 3, 4, and 5 hurricanes are considered "Major" hurricanes. Wind gusts associated with hurricanes may exceed the sustained winds and cause more severe localized damage (MEMA and DCR, 2013). The Saffir/Simpson scale (Table 4-7) categorizes or rates hurricanes from 1 (minimal) to 5 (catastrophic) based on their intensity. This is used to provide an estimate of the potential property damage and flooding expected along the coast from a hurricane making landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on context (EEA and EOPSS, 2018).

Table 4-7. Saffir/Simpson Scale

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

(MEMA and DCR, 2013. Table originally created by NOAA)

4.4.3.3 Probability

Based on historic occurrences, hurricanes are considered a medium frequency event in Boston. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard can occur between once in five years to once in 50 years (a 2% to 20% chance per year).

4.4.3.4 Location

Hurricanes have a large spatial extent. Due to this, when hurricanes and tropical storms do occur, they will be a City-wide hazard. Boston is a coastal city, leaving the City especially vulnerable to hurricanes. Impacts of hurricanes have been felt along the coast, as storm surge overtops sea walls and other protection barriers. Inland impacts would also occur simultaneously, including riverine flooding, stormwater flooding, and wind damage.

4.4.3.5 Historic Occurrences

The region has been impacted by hurricanes throughout its history, starting with the first recorded hurricane: the Great Colonial Hurricane of 1635. Massachusetts experienced twenty-one hurricanes and seven named tropical storms between 1851 and 2012, including the devastating Hurricane Irene and Hurricane Sandy (both weakened to tropical storms by the time they hit Massachusetts). During the August 2011 Irene, strong winds occurred across Suffolk County, with frequent wind gusts of 35 to 55 mph, along with locally stronger wind gusts exceeding 60 mph. Impacts from Sandy The timing of Hurricane Sandy 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 damage and could put up to 43,000 Bostonians at risk (City of Boston, 2016a). Since 2012, Massachusetts has experienced impacts from four tropical storms: Arthur, Hermine, Jose, and Dorian.

4.4.3.6 Climate Change

Climate change is anticipated to impact hurricanes in the future, although scientists are not yet sure how. The 2016 Boston Research Advisory Group (BRAG) Report cited a likely increase in the frequency of Category 3 and stronger hurricanes. The intensity of these storms, and therefore their potential damage, may also increase (City of Boston, Boston Green Ribbon Commission, Climate Ready Boston, 2016). A new study found that the number of hurricanes reaching the intensity of Category 3 or greater along the Atlantic basin has increased over the past four decades (PNAS, 2020). This indicates that the Atlantic Ocean is likely to experience an increase in the number of hurricanes due to climate change. A study by NOAA examined hurricanes between 1980 and 2018 and found that greenhouse gases combined with other human-caused pollution, has changed how many storms have formed (NOAA, 2020d). Figure 4-12 provides additional information on where hurricanes have formed historically. The Atlantic East coast is highlighted in green, showing the Atlantic as a hurricane generating hotspot.

4.4.3.7 Vulnerability and Risk

Due to the large spatial extent of hurricanes and tropical storms, all populations and all existing infrastructure, including critical facilities, are at

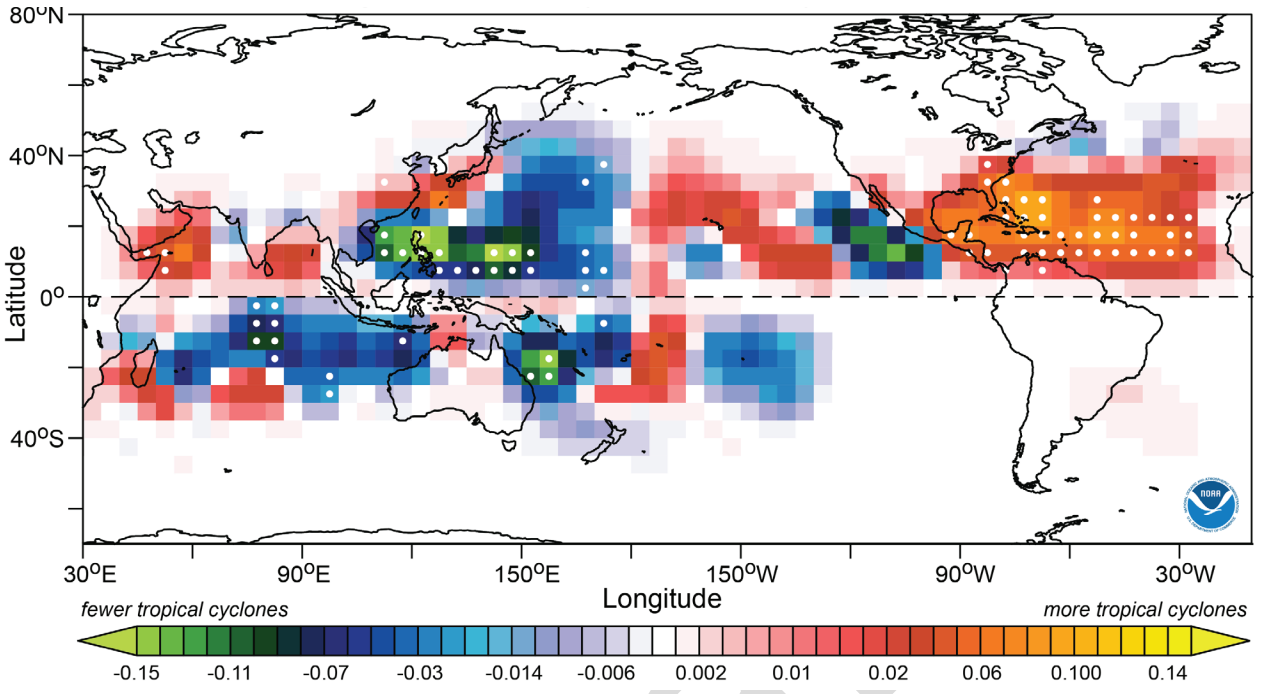


Figure 4-12. Observed Change in Frequency of Hurricanes from 1980 to 2018 (NOAA, 2020d)

risk to hurricane and tropical storm hazards. Potential impacts include damage to buildings from wind and water, business interruption, loss of communications, damage to transportation networks, impairment of water supply and wastewater systems, and power failure. Flooding is a major concern, as slow-moving hurricanes can discharge tremendous amounts of rain on an area. Coastal populations and infrastructure are especially vulnerable to storm surge that occur during a tropical storm or hurricane.

Potential hurricane damage in Boston was estimated using a hurricane modeling software. Table 4-8 provides an overview of the estimated impacts of damages in Boston from Category 2 and Category 4 hurricanes. Hazus Multi-Hazard (Hazus) is a GIS model developed by FEMA to estimate losses in a defined area due to a specified natural hazard. The Hazus hurricane model allows users to input specific parameters in order to model a defined hurricane magnitude, which is based on wind speed. The largest hurricane ever witnessed in Massachusetts was a Category 3 hurricane, which occurred in 1954. For the purpose of this analysis, in order to estimate potential damage, both a Category 2 and a Category 4 hurricane were modeled. Although there have been no recorded Category 4 hurricanes in Massachusetts, the storm was modeled to show the impact that could occur from an extreme scenario. A Category 4 hurricane could potentially occur in the future due to climate change.

In Massachusetts, the return period for a Category 2 hurricane is approximately 0.01 percent, and for a Category 4 hurricane it is approximately 0.005 percent. Hazus models hurricanes based upon their return period. Therefore, a Category 2 was modeled as a 100-year hurricane and a Category 4 was modeled as a 500-year hurricane. To model each of these hurricanes, the study region was defined. The geographic size of the region is 50.58 square miles and contains 180 census tracts. At the time of the 2010 census, over 252,000 households were located in the region, and there was a total population of 617,603 people. An estimated 111,000 buildings were located in the tracts with $93,020 million dollars value, and 83% of the buildings were residential (2010 census data and 2014 dollars).

The City of Boston was outlined by the census tracts that covers the City, and the probabilistic scenario

was used. This scenario considers the impact of thousands of storms that have a multitude of tracks and intensities. The output shows the potential impact that could occur in Boston's census tracts if either a Category 2 or a Category 4 hurricane passed by. Hazus is based on 2010 Census data and 2014 dollars. The table below shows the estimated damage from a Category 2 and a Category 4 hurricane in the City.

In addition to the infrastructural damage, Hazus also calculated the potential societal impact of a Category 2 and Category 4 hurricane on the community. Following a category 2 hurricane, 155 households would be displaced, and 73 people would require shelter. Those numbers would increase significantly following a Category 4 hurricane, with 3,874 households displaced and 2,251 people seeking shelter. Hazus also calculates monetary wage, capital-related, rental and relocation costs, as well as expected damages to essential facilities and damages by building material type.

Table 4-8. Estimated Damages in Boston's from Probabilistic Category 2 and Category 4 Hurricane Models

	CATEGORY 2	CATEGORY 4
BUILDING STOCK		
Estimated total number of buildings	111,000	
Estimated total building replacement value (Year 2014 $) (Millions of Dollars)	$93,020	
BUILDING DAMAGES		
# of buildings sustaining minor damage	5,142.69	21,689.55
# of buildings sustaining moderate damage	907.65	6,741.43
# of buildings sustaining severe damage	41.40	533.63
# of buildings destroyed	1.63	82.73
POPULATION NEEDS		
# of households displaced	155	3,874
# of people seeking public shelter	73	2,251
DEBRIS		
Total debris generated (tons)	90.337	325,047
Tree debris generated (tons)	11,146	28,828
Brick/wood debris generated (tons)	79,191	296,189
Concrete/steel debris generated (tons)	0	30
# of truckloads to clear building debris (@25 tons/truck)	3,168	11,849
VALUE OF DAMAGES (THOUSANDS OF DOLLARS)		
Total property damage	$573,136.67	$2,555,040.56
Total losses due to business interruption	$55,689.88	$338,397.97

4.4.4 Nor'easters

4.4.4.1 Description

A nor'easter is characterized by large counterclockwise wind circulation around a low-pressure center that often results in heavy snow, high winds, waves, and rain along the East Coast of North America. These storms usually develop between Georgia and New Jersey, within 100 miles east or west of the East Coast. They progress generally northeastward and typically attain maximum intensity near New England and the Maritime Provinces of Canada (NWS, n.d.-b). The term nor'easter refers to their strong northeasterly winds blowing in from the ocean. Boston is subject to the coastal hazards as well as inland hazards associated with nor'easters, including stormwater flooding and surcharge, riverine flooding, ice, storm surge and coastal flooding. The City of Boston is also vulnerable to high winds, snow, and heavy rain during nor'easters.

4.4.4.2 Severity

The storm radius of a nor'easter can be as 1000 miles or greater, with sustained wind speeds of 20 to 40 mph and short-term gusts of up to 50 to 60 mph. Nor'easters are commonly accompanied by a storm surge equal to or greater than two feet. High storm surge and winds during a hurricane can last from 6 to 12 hours, while these conditions during a nor'easter can last from 12 hours to three days (EEA and EOPSS, 2018). These winter weather events are among the season's most ferocious storms, often causing beach erosion, flooding, and structural damage (EEA and EOPSS, 2018).

4.4.4.3 Probability

Nor'easters generally occur on at least an annual basis, and some years bring multiple nor'easter events. Nor'easters in Boston are high frequency events. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard may occur more frequently than once in five years (a greater than 20% chance per year).

4.4.4.4 Location

Due to their large size, the entire City is impacted by a nor'easter event. Coastal locations can experience additional impacts related to storm surge, making them more susceptible to damage. Nor'easters are a City-wide hazard.

4.4.4.5 Historic Occurrences

Some of the historic events described in the "Flood-Related Hazards" section of this report were preceded by nor'easters, including the January 2015 Winter Storm Juno. Since 2010, twenty-six nor'easters have affected Boston. There was a case of four back-to-back nor'easters in March 2018. The first, known as Winter Storm Riley, produced storm surge heights close to Hurricane Sandy, and wind gusts greater than hurricane strength gusts. The second, Winter Storm Quinn, started just one day after the first and dropped over two feet of wet snow in some areas knocking out power. A two-day window of clear weather lead into the third event, known as Winter Storm Skylar, bringing more snow to the area and causing school closures in Boston. Just over one week later, the fourth nor'easter, known as Winter Storm Toby as well as "Four'Easter" by media outlets, passed along the east coast but luckily did not have much of an impact on Boston.

4.4.4.6 Climate Change

There is evidence suggesting that nor'easters along the Atlantic coast are increasing in frequency and intensity. Future nor'easters may become more concentrated during the coldest winter months when atmospheric temperatures are still low enough to result in snowfall rather than rain (EEA and EOPSS, 2018). While Boston's current 100-year wind speed is 99 mph, climate change will likely increase wind speeds, thus worsening events and severity (ASCE, 2018).

4.4.4.7 Vulnerability and Risk

Nor'easters have the potential to be extremely destructive especially in coastal areas such as Boston. The impacts of these events can lead to property damage, downed trees, coastal erosion, power service disruptions, surcharged drainage systems, and localized flooding. Nor'easters can often last several days, affecting multiple tide cycles. These prolonged conditions can impact evacuation and transportation routes and complicate emergency response efforts directly along the coast and further inland.

2021 Allston Power Line Repair

4.5 Winter Storms

Winter storms present the most common and familiar natural hazard in the region that affect a large geographic area. The northeast has a long history of severe winter storm events. The most severe winter storm in the area was the "Great Blizzard of 1888", which lasted for several days from March 11th to the 14th. Record snowfalls of 40 to 50 inches fell in parts of New Jersey, New York, Massachusetts, and Connecticut. Sustained winds of over 45 miles per hour produced snow drifts in excess of 50 feet. Boston had up to nine inches of slush on the ground (NESEC, n.d.-a).

QUOTES FROM PUBLIC SURVEY

"Winter storms are dangerous for my mom to go see her patients"

"The winter of 2015 was just ridiculous with all the snow."

HEAVY SNOW AND BLIZZARDS

"I recall the blizzard of 1978 here in boston whereas the city was shutdown for two weeks."

ICE STORMS

"I grew up with ice storms of 2008 and 2011 in Central MA. We lost power for multiple nights during those storms. It scares me to think that not only we can have extreme weather storms but also our whole weather patterns have completely change. We use to have consistent snow around Christmas time in Central MA and barely have a dusting."

Boston's urban setting magnifies winter storms impacts. Snow removal becomes difficult when snow must be transferred away from busy streets. Survey responses showed concern about getting around the City during or following a winter storms, due to the road and sidewalk conditions, Heavy snow loads may cause roofs and trees to collapse, leading to structural damage. Deaths and injury are also possible impacts. Additional impacts can include road closures, power outages, business interruption, business losses (i.e. due to road closures), hazardous driving conditions, frozen pipes, fires due to improper heating, and second-hand health impacts caused by shoveling (such as a heart attack). Public transportation is used by many residents and commuters in the City. During a winter storm, public transportation may be temporarily suspended or inaccessible, leaving people stranded. Public safety issues are also a concern, as streets and sidewalks can become difficult to pass. This issue may be especially difficult for vulnerable populations such as elderly

2019 Snowstorm

people who may have trouble crossing at intersections due to large accumulations of snow. Impassable streets can also complicate emergency response efforts during an extreme event. Winter storms can combine with the nor'easters discussed previously in the "Wind-Related Hazards" section, amplifying the impacts significantly.

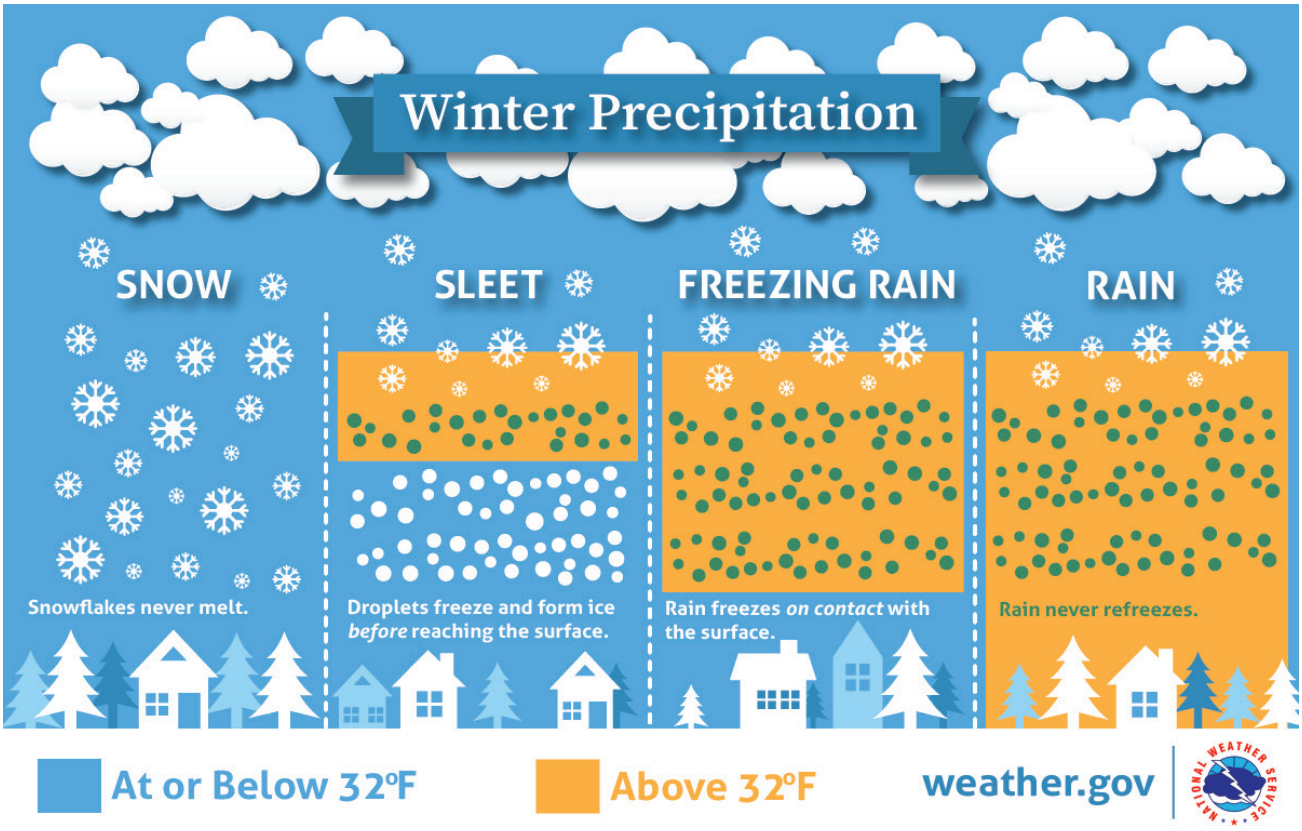
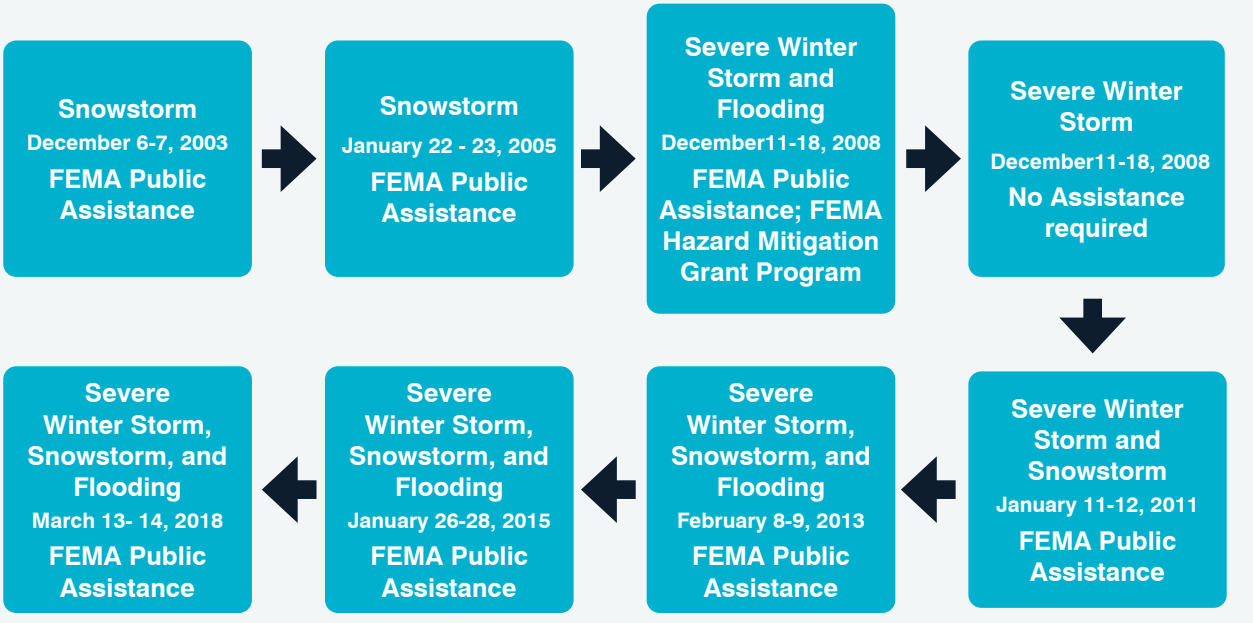


Figure 4-13. Winter Precipitation (NOAA, n.d.-b)

Due to the potentially widespread variety of impacts associated with winter storms, they are considered a City-wide hazard in Boston. These events can include wind, heavy snow, blizzards, and ice storms. Winter storms in Massachusetts can range from an inconvenience to extreme events that cause significant impacts and require a large-scale, coordinated response. Winter storm events are sometimes serious enough to trigger a federal disaster declaration.

Previous Federal Disaster Declarations – Winter Weather



(FEMA, 2021)

4.5.1 Heavy Snow and Blizzards

4.5.1.1 Description

In this chapter heavy snow and blizzards are collectively referred to as snow events. The National Weather Service defines "heavy snow" as snowfall accumulating to 4" or more in 12 hours or less; or snowfall accumulating to 6" or more in 24 hours or less (NOAA, n.d.-a). A blizzard is a winter storm with sustained wind or frequent wind gusts of 35 mph or more, accompanied by falling or blowing snow that reduces visibility to or below a quarter of a mile. These conditions must be the predominant condition over a 3-hour period. Extremely cold temperatures are often associated with blizzard conditions but are not a formal part of the criteria. However, the hazard created by the combination of snow, wind, and low visibility increases significantly with temperatures below 20°F. A severe blizzard is categorized as having temperatures near or below 10°F, winds exceeding 45 mph, and visibility reduced by snow to near zero (EEA and EOPSS, 2018).

BLIZZARD

- WINDS 35+ MPH
- 1/4 mi or less visibility
- 3 hour period

SEVERE BLIZZARD

- near or below 10°F
- WINDS 45+ MPH
- 0 mi visibility

4.5.1.2 Severity

The severity of a snow event in Boston is influenced not just by the intensity of the event itself, but also by external factors. Snow events can present hazardous circumstances that require a response on behalf of the City. Managing the snow can be a challenging task. Typically, the more snow that occurs, the more severe the event, and the more intense the response. The severity can increase when dense development patterns impede the ability to respond effectively and

ensure that emergency responders have adequate access. The ability to respond is also impacted by the time of day the event occurs. Overnight storms present an opportunity to respond with significantly less interference than those that occur during the day, while there are more vehicles on the road. Table 4-9 below provides one-, two-, and three-day maximums for snowfall events in Suffolk County. The data includes instances through June 2020 (NOAA, 2020e).

4.5.1.3 Probability

The Northeast generally experiences at least one or two major winter storms each year with varying degrees of severity (NESEC, 2021a). Based on the record of previous occurrences, snow events are classified as high frequency events in Boston. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard can occur more than once in five years (a greater than 20% chance of occurring each year).

4.5.1.4 Location

As previously mentioned, winter snow events can impact a large geographical area. During these events, the entire City is impacted, although the impacts are not evenly distributed throughout. More densely developed portions of the City, such as Beacon Hill, Charlestown, and the North End face greater challenges related to snow removal. Geographically, the City experiences varying snowfall averages. The average annual snowfall for the northern portion of Boston (including Jamaica Plain, Roxbury, Mattapan, north Dorchester, South End, South Boston, Allston/Brighton, Back Bay, Beacon Hill, the Financial District, North End, East Boston, and Charlestown) is within a range of 38.1 to 48 inches. The southern portion of the City, including Roslindale, West Roxbury, and Hyde Park experience a range of 48.1 to 72 inches of snow annually (City of Boston, 2016c).

Table 4-9. Snowfall Extremes in Suffolk County

EVENT TYPE	DATE	SNOWFALL MAXIMUMS (INCHES)
1- Day	2018-03-14	23.6
2-Day	1997-04-02	28.0
3-Day	1997-04-02	28.0

4.5.1.5 Historic Occurrences

In order to establish the historic frequency of winter snow events, a query for such events was made in the NOAA Storm Event Database. The information presented in this section is related to snow events classified as blizzards, heavy snow, and winter storms in the NOAA Storm Event Database. There have been 59 snow event occurrences in Suffolk County between 2000 and 2020, totaling approximately $649,500 in storm damage. No injuries or deaths were reported as a result (NOAA, 2020a). Winter snow events have been a predominant hazard in Massachusetts, and Boston, since the area was inhabited. More recent history reminds us of how much of an impact these events can have on the City's ability to function. The "Blizzard of 1978" is a well-known winter snow event that deposited more than three feet of snow in the area and led to the multi day closure of roads, businesses, and schools.

Table 4-10 provides more information related to some of the more significant historical snow events experienced in Boston.

Figure 4-14. Route 128 during Blizzard of 78' (NESEC, n.d.-a)

Table 4-10. Significant Blizzards and Winter Storm Events in Boston

TYPE OF EVENT	DATE
Blizzard of 78'	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	December 2010
Severe Snowstorm	January 2011
Blizzard	February 2013
Blizzard	January 2015
Blizzard	March 2018

(NHMP, 2016; updated NOAA, 2020a)

4.5.1.6 Climate Change

Annual winter precipitation has been increasing in recent years and this is predicted to continue. It is expected that the increase in precipitation will occur as heavy snowfall or rain in a small span of time, rather than spread out. This will cause greater impacts as communities have to deal with severe storms causing more damage.

4.5.1.7 Vulnerability and Risk

Significant snow events can immobilize an entire city. They present a wide variety of issues that can impact the day-to-day operation of businesses and residents. Due to the variability of the potential impacts, the entire infrastructure of the City, as well as the population, is at risk during more severe snow events. Boston's coastal location increases susceptibility to impacts from snow events. Since severe winter storms often produce high winds and a storm surge, coastal areas are more vulnerable. Boston's coastline is highly developed and high winds and storm surge associated with severe snow events can cause impacts and damages in addition to those experienced as a result of large snowfall totals.

4.5.2 Ice Storms

4.5.2.1 Description

Ice storms consist of freezing rain and sleet. Sleet occurs when droplets freeze and form ice before reaching the ground, while freezing rain starts as a liquid and then freezes upon contact with a surface. Sleet, while seemingly similar to hail, is a wintertime phenomenon while hail usually falls during thunderstorms in the spring and summer (MEMA and DCR, 2013). An ice storm warning will be issued when one-half inch or more of freezing rain is expected.

4.5.2.2 Severity

Ice storm severity can range from an inconvenience, lasting only for a short duration or debilitating and lasting for several days. This is highly dependent on how the storm coincides with temperatures. Ice storms usually occur when the air temperature is at or just above freezing (32-38˚F). Ice storms can have a significant impact on road conditions, making travel dangerous. Ice storms can also cause structural damage from falling trees and limbs. Electrical lines are particularly susceptible to the weight of the ice and power outages are common during ice storm events.

4.5.2.3 Probability

Based on the record of previous occurrences, ice storms are classified as medium frequency events in Boston. As defined by the 2013 State Hazard Mitigation Plan, medium frequency events occur between once in five years to once in 50 years (a 2% to 20% chance of occurring per year) across the state.

4.5.2.4 Location

The entire City is equally susceptible to the impacts of ice storms. In the colder months when precipitation falls as snow inland, the warmer coastal air causes rain in Boston instead. However, the cold temperatures create freezing conditions once the rain reaches a surface. Roadways, power infrastructure, and trees throughout the City can sustain impacts from ice storms.

4.5.2.5 Historic Occurrences

According to the NOAA Storm Database, no ice storms were recorded in Suffolk County between 2000 and 2020. In November of 1921 a severe ice storm impacted New England, specifically Massachusetts, northern Rhode Island, and Connecticut. The storm was coined “the worst ice storm in the history of New England”. Ice covered everything and there was massive destruction to trees and telephone poles. Transportation of all forms came to a halt and the region was immobilized for three days.

2021 Snowstorm

4.5.2.6 Climate Change

Climate related changes in temperatures are trending towards a greater number of days hovering around freezing, resulting in more freezing rain than has historically been experienced in Boston. The climate related increase in frequency and intensity of rainfall events, coupled with this temperature shift, will likely result in an increase in the occurrence of ice storms that Boston experiences in the future.

4.5.2.7 Vulnerability and Risk

Ice storms can coat surfaces in ice, making an otherwise simple walk or drive treacherous. Ice storms can often be more damaging than heavy snowfall events because ice accumulation can add significant weight to power lines, telecommunication infrastructure, and tree limbs. The accumulation of excessive weight on these components can often result in loss of services. Cities and towns in the state of Massachusetts that have experienced ice storms were sometimes without power for days causing a major disruption to day-to-day life for residents and businesses. Ice accumulation can also affect roads, rail beds, and mass transit infrastructure, creating difficult and dangerous conditions for commuters, commercial vehicles, and other travelers. Icy roads can also pose a significant risk, complicating emergency response efforts.

4.6 Geological Hazards

Earthquakes and landslides are the two main geologic hazards in Boston. We have also included a profile on tsunamis as earthquakes and landslides may cause this secondary event.

4.6.1 Earthquakes

4.6.1.1 Description

An earthquake is the vibration of the earth's surface following a release of energy in the earth's crust due to fault fracture and movement (City of Boston, 2016c). The cause of this energy release in eastern North America is the moving of the tectonic plates over the surface of the Earth. New England is located in the center of the North American plate. The eastern edge of the North American plate is located in the middle of the Atlantic Ocean, where the plate is spreading away from the European and African plate. New England's earthquakes are the result of the cracking of the crustal rocks due to compressions as the north American plate is being very slowly squeezed by global plate movements (City of Boston, 2016c).

4.6.1.2 Severity

The magnitude and intensity of an earthquake is measured by the Richter Magnitude Scale (Richter Scale) and the Modified Mercalli Intensity (MMI) scale, respectively. The Richter Scale measures the amount of seismic energy released by an earthquake, while the MMI scale describes the intensity of an earthquake based on its observed effects at a site where earthquake shaking is felt (NESEC, n.d.-b). The Richter Scale is the most widely recognized and used scale to measures earthquakes. It was developed in 1932 as a mathematical device to compare the size of earthquakes. It has no upper limit and is not a direct indication of damage. An earthquake in a densely populated area, which results in many deaths and considerable damage, can have the same magnitude as an earthquake in a remote area that causes no damage. Table 4-11 summarizes Richter Scale magnitudes and corresponding earthquake effects. Earthquakes that occur in the New England area often register on the Richter Scale as less than 3.5 and therefore are not felt.

Table 4-11. Richter Scale and Effects

RICHTER MAGNITUDES	EARTHQUAKE EFFECTS
0-3.4	Generally, not felt, but recorded
3.5- 5.4	Often felt, but rarely causes damage
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1-6.9	Can be destructive in areas up to about 100 km across where people live.
7.0- 7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred meters across.

(Louie, 1996)

The MMI scale generally describes the manner in which the earthquake is felt by people. The greater numbers of the scale are based on observed structural damage. Table 4-12 below provides additional information on the MMI scale.

Table 4-12. Modified Mercalli Scale

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.
IV	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.
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.

(USGS, 2016)

4.6.1.3 Probability

The probability of earthquakes occurring in Boston is determined by both historic occurrences and Boston's seismic hazard rating. Ground motion during an earthquake is the primary cause of damage to structures. Soft soils amplify ground motion, while hard rock reduces it. Boston is a City built on fill, and these soft soils below the City would amplify impacts from an earthquake. In order to measure the ground motion during an earthquake, scientists look at the maximum horizontal acceleration (peak ground acceleration). This is expressed as a "percentage of gravity" or percentage of the force we experience from gravity. It is often shorted to %g. Probability of occurrence is described as the peak ground acceleration (%g) with a 2% probability of exceedance in 50 years. Peak ground acceleration in the state ranges from 8%g to 20%g (USGS, 2016).

A serious earthquake in Massachusetts is possible. Boston is located in an area with a PGA of 14-20 %g with a 2% probability of exceedance in 50 years (Figure 4-15). This is the second highest seismic hazard zone in the state.

Based on the historic data available, earthquakes occur fairly regularly in New England, with smaller earthquakes averaging about two occurrences a year (MEMA and DCR, 2013). Earthquakes in Massachusetts occur and are recorded far more frequently than they are felt, as a majority of them cause no damage and are

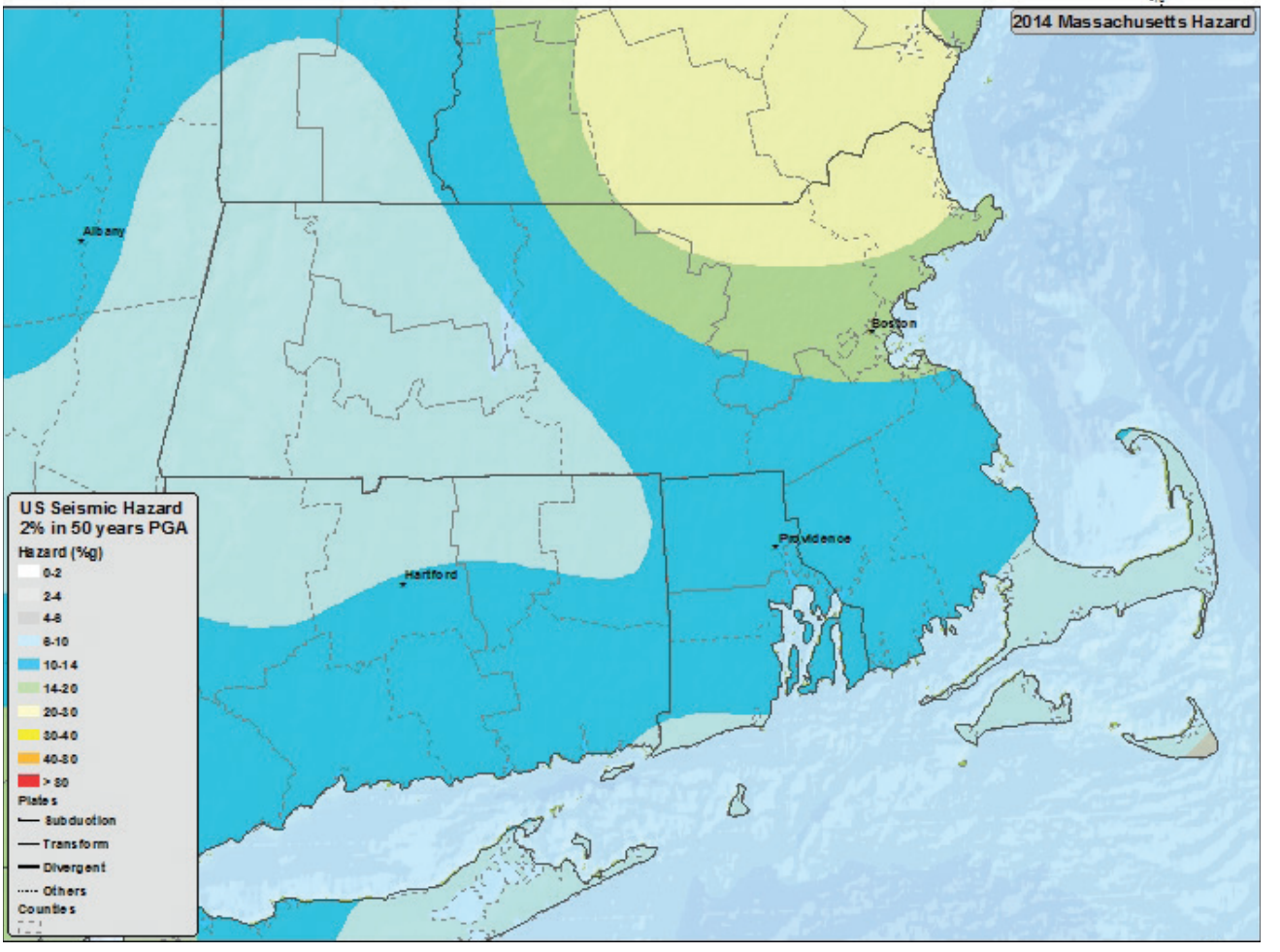


Figure 4-15. 2014 Seismic Hazard Map- Massachusetts (USGS, 2014)

not perceptible to people. Despite the fact that they do occur on average two times a year, earthquakes that are perceptible and cause damage are far less frequent. According to the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, the probability of a magnitude 5.0 or greater earthquake centered in New England is about 10-15% in a 10-year period. For this reason, damaging earthquakes are classified as a low frequency event in Boston. As defined by the 2013 State Hazard Mitigation Plan, these events occur from once in 50 years to once in 100 years, or 1% to 2% per year.

4.6.1.4 Location

Earthquakes are a City-wide threat due to the extensive area in which the impacts can be observed. Certain areas of the City may be at higher risk due to a phenomenon known as liquefaction. Liquefaction poses a particular risk for Boston because of the large area of the City that is constructed on filled land. During a seismic event such as an earthquake filled soils can become unstable, effectively liquifying, and destabilizing the buildings above. This destabilization can lead to significant building damage and sometimes collapse. Boston has a significant underground transportation system that is also highly susceptible to the effects of liquefaction. Figure 4-16 below provides more information on the areas of Boston that are susceptible to liquefaction. Type A soils have the least applicfication, while type E has the most.

Boston is one of the oldest cities in the US and there are many 19th-century buildings that are culturally and historically significant. These buildings are also primarily unreinforced masonry (URM) structures that are known to be very susceptible to damage or collapse during earthquakes (Kianiard, 2015). It is estimated that there are 18,919 unreinforced masonry buildings in the City (City of Boston, 2016c). These buildings house a variety of uses from residential homes to businesses, schools, fire stations, and police stations. The damage and destruction of these buildings during an earthquake event poses a serious threat to the City's ability to respond and recover.

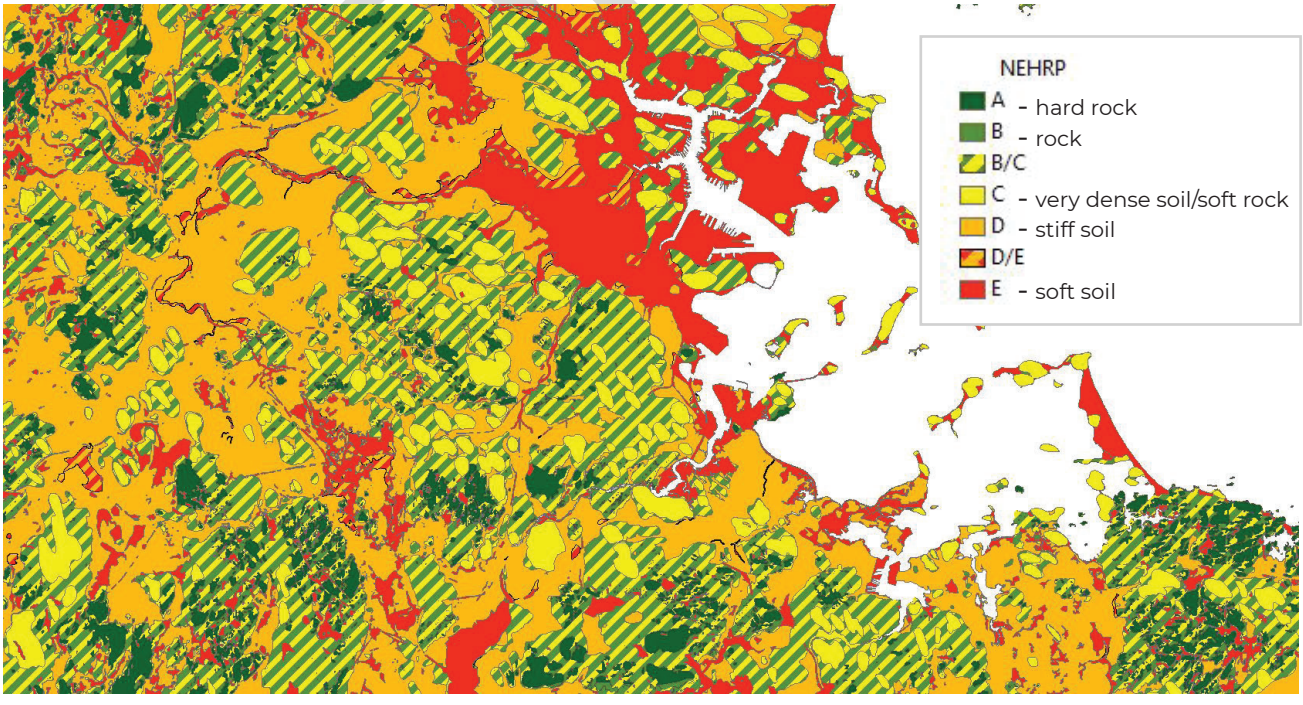


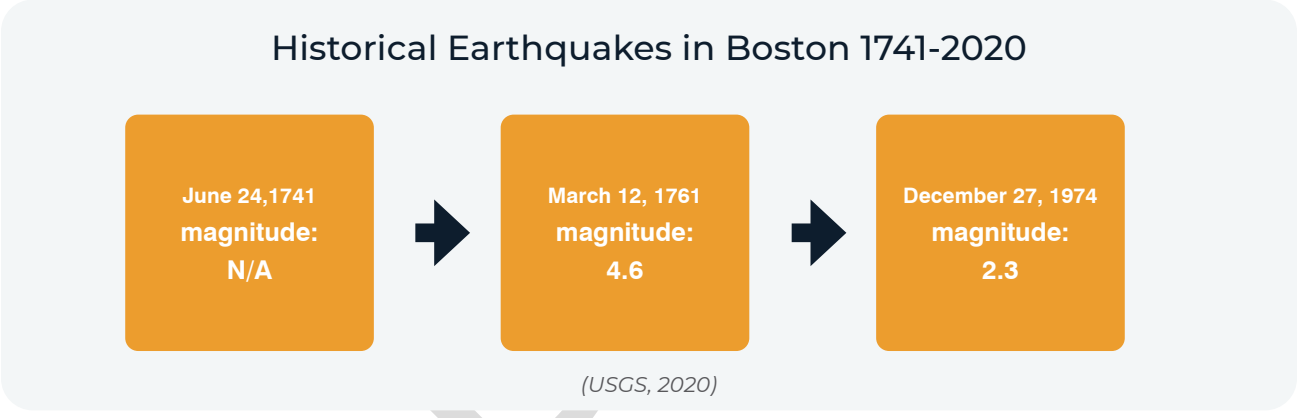
Figure 4-16. National Earthquake Hazard Reduction Program (NEHRP) Soils (EEA and EOPSS, 2018)

4.6.1.5 Historic Occurrences

According to the U.S Geological Survey, Massachusetts has recorded over 400 felt earthquakes since records began in 1668. The first recorded earthquake in MA was noted by the Plymouth Pilgrims and other early settlers in 1638. Boston's PGA Zone has had five reported earthquakes of magnitude 3 in the past. Only one earthquake, magnitude 2.3, had its epicenter just off the coast of Boston. The worst earthquake occurred off of Cape Ann with a magnitude of 6+. Historically, moderately damaging earthquakes strike somewhere in the region every few decades, and smaller earthquakes are felt approximately twice per year (MEMA and DCR, 2013). A summary of historic earthquakes in Massachusetts is included in Table 4-13 below.

4.6.1.6 Climate Change

Earthquakes are not known to be affected by climate change, although climate change impacts on other hazards could indirectly increase the damage caused by earthquakes if residents are forced to relocate to locations with a higher earthquake risk. Human water use has been known to affect earthquakes through "induced seismicity" when the water level at a fault changes due to human activity. This has been recorded in the United States near dams, when the water level behind the dam changes quickly (NASA, 2019).



(USGS, 2020)

4.6.1.7 Vulnerability and Risk

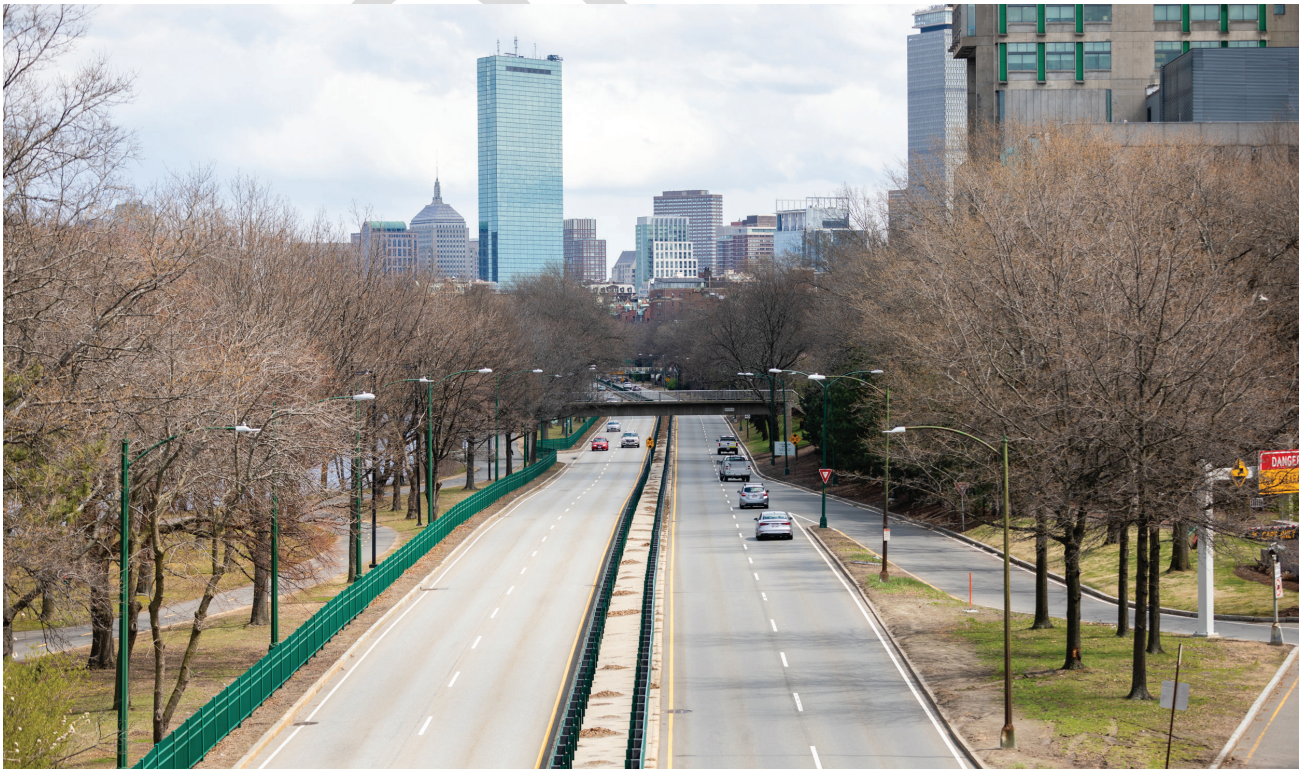
Geologic hazards to pose a threat to the City, as many structures predate current building codes, which require seismic standards, making those older structures more vulnerable to geological hazards. Although new construction under the most recent building codes generally will be built to seismic standards, much of the development in the City pre-dates the current building code. These events can strike without warning and can have a devastating impact on infrastructure and buildings constructed prior to earthquake resistant design considerations. It can be assumed that all existing and future buildings and populations are at risk to an earthquake hazard. If an earthquake occurs, the entire region, not just the City of Boston, could face significant challenges.

Impacts from earthquakes can range from slight to moderate building damage, to catastrophic damage and fatalities, depending on the severity of the event. Events may cause minor damage such as cracked plaster and chimneys, or broken windows, or major damage resulting in building collapse. Based on the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, the degree of exposure "depends on many factors, including the age and construction type of the structures where people live, work, and go to school; the soil type these buildings are constructed on; and the proximity of these building to the fault location." Furthermore, the time of day exposes different sectors of the community to the hazard.

Earthquakes can lead to business interruptions, loss of utilities and road closures which may isolate populations. People who reside or work in unreinforced masonry buildings are vulnerable to liquefaction (the phenomenon that occurs when the strength and stiffness of a soil is reduced by an earthquake). Earthquakes often trigger fires, and the water distribution system may be damaged as a result of the earthquake, thus posing a risk for public health and safety.

Potential earthquake damage was modeled for the City of Boston using Hazus. The Hazus earthquake model allows users to input specific parameters in order to model a defined earthquake magnitude, with the epicenter located at the center of the municipality. In this analysis, two earthquakes were modeled: a magnitude 5.0 and a magnitude 7.0 earthquake. While large earthquakes are rare in Massachusetts, there was a magnitude 5.0 earthquake recorded in 1963, a 5.5 recorded in 1727, and a 5.9 recorded in 1755. The tables below show the estimated damage from both a magnitude 5.0 and a magnitude 7.0 earthquake in the municipality. In addition to the infrastructural damage, Hazus also calculated the potential social impact, property damage, and business interruption loss. This calculation included utility system inventory, building damage by construction type, damage to essential facilities and transportation systems, and casualty estimates.

In a magnitude 5.0 earthquake scenario, approximately 76% of the buildings (and 41% of the building value) damaged are associated with residential housing. All transportation lifeline systems would be affected, including highway roads and bridges, MBTA facilities and rail segments, ferry facilities, port facilities, and Logan Airport. All transportation lifeline facilities could be repaired to greater than 50% functionality after one day, except for 40 highway bridge sections that would take one week to achieve greater than 50% functionality, and eight highway bridges greater than one week. Utility system lifelines would also be interrupted but would have more than 50% functionality after one week, including water and wastewater facilities, gas distribution lines, electrical facilities, and communications facilities.



In a magnitude 7.0 earthquake scenario, approximately 83% of the buildings (and 47% of the building value) damaged are associated with residential housing. All transportation lifeline systems would be affected, including highway roads and bridges, MBTA facilities and rail segments, ferry facilities, port facilities, and Logan Airport. Of the 315 total highway bridge segments in Boston, 296 would suffer complete damage, and another 16 would suffer moderate damage. Only four bridge segments could be repaired to functionality of greater than 50% after a week. One hundred of the MBTA facilities in Boston would suffer at least moderate damage, with 97 facilities suffering complete damage and only one facility back to at least 50% functionality after a week. Utility system lifelines would also be interrupted including water and wastewater facilities, gas distribution lines, electrical facilities, and communications facilities. All utility system lifelines could be running with functionality greater than 50% after one week. Tables 4-13 and 4-14 provide additional information related to the forecasted damages for these earthquake modeling scenarios.

Table 4-13. Estimated Damage to Critical Lifelines from Probabilistic Magnitude 5.0 and 7.0 Earthquake

FACILITY TYPE	AT LEAST MODERATE DAMAGE (>50%)		COMPLETE DAMAGE (>50%)		FUNCTIONAL >50% ON DAY 1	
	Mag 5	Mag 7	Mag 5	Mag 7	Mag 5	Mag 7
Hospitals	15	21	0	21	0	0
Schools	150	239	0	239	0	0
Emergency Op Centers	0	0	0	0	0	0
Police Stations	14	20	2	20	1	0
Fire Stations	2	2	0	2	0	0

Table 4-14. Estimated Damage in Boston from Probabilistic Magnitude 5.0 and 7.0 Earthquakes

	MAGNITUDE 5.0	MAGNITUDE 7.0
Building Stock		
Estimated total number of buildings	111,000	
Estimated total building replacement value (Year 2014 $) (Millions of dollars)	$93,019	
Building Damages		
# of buildings sustaining slight damage	29,311	6,915
# of buildings sustaining moderate damage	19,901	24,926
# of buildings sustaining extensive damage	7,605	26,681
# of buildings completely damaged	2,157	54,166

Table 4-14. Estimated Damage in Boston from Probabilistic Magnitude 5.0 and 7.0 Earthquakes

	MAGNITUDE 5.0	MAGNITUDE 7.0
Population Needs		
# of households displaced	19,496	171,480
# of people seeking public shelter	13,299	116,988
# life threatening injuries (depends on time of day)	Between 81 and 142	Between 1,500 and 2,371
# deaths (depends on time of day)	Between 158 and 264	Between 2,926 and 4,555
Debris		
Building debris generated (millions of tons)	3.49	23.15
# of truckloads to clear building debris (@25 tons/truck)	139,560	925,800
Building-Related Economic Loss (Millions of Dollars)		
Income Losses	$3,412.5137	$15,965.6959
Direct Building Losses	$13,055.4830	$88,892.9781
Direct repairs (transportation and utility)	$16,369.01	$16,369.01

4.6.2 Landslides

4.6.2.1 Description

Landslides can range from falling rocks to complete slope failure. Landslides typically occur when soil type and slope of land create unstable conditions (City of Boston, 2016c). Landslides can also be caused by erosion, slopes weakened through saturation by snowmelt or heavy rains, earthquakes, and other means (USGS, 2019). Vegetation and root structures can help stabilize soil. Engineering and design professionals should also consider soil stabilization during the design and construction process.

4.6.2.2 Severity

Landslide intensity can be measured in terms of destructiveness, as demonstrated by Table 4-15 (City of Boston, 2016c). The damages that result from landslide activity can be minimal or devastating depending on the location and severity of the landslide event. Landslides in densely populated areas such as Boston are more destructive to infrastructure compared to landslides in remote locations where often more severe of an event can have minimal to no impact on infrastructure.

4.6.2.3 Probability

Based on the limited extent of past occurrences, landslides are classified as low frequency events in Boston (City of Boston, 2016c). However, Boston's hilly terrain mixed with aging retaining walls, unreinforced masonry, granite boulders or stone slopes create circumstance where landslides may increase the likelihood in the future.

Table 4-15. Landslide Volume and Velocity

ESTIMATE VOLUME (M^3)	EXPECTED LANDSLIDE VELOCITY		
	FAST MOVING (ROCK FALL)	RAPID MOVING (DEBRIS FLOW)	SLOW MOVING (SLIDE)
<0.001	Slight intensity	--	--
<0.5	Medium intensity	--	--
>0.5	High intensity	---	--
<500	High intensity	Slight intensity	--
500-10,000	High intensity	Medium intensity	Slight intensity
10,000 – 50,000	Very high intensity	High intensity	Medium intensity
>500,000	--	Very high intensity	High intensity
>>500,000	--	--	Very high intensity

(Cardinali et al, 2002)

4.6.2.4 Location

According to information from the Massachusetts Geological Survey, almost all of Boston is classified as stable as shown in green in Figure 4-17. There are a few areas considered nominally/moderately stable (yellow), a few areas meeting the lower threshold of instability (pink), and every few areas meeting the upper threshold of instability or unstable (red).

4.6.2.5 Historic Occurrences

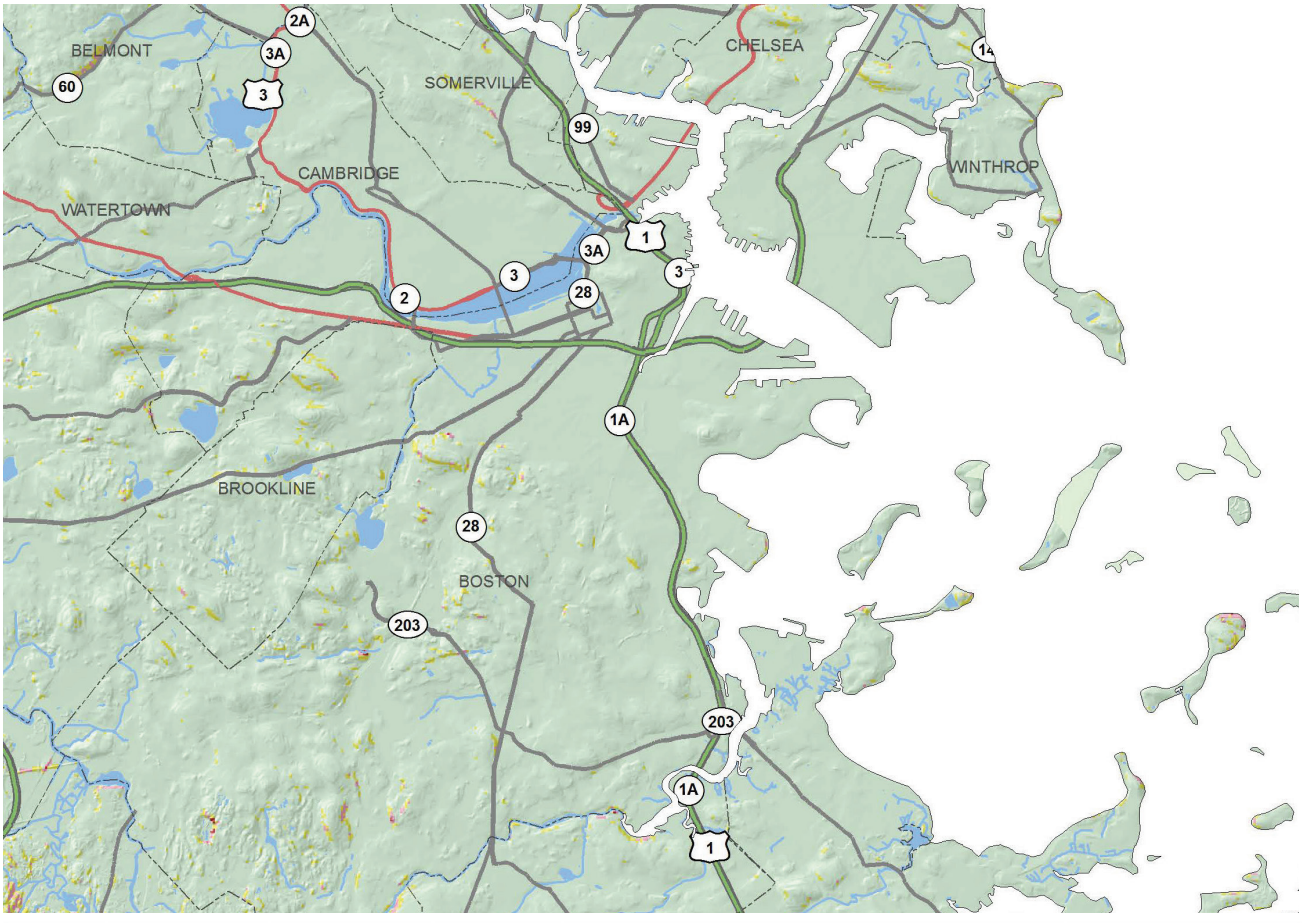
The City has experienced small landslides in some neighborhoods (City of Boston, 2016c), but no significant landslides have been recorded for Boston or Suffolk County (Appendix B of EEA and EOPSS, 2018). A retaining wall in East Boston's Orient Height neighborhood collapsed. In 2013, following three major back-to-back weekend winter storms, a 40-foot rock cliff collapsed carrying mud and large boulders onto Olive Street in the Brighton (City of Boston, 2016c).

4.6.2.6 Climate Change

The risk of landslide events can be expected to increase with climate change as the frequency and severity of rainfall events will cause rapid soil saturation and possibly erosion. Rapid snow melt and the frequency of rain-on-snow events may also trigger of landslides (Gariano and Guzzetti, 2016).

4.6.2.7 Vulnerability and Risk

Landslides can cause injury or death, property damage, and natural resource damage. Landslides may block roadways and waterways with sedimentation, rocks, and mud. Landslides blocking waterways may also cause flooding. Areas with a dense built environment and aging infrastructure, may incur greater damage if inflicted by a landslide. The physical vulnerability of areas with unstable soils and steep slopes cannot be removed. However, geologic investigations, good engineering practices, and effective enforcement of land-use management regulations can reduce landslide hazards risk (USGS, 2019).



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 4-17. Slope Stability Map of Massachusetts Focusing on Boston
(Source: The Massachusetts Geological Survey, 2013)

4.6.3 Tsunami

4.6.3.1 Description

Tsunamis are huge waves that form following geological activity, such as an earthquake or volcanic activity, that occurs under the ocean. They can also happen due to an underwater landslide (submarine landslide) and an onshore landslide where debris fall into the water. As the waves travel landward and the water becomes shallower, the waves increase in height. By the time they hit land, they can be as high as 100 feet. However, this is rare, and most tsunamis cause the sea to rise by a maximum of ten feet.

4.6.3.2 Severity

Tsunamis behave similar to a very fast-moving tide. They extend inward quickly and will inundate land areas that are not normally affected by tidal waters. When an event triggers a tsunami just off the coast, the tsunami can reach land within minutes. Smaller tsunamis, with a height of only six feet, can still easily knock a person over (USGS, n.d.).

4.6.3.3 Probability

Based on past occurrences of tsunamis in Boston, this hazard is rated as a very low frequency event, occurring less frequently than once in 100 years, or less than 1% per year.

4.6.3.4 Location

Areas with the greatest tsunami risk are coasts less than 25 feet above sea level, and within a mile of the shore. Many of the coastal neighborhoods are within this criterion, including most of Charlestown, East Boston, Downtown, Dorchester, Harbor Islands, and South Boston.

4.6.3.5 Historic Occurrences

To date, there has not been a recorded tsunami that has impacted Boston. The nearest tsunami occurred in 1929 in Newfoundland when a 7.2 magnitude earthquake occurred off the coast of Canada. Water levels rose by between 42 and 88 feet, houses were lifted off of their foundations, infrastructure was destroyed, and 28 people died while hundreds more were left homeless (Heritage, 2007).

4.6.3.6 Climate Change

Tsunamis are caused by a series of natural disasters, including earthquakes, volcanic activity, and landslides. The direct correlation between these hazards and climate change is not fully understood, but it would stand to reason that if they were to increase, the risk of tsunamis would also increase.

4.6.3.7 Vulnerability and Risk

When compared to the west coast and other parts of the world, a tsunami occurring in Boston is rare due to the low seismic activity in the Atlantic Ocean. However, there is a high risk associated with this hazard due to the submarine topography off of the east coast of the United States. Tsunamis in this area would likely be caused by a submarine landslide originating either on the open slope or in submarine canyons.

Tsunamis have the ability to impact coastal infrastructure that is normally protected from storm surge and flooding. Communication infrastructure, transportation systems, emergency services, businesses, and houses can all be severely impacted within minutes. Water can travel inland at a rapid speed, giving the community very little time to respond and retreat to safety. The USGS states, “A rule of thumb is that if your see the tsunami, it is too late to outrun it” (USGS, n.d.). Early warning signs of a tsunami include a tsunami warning, a strong ground shaking near the coast, or unusual wave activity (such as the sea retreating from the coast). While these warnings allow for some time to respond, it is often within minutes that the tsunami can hit the coast. This leaves little time for emergency management responders to organize and protect the coastal population.

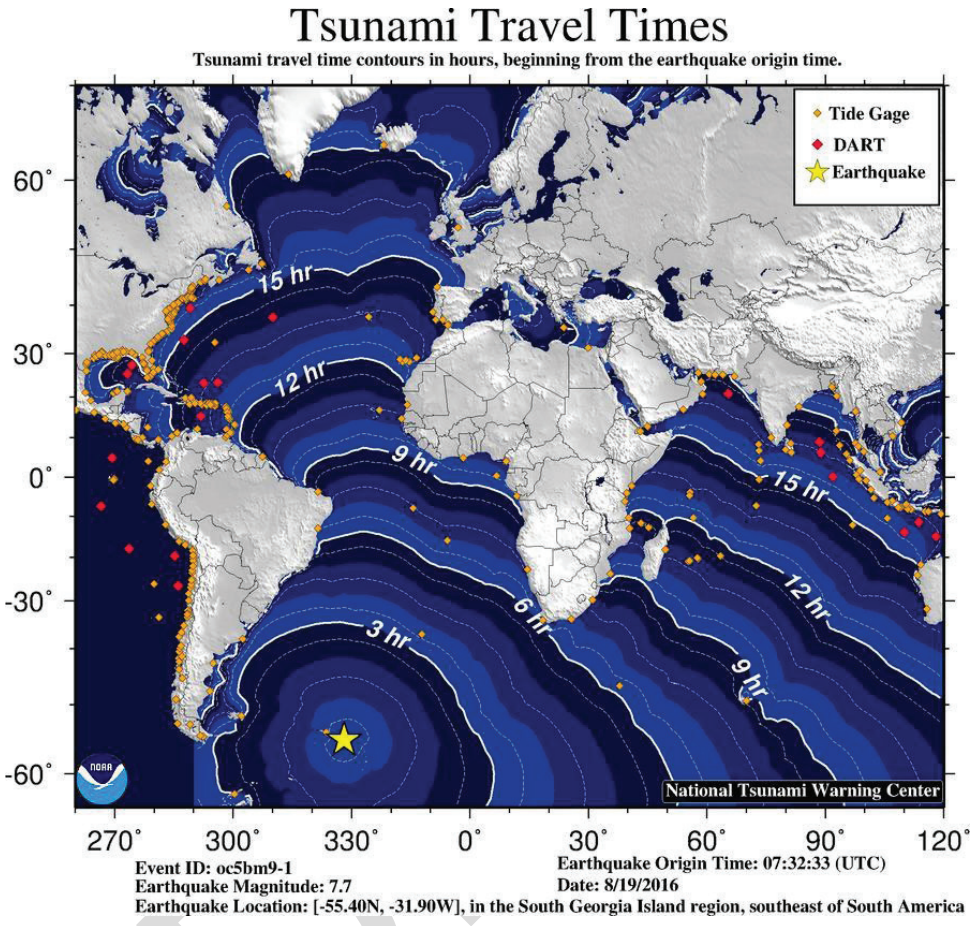


Figure 4-18. Tsunami Travel Times
(Source: NOAA, 2016)

4.7 Fire Related Hazards

4.7.1 Description

Boston is susceptible to two types of fire related hazards: brushfires and urban conflagrations (City of Boston, 2016c). For the purposes of this plan, a brushfire will be considered an uncontrolled fires in vegetative wildland areas primarily burning underbrush, such as grass, shrub, leaf litter, and downed limbs. Urban conflagrations are large building to building fires that spread over a relatively large urban area. While this type of fire is not usually considered a natural hazard, urban conflagrations can be ignited by a natural hazard event like an earthquake, tornado, or lightning strike. Fires can be caused by natural events, human activity or in an intentional controlled manner, as in the case of prescribed fire (MEMA and DCR, 2013, 252). Wildfires, or expansive fires burning large swathes of forested land, typically seen in the western United States, are not considered a hazard in Boston.

4.7.2 Severity

Brushfires can be measured by the number of acres burned. Fire severity is influenced by fuel (the type of material), terrain, and weather. Strong winds can exacerbate fire conditions, especially wind events that persist for long periods, or ones with significant sustained wind speeds that quickly promote fire spread through the movement of embers or exposure within tree crowns. Fires can spread quickly in developed areas as well. Building fires can spread quickly in urban settings like Boston, where structures are located in close proximity to each other.

4.7.3 Probability

Based on past occurrences of brushfire in the Boston area, the Massachusetts Hazard Mitigation Plan (2013) rated brushfires as a medium frequency event, meaning that a typic event is likely to occur between once every five years to once every fifty years (MEMA and DCR, 2013). Due to the

development in Boston, the City is more likely to experience an urban conflagration. Based on historic occurrences, urban conflagration is a low frequency event with a high impact for the City (City of Boston, 2016c). In the rare case an urban conflagration was to occur, Boston's narrow streets, tightly spaced buildings, and pre-building code construction would exacerbate the event posing an issue with response time and containment.

4.7.4 Location

The State Hazard Mitigation and Climate Adaptation Plan (EEA and EOPPS, 2018) does not designate any areas with Suffolk County as more susceptible to brushfires. Parks, especially those with large areas of phragmites (wetland grasses), are the most likely areas to experience brushfires (City of Boston, 2016c). According to Boston's Fire Department, areas that are more susceptible to brushfires include West Roxbury, Roslindale and Hyde Park. Residential areas near parks may be more likely to have an urban conflagration caused from a brushfire. Urban areas with closely built structures, wood building materials, manual or aging fire suppression systems, dilapidated or abandoned structures, are at higher risk. Figure 4-19 shows areas of Boston that have a high susceptibility to brushfires. These fires are displayed as interface, where structures are adjacent to the vegetation starting the fire, and intermix, where structures and vegetation are interspaced.

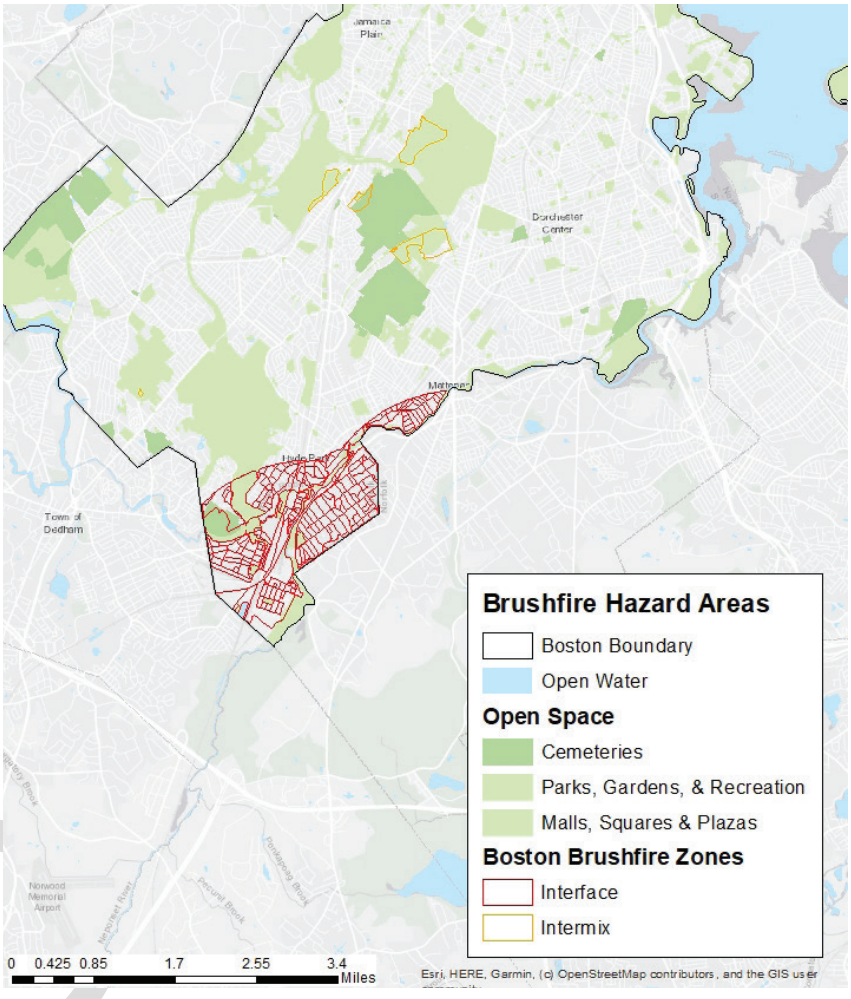


Figure 4-19. Brushfire Hazard Areas

4.7.5 Historic Occurrences

On average, brush fires occur annually or biennially, most often in the fall. Boston has experienced several conflagrations over the last few hundred years, which have caused significant damage. The largest property loss to conflagration was the Great Boston Fire of 1872, which destroyed 776 buildings (City of Boston, 2016c). The Great Boston Fire caused $75,000,000 of damage, which would be well over $3-4 billion dollars today. Many building codes were updated due to historic fires in the City, though much of the housing stock predates those changes. Two other notably large fires occurred in Dorchester in 1964 and 1987, but these did not start from natural causes.

In April 2012, 50-100 acres along the Neponset River Reservation near Trenton road in Dedham and bordering Boston was damaged by a brushfire. High winds scatted ashes throughout West Roxbury, Hyde Park, Jamaica Plain, Mattapan, and Dorchester and along the Route 28 corridor of Quincy and Milton.

4.7.6 Climate Change

Climate change has the potential to impact the frequency and severity of fire related hazards. Fire related hazards that are linked to a natural event such as lightning strikes will likely increase with climate change impacts. A 2014 study found that the frequency of lightning strikes could increase by more than 10% for every degree Celsius of warming (EEA and EOPSS, 2018).

4.7.7 Vulnerability and Risk

Brushfires can lead to injury, death, property damage and impacts to natural resources. Fire responses times in Boston reduce the likelihood of injuries and casualties. Smoke and air pollutions can be a health hazard. All structures located in brush fire hazard areas are at risk, and closely situated buildings, especially those without fire barriers, increase this risk. The most vulnerable members of the population are those who would be unable to evacuate quickly, including those over the age of 65, households with young children under the age of 5, people with mobility limitations, and people with low socioeconomic status (EEA and EOPSS, 2018). Using the social vulnerability mapping introduced in Chapter 3, 10% of the highly vulnerable tracts are exposed to wildfire-prone areas

Secondary effects from brush fire include contamination of reservoirs, destroyed power, gas, water, broadband, and oil transmission lines.

THE GREAT BOSTON FIRE OF 1872 DESTROYED

776 buildings

AND CAUSED

$75,000,000

OF DAMAGE

WHICH WOULD BE WELL OVER

$3-4 billion

TODAY

Brush fires can also contribute to flooding as they strip slopes of vegetation, thereby exposing them to greater amounts of runoff which may cause soil erosion and ultimately the chance of flooding. Additionally, subsequent rains can worsen erosion because brush fires burn ground vegetation and ground cover. First responders and fire firefighters are also at risk.

In the case of urban conflagrations, there is the potential for serious damage both structurally and economically. Large urban conflagrations can cause serious damage to a large number of structures and significant economic costs. The aftermath of these events can be death, injury, loss of belongings, loss of economic revenue, and loss of homes and businesses.

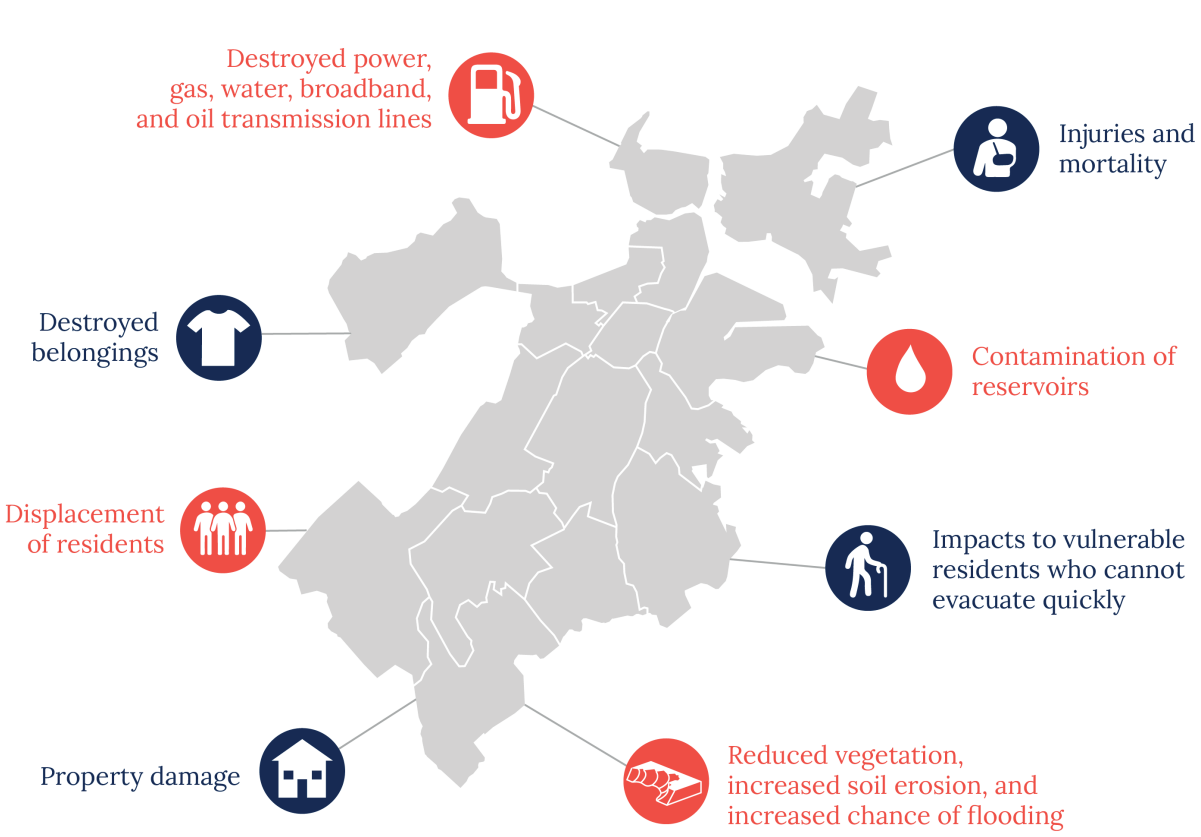


Figure 4-20. Examples of Potential Impacts of Fire Hazards

4.8 Extreme Temperatures

QUOTES FROM PUBLIC SURVEY

EXTREME HEAT

"Hot summers are also concerning, seeing as many apartments in Brighton (where I lived previous to 2021) do not come with central AC and with the work from home measures this past year, have come to some close calls with heat stroke due to trying to save money and being unable to work on a mobile tablet in a cooled public space."

"Flooding in East Boston on the waterfront and through the Greenway is a true problem. ***The heat is a major issue as well****, there are beautiful parks in East Boston but very little overall (most are Massport run) and there are way fewer trees than in other neighborhoods."*

Extreme temperatures can impact many facets of everyday life. Economic activities, cultural artifacts, infrastructure such as electrical grids, water lines, and transportation, and public health are all susceptible to the impacts of extreme temperatures. Ocean temperatures are also impacted, and since 2007 they have risen by a rate of 0.25°F per year (NCA, 2018). Massachusetts has four clearly defined seasons, with average seasonal temperatures for each. Extreme temperatures are considered outliers, or temperatures that fall outside the typical range for each season. This section focuses on events with either extremely hot or extremely cold temperatures. Extreme temperature events can last from an afternoon to a few days. Day and nighttime temperatures also play a role when considering the effect of temperature. For example, when the temperature does not cool off at night during an extreme heat wave, the risk of heat related illnesses is intensified. NOAA provides data related to temperature called "Climate Normals" for over 9,800 stations across the US. This Climate Normals data is a three-decade average for temperature from 1981-2010. Table 4-16 provides Climate Normals for Boston.

Table 4-16. Climate Normals in Boston, MA from 1981-2010 by Season

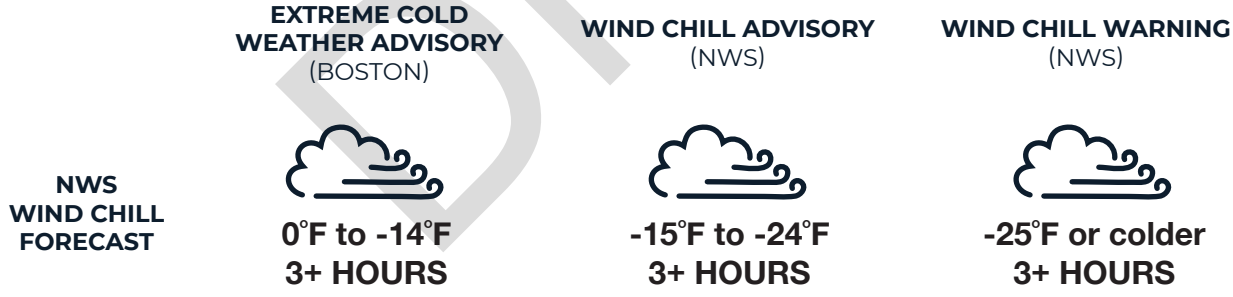
SEASON	AVERAGE TEMPERATURE (°F)
Annual	51.5
Winter	31.8
Summer	71.1
Spring	48.1
Autumn	54.5

(NOAA, 2010)

4.8.1 Extreme Cold

4.8.1.1 Description

Although no specific definition exists for extreme cold, extreme cold event are typically when temperatures are at or below freezing. This can occur for a day, or several days. Extremely cold weather can wreak havoc on the City, as it can create an extremely dangerous situation. Wind chill factor, which is the combined effect of cold temperatures and wind speed, can significantly decrease the "feel like" temperature and add to the threat posed by very cold temperatures. Boston recognizes an extreme cold weather situation to exist when the NWS forecasts a wind chill of 0˚F or below for three hours or more. During an extreme cold event, depending on the conditions, the City will issue one of the three types of alerts:



(City of Boston, 2016c)

4.8.1.2 Severity

Extremely cold temperatures are measured using the Wind Chill Temperature Index provided by the National Weather Service (NWS) (Figure 4-21). The updated index was implemented in 2001 and helps explain the impact of cold temperatures on unexposed skin.

4.8.1.3 Probability

Based on past occurrences, extreme cold is considered a medium frequency event as defined by the 2013 State Hazard Mitigation Plan. These events occur from once in five years to once in 50 years, or 2% to 20% per year.

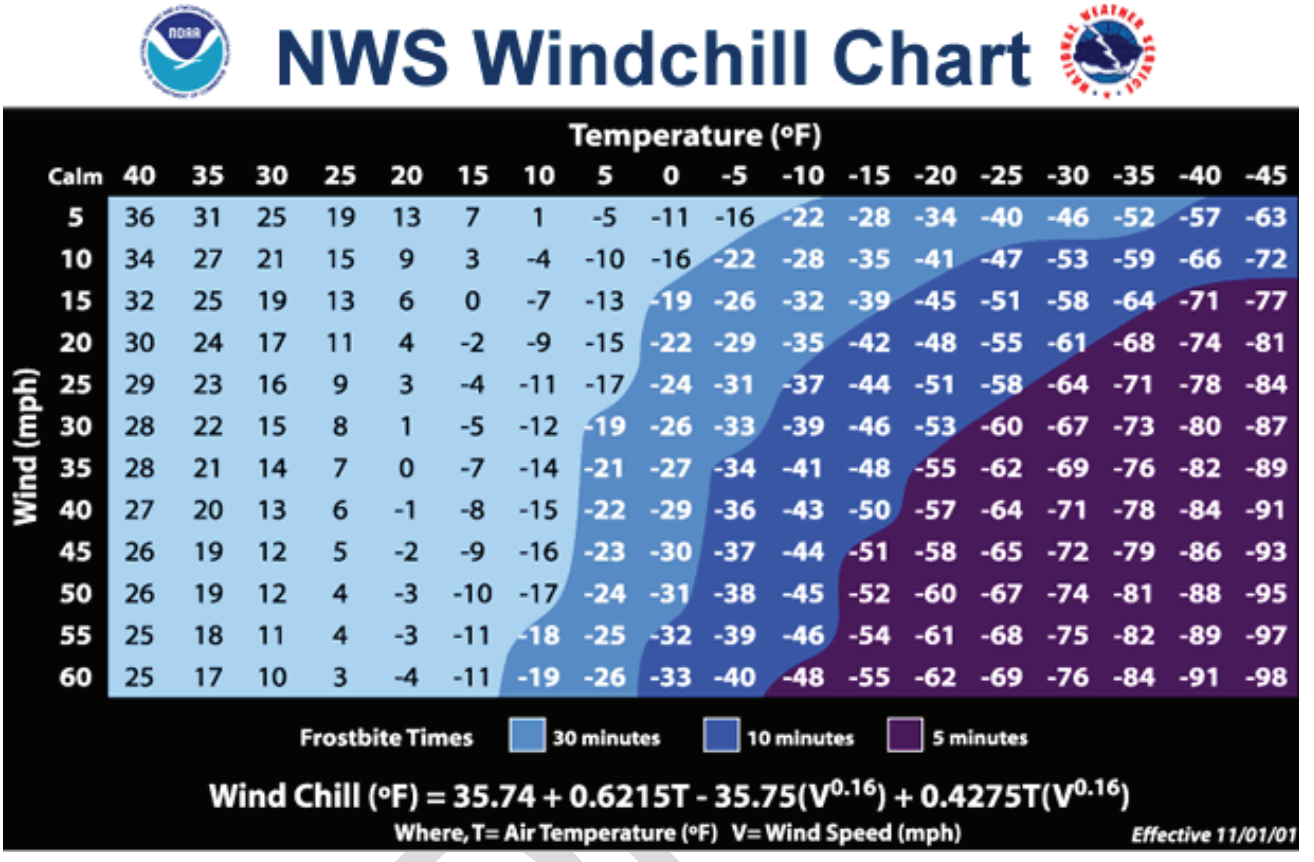


Figure 4-21. Windchill Temperature Index and Frostbite Risk (NOAA, 2001)

4.8.1.4 Location

Extreme cold temperatures are considered a City-wide hazard in Boston. All areas of the City are impacted by cold temperatures.

4.8.1.5 Historic Occurrences

Temperatures generally fall below 32˚F from November to March. In Boston, extreme cold events are most likely to occur in January. On average Boston has 92 days out the year that fall below 32˚F. Between 2000-2020, 2013 experienced the most days under 32˚F (106 times) and 2020 had the fewest days (71 days) (NOAA, 2020b). In the same time period, thirteen days fell below 0˚F. The NOAA Storm Event Database documents cold/wind chill and extreme cold/wind chill events for extremely low temperatures or wind chill temperatures reaching or exceeding locally/regionally defined warning criteria. According to NOAA's Storm Event Database, between 2000 and September 2020, Suffolk County experienced seven extreme cold and wind chill events. These events were reported to cause no injuries or property damage, but did result in one death in February 2007 (NOAA, 2020a). The lowest recorded temperature ever was -18˚F in February of 1934 (City of Boston, 2016c).

4.8.1.6 Climate Change

As seasonal weather trends continue, winters in Boston are predicted to be warmer overall, but the risks of cold snaps and freeze snaps will continue. This leads to dangerous conditions when residents are not prepared for fast drops in temperature.

4.8.1.7 Vulnerability and Risk

Extreme cold events can produce a variety of impacts. Unusually cold temperatures can have far reaching impacts on public health, transportation, agriculture, energy, water resources, and infrastructure.

Extremely cold temperatures can create dangerous conditions for the general population who is out navigating the City. Extreme cold can make otherwise simple travel dangerous. The homeless, the elderly, and people with disabilities are often most vulnerable during these events. In Boston, 11.5% of the population is over 65 years old and 8.2% of the population has a disability (US Census Bureau, 2019). Cold weather events can also have significant health impacts such as frostbite and hypothermia. Furthermore, power outages during cold weather may result in inappropriate use of combustion heaters, cooking appliances, and generators in poorly ventilated areas, which can lead to increased risk of carbon monoxide poisoning and fires.

In Boston

11.5% OF THE POPULATION IS OVER 65

8.2% HAS A DISABILITY

In 2015

4 CONSECUTIVE BLIZZARDS AND EXTREMELY **cold** TEMPERATURES

resulted in the T being shut down

Extreme cold and winter weather can affect the public transportation system in Boston. In 2015, four consecutive blizzards, coupled with extremely cold temperatures, resulted in the T being shut down. Many Bostonians resorted to driving in hazardous blizzard conditions because there was no public transportation. The extreme amount of snow made sidewalk and bike lane travel difficult, and many pedestrians and bicyclists had to travel in the vehicle lanes. During extreme cold events energy consumption rises significantly as individuals require more fuel to heat their homes. Lack of heat during these events can cause water pipes to freeze and burst disrupting water services. Buried water pipes are also susceptible as ground freezing can cause underground pipes to freeze and burst causing massive ice problems and loss of water pressure. A broken water main can have devastating effects in a metropolitan area.

4.8.2 Extreme Heat

4.8.2.1 Description

Extreme heat is described as a period of very hot weather, which may include high humidity. These events can last from one to several days. Generally, if three or more consecutive days are above 90˚F, it is considered a heat wave. Extreme heat is the primary cause of weather-related fatalities in the United States. During the summer months, Boston is especially vulnerable to heat-related hazards. The City can be as much as 16˚F warmer than surrounding areas (City of Boston, 2016c). This is due to the dense development pattern, which includes a large amount of asphalt and concrete. This scenario traps heat creating what is known as the "Urban Heat Island" effect, making metropolitan areas significantly warmer than surrounding less densely developed areas. Typically, July is the hottest month in Boston, with the monthly temperature averaging at 74.4°F from 2000-2020 (NOAA, 2020b).

Average annual temperatures have increased almost 3F in Massachusetts over the past century.

(NOAA, 2017)

4.8.2.2 Severity

The National Weather Service (NWS) issues a Heat Advisory when the Heat Index (Figure 4-22) is forecasted to reach 100-104˚F for two or more hours (NOAA, n.d.). The NWS issues an Excessive Heat Warning if the Heat Index is forecast to reach 105˚F or higher for two or more hours.

4.8.2.3 Probability

According to the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, between four and five heat waves occur annually in Massachusetts.

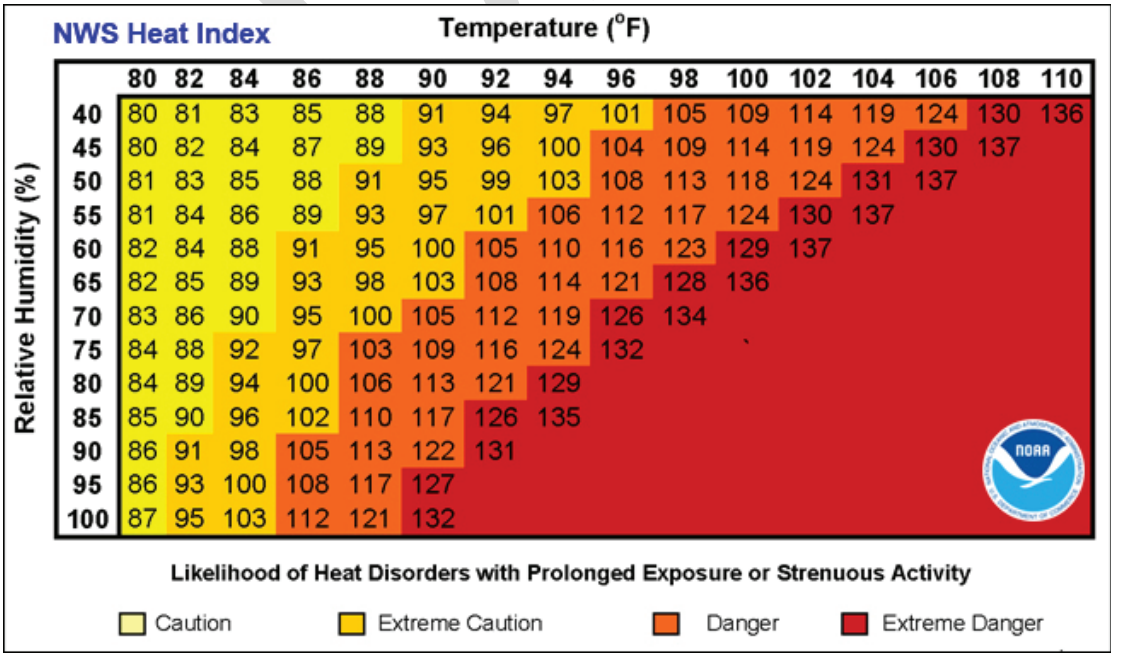


Figure 4-22. Heat Index Chart
(NOAA, n.d.-c)

4.8.2.4 Location

The entire City is at risk during extreme heat events. Projected heat days and heat waves can have an increased impact in densely settled urban areas like Boston. The many public spaces in Boston that are home to trees and green spaces can aid in combatting the heat island effect and reduce temperatures within the City overall. Although there are many beautiful green parks throughout the City, there are also areas with little green space. These areas often experience hotter air temperatures, and have fewer locations that residents can go to cool off. Public spaces could benefit from the addition of trees to mitigate heat island effect, as well as artificial shading to protect community members while they are commuting, exercising, waiting for the bus, and engaging in other activities that require them to be outdoors during summer months.

4.8.2.5 Historic Occurrences

Ninety degrees days are most likely to occur between April and September. Between 2000 and 2020, Boston experiences on average 14 days of above 90° Fahrenheit annually, with a maximum of 27 days above 90°F in 2002. July and August have on average six and four days, respectively, over 90°F (NOAA, 2021c). The highest temperature record was 104°F on July 4, 1991 followed by 103°F on July 22, 2011 (City of Boston, 2016c). The NOAA Storm Event Database documents heat and excessive heat for extremely high temperatures and humidity reaching or exceeding locally/regionally defined warning criteria. Between 2000-2020, Suffolk County recorded seven heat or extreme heat events.

4.8.2.6 Climate Change

The average summer temperatures in Boston between 1981 and 2010 was 71.1°F. Climate projections are estimating that the average summer temperature in 2050 could be 76°F (City of Boston, 2016a). Between 2000 and 2020, Boston experienced an average of one day per year in excess of 100°F. That could increase to six days per year by 2070, and 24 days per year by 2099. Under these conditions, by the end of the

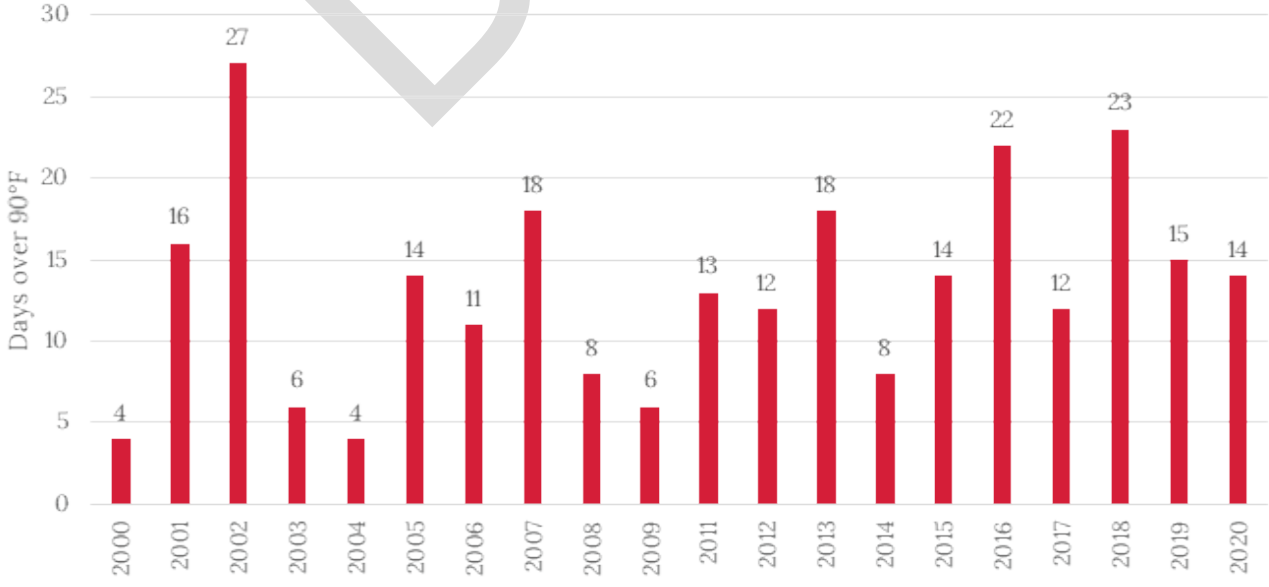


Figure 4-23. Days over 90°F per Year

century, with a continual increase in the average temperature due to climate change, Massachusetts's climate would eventually more closely resemble that of Maryland or the Carolinas (refer to Figure 4-24 below).

4.8.2.7 Vulnerability and Risks

Because most heat-related deaths occur during the summer, people should be aware of who is at greatest risk and what actions can be taken to prevent a heat-related illness or death.

Homeless community members are increasingly vulnerable to extreme heat. The capacity of temporary housing is typically limited, and this can leave homeless individuals more exposed during extreme heat events. In Boston, children under five years old make up 5% of the population, and 11.5% are over 65 years old (ACS, 2014-2018). However, even young and healthy individuals can succumb to heat if they participate in strenuous physical activities during hot weather. Some behaviors also put people at greater risk, including drinking alcohol, taking part in strenuous outdoor physical activities in hot weather, and taking medications that impair the body's ability to regulate its temperature or that inhibit perspiration (MEMA and DCR, 2013).

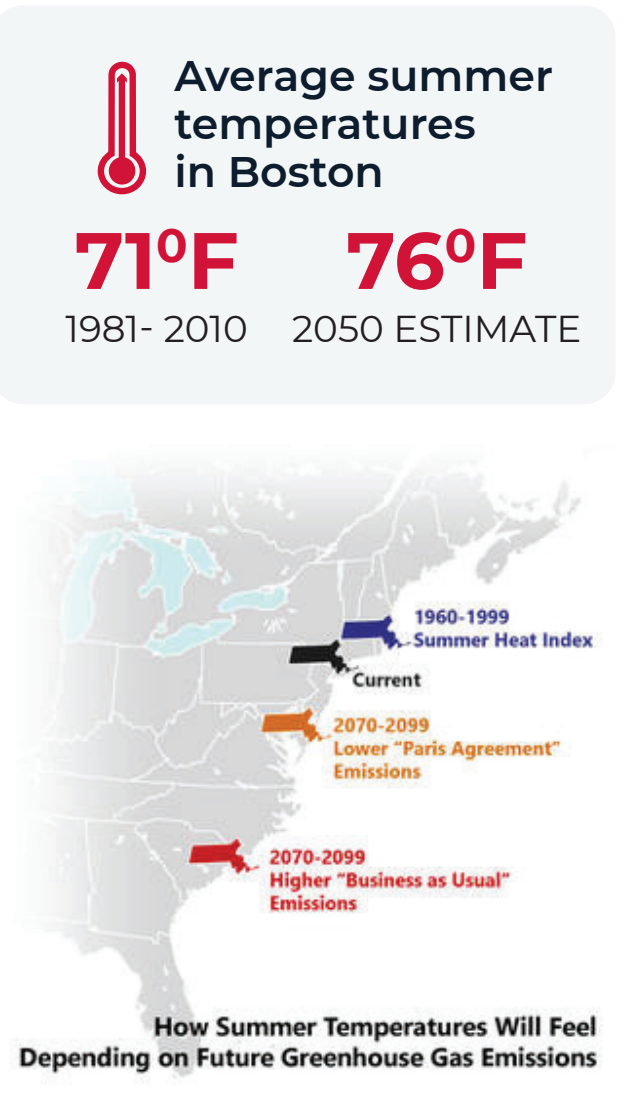


Figure 4-24. Massachusetts Extreme Heat Scenarios (Frumhoff et al., 2007)

The Massachusetts Department of Public Health Bureau of Environmental Health provides a community profile related to public health metrics (MA DPH, 2021). Boston's largest concern during heat waves is likely to be older adults (over 65) that make up 11.5% of the population and are more likely to have pre-existing health conditions. Impacts from heat stress can exacerbate pre-existing respiratory and cardiovascular conditions.

Heat can impact infrastructure in the City as well and residents. Extremely hot days can affect the subway and commuter rail lines, causing cars to overheat and the rail lines to expand and buckle. Extreme heat can also impact utilities. The probability of large-scale power outages is increased during extended heat events. Power outages can displace large numbers of residents who lose access to air conditioning.

Increased extreme heat events can also pose an environmental threat. These changes in temperature would have a detrimental impact on air quality and public health concerns, including asthma and other respiratory conditions (Frumhoff et al., 2007). Increased temperatures can lead to a longer growing season, which in turn leads to a longer pollen season. Warmer weather can also support the migration of invasive species and lead to an increase in vector-borne diseases. Increasing temperatures can also worsen air pollution, which can lead to negative health impacts such as respiratory problems.

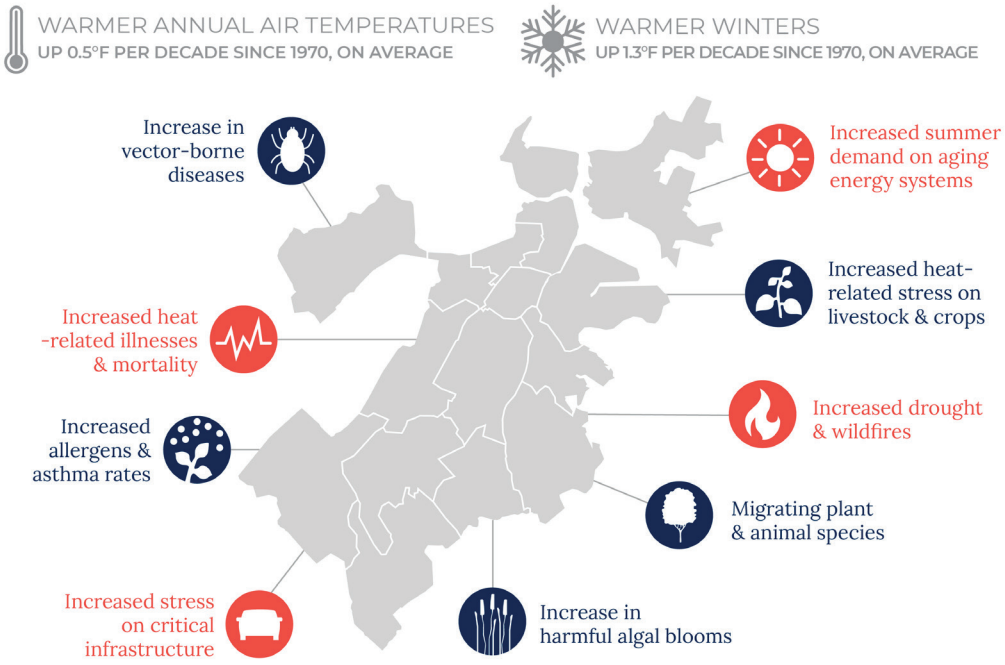
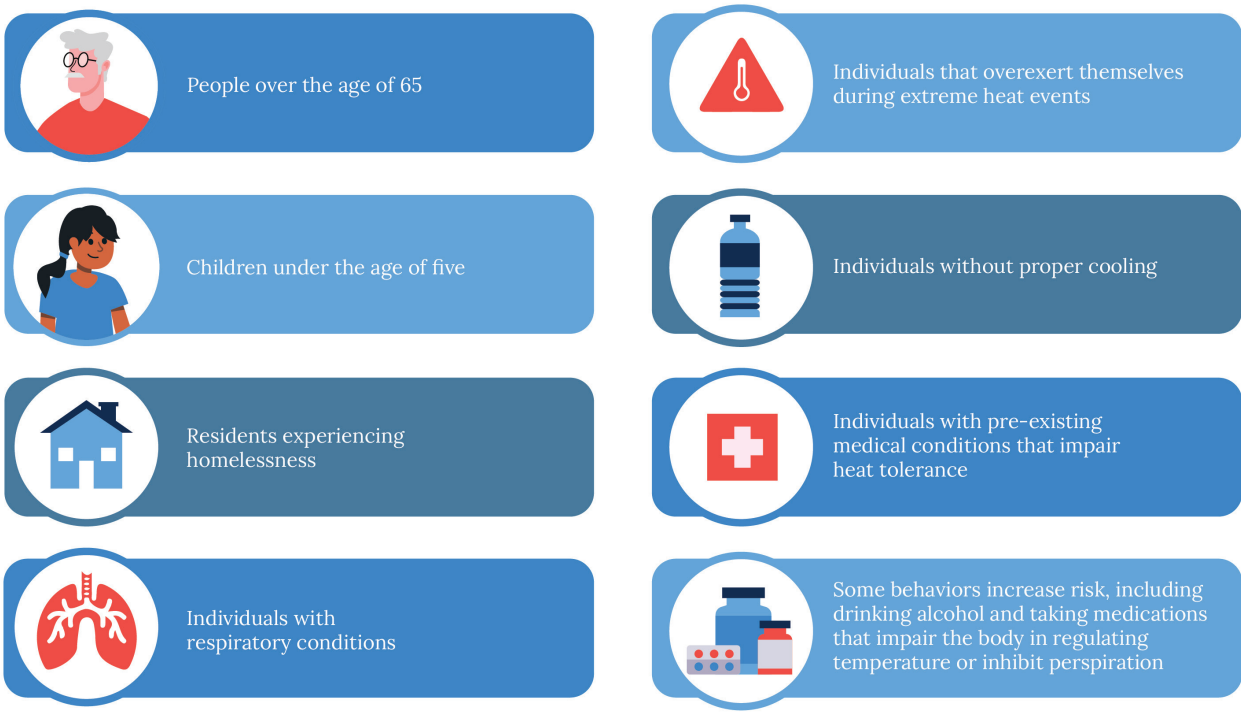


Figure 4-25. Impacts of Rising Temperatures in Boston

According to the Centers for Disease Control and Prevention, the populations most vulnerable to extreme heat impacts include the following:



4.9 Drought

4.9.1 Description

Drought is an extended period of deficient precipitation and occurs in virtually all climatic zones. In Boston, the annual average rainfall from 1981-2010 was 43.77 inches equating to about 10- or 11-inches each season or 3- to 4- inches every month, as shown in Table 4-17 (NOAA, 2010). Massachusetts' annual precipitation typically ranges from 30 to 61 inches in the driest and wettest years, respectively (EEA and MEMA, 2019).

Two types of droughts are likely to occur in Boston: flash droughts and prolonged droughts. A flash drought is a rapidly occurring or intensifying drought. They can happen because of low rates of precipitation, often accompanied by high temperatures, winds, and radiation. These conditions together can intensify the climate in an area (NOAA, 2020f). A prolonged drought has a slower evolution and is caused by a long period of dry weather caused by a lack of precipitation. These two types of droughts are not differentiated within this section because location is not variable, and historic occurrences are not differentiated. The primary difference between the two drought types is the severity, which is determined on a month-by-month basis.

Table 4-17. Average Rainfall per Season 1981-2010

SEASON	AVERAGE PRECIPITATION (IN)
Annual	43.77
Winter	10.39
Summer	10.46
Spring	11.55
Autumn	11.37

(NOAA, 2010)

4.9.2 Severity

According to the Massachusetts Drought Management Plan (EEA and MEMA, 2019), the Drought Management Task Force provides recommendations to the Secretary of Energy & Environmental Affairs about the location and severity of drought in the Commonwealth. The Drought Management Task Force uses six indices to determine the severity of a drought: precipitation, groundwater, streamflow, lakes and impoundments, evapotranspiration (crop moisture), and fire danger. Drought conditions are categorized into are five levels: a normal condition and four drought severity levels. The end of a drought is determined by precipitation and groundwater levels, since these have the greatest long-term impact on streamflow, water supply, reservoir levels, and soil moisture (EEA and MEMA, 2019). Table 4-18 below provides more information on drought levels and varying degrees of action.

Table 4-18. Drought Levels

#	LEVEL	FREQUENCY	AKA	CONDITIONS	ACTION
0	Normal		-		No action required
1	Mild Drought	>20 and ≤30%	Advisory	Precautionary assumption that conditions may deteriorate further	Increased assessment, proactive education, communication, and planning
2	Significant Drought	>10 and ≤20%	Watch	Conditions are becoming significantly dry	Water restrictions might be appropriate depending on the capacity of each individual water supply system.
3	Critical Drought	>2 and ≤10%	Warning	Many sectors, community functions, and environmental resources are facing critical strain	Many water suppliers may be relying on mandatory conservation measures and preparation for emergency conditions begins
4	Emergency Drought	≤2%	-	State may face failure of local or regional drinking water supplies, impairment or loss of supply for firefighting, major agricultural and business losses, and impairment or loss of critical natural resources	The Governor may exercise authority to require mandatory water restrictions

(EEA and MEMA, 2019)

4.9.4 Location

Drought levels can be declared on a regional, county, or watershed-specific basis. The Drought Management Plan (EEA and MEMA, 2019) divides the state into seven regions: Western, Central, Connecticut River Valley, Northeast, Southeast, Cape, and Islands. Boston is located within the Northeast region. Drought levels would likely be consistently declared across the City unless a watershed-specific event declaration was made. For example, in 2020, the Charles River watershed was in a Level 3 – Critical Drought, while the rest of the Northeast Region was in a Level 2 – Significant Drought.

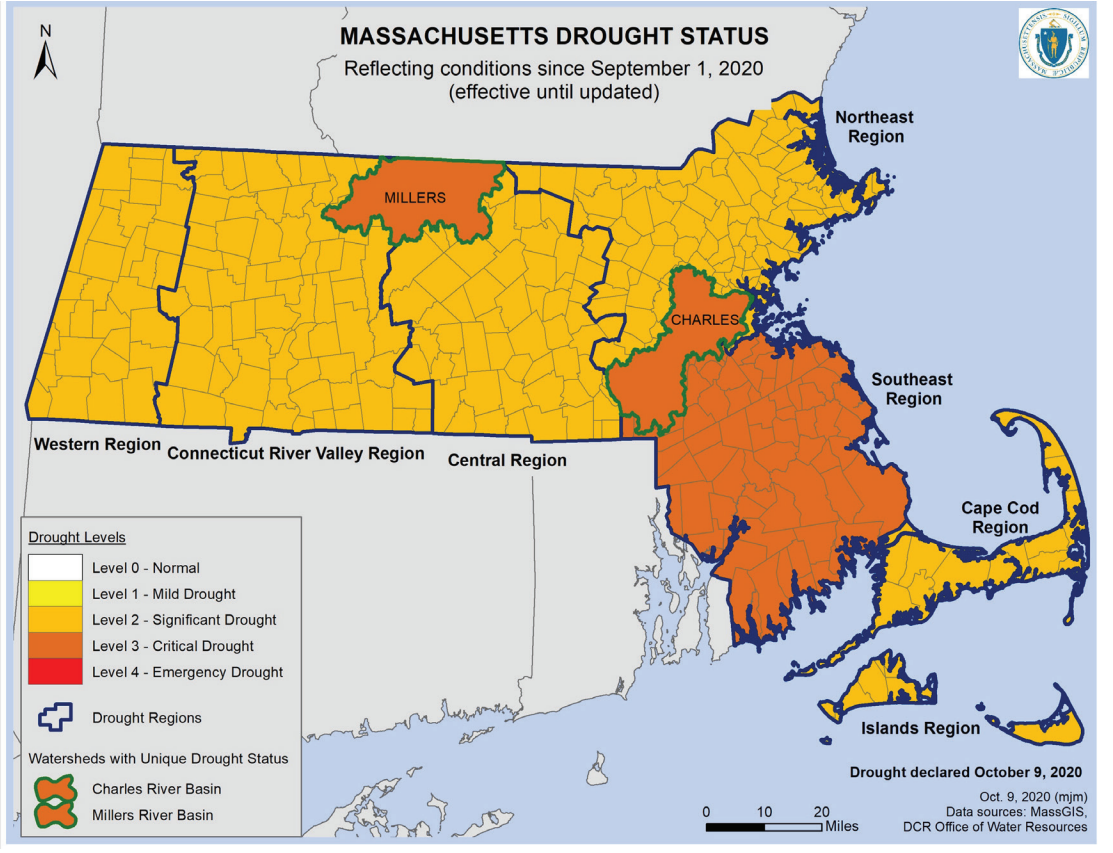


Figure 4-26. Massachusetts Drought Status, September 2020 (DCR, 2020)

4.9.5 Historic Occurrences

The historical data available for the severity and geographic extent of droughts is not comprehensive, although some data is provided in the Drought Management Plan for the following historical drought occurrences across the state:

- 1879-1883
- 1908-1912
- 1929-1932
- 1939-1944
- 1957-1959
- 1961-1969
- 1980-1983
- 1995
- 1998-1999

The nine-year drought from 1961-1969 is widely considered the most severe drought of record in Massachusetts. The length and severity of this drought forced public water suppliers to implement water-use restrictions, and numerous communities utilized emergency water supplies (EEA and MEMA, 2019). More accurate records have been kept since the development the first Massachusetts Drought Management Plan in 2000 that was developed in response to a period of deficient precipitation that began in 1999. The Northeast Region designated by the Drought Management Plan experienced six drought periods from 2000 to 2020 (EEA, 2021), as seen in the Figure 4-27 and Table 4-19.

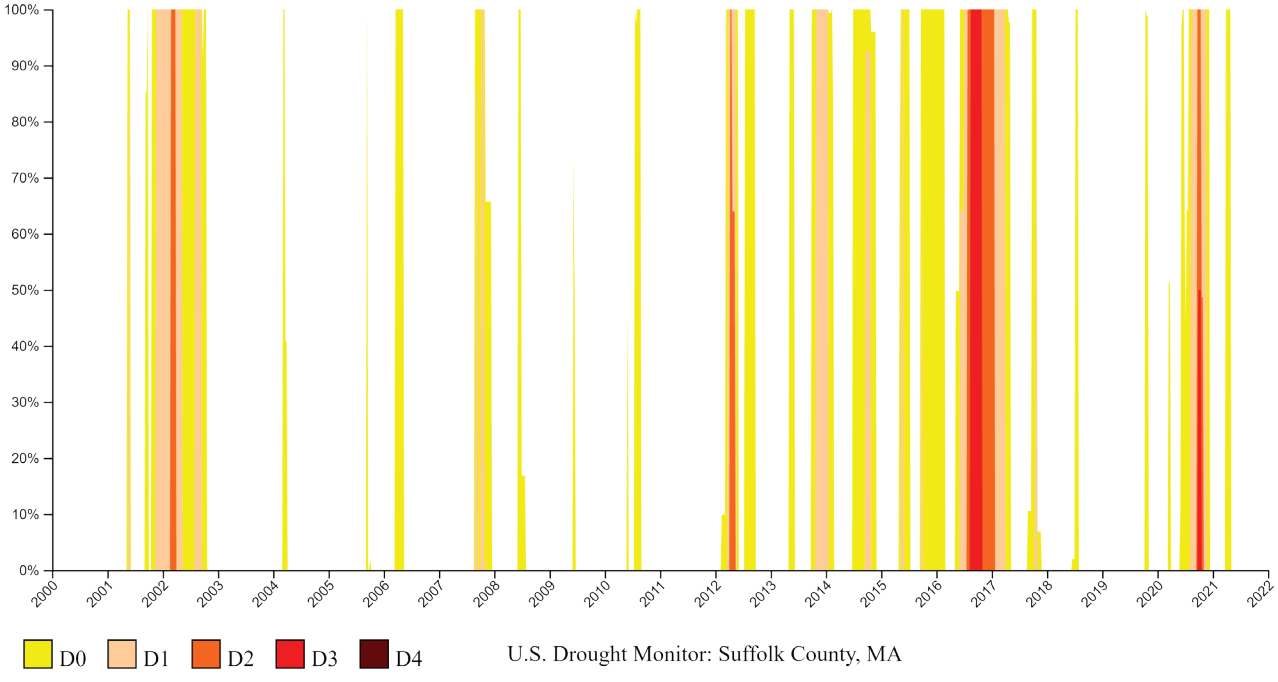


Figure 4-27. Historic Drought Occurrences in Suffolk County (NOAA, 2021a)

Table 4-19. Northeast Region Drought Occurrences 2000-2020

DEC 2001-JAN 2003	ADVISORY/WATCH
10/2007-3/2008	Advisory
8/2010-11/2010	Advisory
10/2014-11/2014	Advisory
7/2016-4/2017	Advisory/Watch/Warning
5/2020-12/2020	Mild (Advisory)/Significant (Watch)/Critical (Warning)

(EEA, 2021)

4.9.6 Climate Change

Drought conditions are expected to be exacerbated by climate change due to projected increasing air temperatures and changes in precipitation. Between 1970 and 2000, the median number of consecutive dry fall days in Massachusetts was 11.4 days. This is in comparison to a projected median of 13.5 consecutive days by the end of the century (EEA and EOPSS, 2018). The same report also mentions that the occurrence of droughts lasting 1 to 3 months could go up by as much as 75% over existing conditions by the end of the century, under the high emissions scenario in the Northeastern States.

4.9.7 Vulnerability and Risk

Urban agriculture, water supply, aquatic ecosystems, wildlife, and the economy are vulnerable to the impacts of drought (EEA and EOPSS, 2018). The City of Boston receives its drinking water from Massachusetts Water Resources Authority. Massachusetts Water Resources Authority (MWRA) has the potential to supply water to 53 communities throughout Massachusetts, sourced from the Quabbin and Wachusett Reservoirs. The reservoirs have a combined capacity of 477 billion gallons. The Quabbin/Wachusett system is so large that it can withstand short-term and medium-term dry periods and droughts without much of an impact on the operating levels. During a drought, voluntary restrictions begin in the drought warning stage and mandatory restrictions in the Drought Emergency stages (MWRA, 2021). A long-term drought could impact Boston's wetlands, rivers, and streams, and the Massachusetts Water Resources Authority drinking water reservoirs. Commercial, municipal, and residential water conservation is important during times of drought or low water levels.

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 with water supply low, this can increase the risk of and damage from brush fires.

FIVE: EXISTING MITIGATION MEASURES

5.1 Introduction

The City of Boston is already implementing measures to mitigate local hazards in day to day operations, planning, and enforcement of regulations. Chapter 5 documents the City's current operational capacity and discusses potential improvements. These existing mitigation measures are presented by hazard type. Several existing mitigation measures have become ongoing operational procedures since identified as action items in the previous plan. This is further described in Chapter 6. Most notably, the results of the 2014 Natural Hazard Mitigation Plan (NHMP) were integrated into planning processes like those related to Climate Ready Boston, plans to treat catch basins with mosquito larvacides, outreach and notifications, and grant applications.

5.2 Summary of Citywide Existing Mitigation Measures

There are numerous existing natural hazard mitigation measures already in place in Boston. The following list also includes actions related to climate mitigation, preparedness, and adaptation as ongoing priority in the City. The mitigation measures below are likely to evolve and change over time as leadership priorities, staff expertise, and community involved inform future operations. The current listing was identified through feedback from the Executive Steering Committee, Local Hazard Mitigation Team, additional stakeholders' interviews, research, and a crosswalk of existing plans, projects, and initiatives.

Multi-Hazard Mitigation Measures

MULTI-HAZARD MITIGATION MEASURE	IMPROVEMENTS
Alert Boston: Emergency Notification System The AlertBoston system is for residents, businesses, and visitors to the City of Boston. The City notifies subscribers by phone, text, or email in the event of an emergency.	Make system and operational updates to AlertBoston to promote access and equitable user-experience. Emergency messages could be translated into more languages and available through wifi-based messaging services, such as Whatsapp.
Evacuation Routes OEM recently developed new emergency evacuation routes that will be reviewed, approved, and widely disseminated.	Increase outreach on evacuation routes once finalized.

MULTI-HAZARD MITIGATION MEASURE	IMPROVEMENTS
Emergency Shelters for Natural Hazard Protection Office of Emergency Management (OEM) has designated emergency shelters in each neighborhood of Boston. The City of Boston is vulnerable to many hazards. These include floods, nor'easters, extreme temperatures, hurricanes, and more. During these incidents, residents may need to evacuate their homes and go to a neighborhood emergency shelter.	Adapt shelters to be more resilient to climate change impacts; ensure all shelters have backup power supply (generators, transfer switches, or microgirds) and central air conditioning so that they can operate as a cooling center.
Emergency Operations Plan (EOP) OEM annually reviews the EOP and makes major updates every five years. The EOP is put into practice every time there is an emergency operations center activation. This requires continued coordination with other departments. The EOP has an hazard specific annexes.	Continue to update the EOP as needed.
Conduct Multi-Cultural and Multi-Lingual Climate Hazard Mitigation Outreach Extensive outreach has been conducted for Boston's Hazard Mitigation Plan, Climate Ready Boston Neighborhood Plans, and the Boston Climate Action Plan.	Continue to innovate new strategies to engage a diverse range of community members.
OEM's Preparedness Workshops and Outreach Working in close partnership with Boston's public safety and public health agencies, OEM plans and prepares for emergencies, educates the public about emergency preparedness, conducts training exercises and drills, and performs other services to support the City's overall preparedness. OEM follows an all-hazards approach, preparing for various types of emergencies.	Continue to tailor preparedness workshops based on available information about best practices.
Backup Energy for Critical Facilities Many critical facilities have backup generators. The BWSC has backup power for all facilities or transfer switches to connect to portable generators. OEM recently conducted a study on emergency shelters and energy needs. PWD has backup power at the main operations center.	Complete a comprehensive inventory of energy redundancy.

MULTI-HAZARD MITIGATION MEASURE	IMPROVEMENTS
Boston Medical Reserve Corps (BMRC) The BMRC is a community-based volunteer program that prepares for and may respond to emergencies to support the Office of Public Health Preparedness.	None at this time.
Community Clean Air Grant The Air Pollution Control Commission (APCC) administers programs that promote clean air. This grant program will fund and bring visibility to community-driven projects that reduce air pollution and carbon emissions. The projects will help achieve Boston's goal of carbon neutrality by 2050 and bring more immediate health benefits.	Conduct outreach to enhance awareness of funding availability. Assess success of projects post-implementation.
Greenovate Greenovate works with the broader community to implement the City's Climate Action Plan, which is a roadmap to reduce greenhouse gas emissions 25% by 2020 and to become carbon neutral by 2050.	Expand Greenovate to include Climate Leaders Program that focuses on outreach to socially vulnerable populations.
Zero Waste Boston Zero Waste Boston is an initiative to transform Boston into a zero waste city through planning, policy, and community engagement. Zero waste is a transition towards material use reduction, repair, and reuse. Mayor Walsh has commissioned a technical study of Boston's waste management as part of the City's zero waste planning process. The process will inform Carbon Free Boston, and its results will contribute to the City's next update of its Climate Action Plan (CAP).	Integrate findings of technical study into next CAP update.
Carbon Free Boston Carbon Free Boston is an initiative to prepare the City to go carbon neutral by 2050. The first step within the initiative, the Carbon Free Boston report, will analyze the costs and benefits of policies and technologies that could enable Boston to reach this goal. The City's goal is to reduce greenhouse gas emissions, and our analysis will help inform the City's next update of its Climate Action Plan.	None at this time.

MULTI-HAZARD MITIGATION MEASURE	IMPROVEMENTS
Building Energy Retrofit Resource Hub Boston is providing an Eversource consultant available through the Environment Department for free to assist property owners in evaluating options for energy efficiency retrofits to help save money and energy and reduce carbon emissions.	Examine potential funding mechanisms to support owners with energy retrofits.
Carbon Neutrality Executive Order New municipal building construction will have to be low-energy and fossil fuel-free, while meeting its annual energy needs from a mix of on- and off-site renewable energy assets.	Document progress and track data regarding energy reductions.
Massachusetts State Building Code and Inspection and Outreach The Massachusetts State Building Code contains many detailed regulations regarding wind loads, earthquake resistant design, flood-proofing, and snow loads. The Inspectional Services Department (ISD) enforces the State Building Code through providing permits and writing violations for buildings that are not in compliance. ISD also completes outreach to property owners on steps they can take to improve their building, for example, providing tips on how to identify signs of degradation from the freeze thaw cycle in masonry buildings. ISD notifies construction site managers and property owners of precautions to take prior to a storm. ISD has developed a streamlined process for approving flood barriers, tracking the installations, and notifying property owners when barriers should be deployed. ISD can also cordon off areas that are deemed unsafe for various reasons or ask property owners to remove icicles. Lastly, ISD regularly works with utility providers to turn these services on and off for safety reasons (like turning off the electricity if a building is flooded).	Advocate for the Massachusetts State Building Code to allow greater flexibility for greater climate adaptation standards. Continue to centralize data tracking and notification systems for climate adaptation measures in buildings.
City Facility Energy Upgrades In 2021, the City made an $11 million investment in energy efficiency and renewable energy upgrades to fourteen city facilities.	None at this time.

MULTI-HAZARD MITIGATION MEASURE	IMPROVEMENTS
2019 Climate Action Plan (CAP) The 2019 CAP update includes 18 strategies to increase carbon reductions from buildings and transportation over five years (2024). Each action includes equity provisions.	Continue to update CAP as needed and document progress on 18 strategies.
Article 37 Green Building and Climate Resiliency Guidelines Article 37 establishes the Interagency Green Building Committee (IGBC) to advise the Boston Planning and Development Agency (BPDA) and the Inspectional Services Department (ISD) on project compliance with the City's green building and climate resiliency policies and requirements.	Adopt uniform standards for Article 37 review to streamline and standardize process.
Smart Utilities Policy The Boston Smart Utilities (BSU) Program is aimed toward developing strategies for more efficient, equitable, sustainable, resilient, and innovative utility services in the City of Boston. In order to achieve integrated utility planning and design, Boston has developed a process to review utility systems and infrastructure as part of the Article 80 Development Review process. The process includes submitting and updating a Smart Utilities Checklist and a Utility Site Plan (USP) at different stages of development review.	None at this time.
Carbon Neutrality Manager Boston's Carbon Neutrality Manager oversees Boston's carbon neutrality programs and ordinances to ensure their proper administration, including outreach, compliance, and monitoring.	Expand team as needed.
Monitor Outbreak of Invasive Species and Eradicate Asian Longhorned Beetle USDA Animal and Plant Health Inspection Service (APHIS) implemented a plan for combatting ALB in MA, including quarantining acreage of trees infested with ALB.	None at this time.

MULTI-HAZARD MITIGATION MEASURE	IMPROVEMENTS
Community Choice Electricity Community Choice Electricity (CCE) is a municipal program that allows the City of Boston to buy electricity on behalf of Boston's residents and businesses. By using the City's collective buying power, the City is able to provide affordable and renewable electricity to the program's customers. CCE ensures that energy decisions are made locally and reflect the values of Boston's communities.	None at this time.
Survey of Existing City Assets for Climate Change Climate Ready Boston report issued a survey assessing city assets.	Update survey of assets with best available data as needed.
MBTA the RIDE The RIDE paratransit service provides door-to-door, shared-ride transportation to eligible people who cannot use the subway, bus, or trolley all or some of the time due to temporary or permanent disability. The RIDE is an important service especially during extreme temperatures and precipitation events.	Evaluate public health protocols in light of the COVID-19 or other pandemics.
Boston Resilient Historic Buildings Design Guidelines The Boston Resilient Historic Buildings Design Guide provides recommendations for historic property owners to aid them in preparing their property for climate change impacts.	Integrate resiliency into preservation regulatory language for all Historic Districts.
Metro Mayors Climate Preparedness Taskforce MAPC convenes the Metro Mayors Climate Preparedness Taskforce to review current activities and policies and provide guidance for future development.	None at this time.

MULTI-HAZARD MITIGATION MEASURE	IMPROVEMENTS
Boston Age Strong Shuttle The Age Strong Shuttle provides Boston residents age 60 and older with free transportation within the City of Boston to non-emergency medical appointments, with advance notice. The shuttle is an important service especially during extreme temperatures and precipitation events.	Evaluate public health protocols in light of the COVID-19 and other pandemics.
Tree Planting Program to Mitigate Extreme Heat and Stormwater Impacts Residents can request a tree planting and specific tree species on public land through Parks and Recreation or 311. The area must meet certain requirements to ensure proper maintenance and tree health. Through the historic investments in Boston's public spaces, $500,000 was budgeted for the Urban Forest Plan, hiring of a new arborist, and the planting of an additional 1,000 trees, doubling the yearly total to 2,000 trees planted per year (2021).	Conduct outreach and create partnerships with community organizations.
Boston Urban Forest Master Plan The Boston Urban Forest Masterplan is a planning effort to support, maintain, and enhance the urban forest in Boston to increase canopy cover. The urban forest contributes to stormwater management, the reduction of urban heat islands, and human comfort. The plan prioritizes implementation of strategies in environmental justice neighborhoods.	Consultants Hired. Complete planning process (2021).
Climate Ready Boston Plans The City launched Climate Ready Boston to help Boston plan for the impacts of climate change and build a resilient future. The City is developing plans for each neighborhood that have strategies for preparing for climate change. Climate Ready Downtown and North End, East Boston, Charlestown, South Boston, and Dorchester have been completed.	Implement CRB recommendations.

MULTI-HAZARD MITIGATION MEASURE	IMPROVEMENTS
Building Energy Reporting and Disclosure Ordinance (BERDO) The Building Energy Reporting and Disclosure Ordinance (BERDO) makes building owners, tenants, and other stakeholders more aware of their energy usage and greenhouse gas emissions and opportunities to reduce both. It also requires the City to make this data public. Buildings covered must also show concerted efforts to reduce their emissions every five years through energy actions or audits. This helps Bostonians save money and the City achieve its emissions reduction goals, as laid out in its Climate Action Plan.	Expand energy requirements to smaller developments, incorporating feasible standards for energy savings.
Mutual Aid Agreements PWD has mutual aid agreements with surrounding communities.	None at this time.
Financial Resilience Individual departments regularly develop capital improvement plans. Grants are another major source of capital funding. The The City and the BWSC have a AAA rating.	None at this time.
Departmental Plans and Protocols Many departments have individual plans and protocols in place to prepare and respond to specific hazards. For example, the Fire Department has a Fire Marine Unit that is relocated in preparation of a hurricane. BWSC also has a protocol and checklist for individual hazard preparedness process. OEM also has pre-storm preparations (e.g. sandbags, inspections of key vulnerable sites).	None at this time.
Harbor Spill Response MassDEP has 6-8 Emergency Oil Boom Trailers to mitigate hazardous spills in Boston Harbor. BPD Truck Team, BPD HAZMAT Unit, and BPD Harbor Patrol Unit can transport Oil Boom Trailers to site of disaster.	None at this time.

MULTI-HAZARD MITIGATION MEASURE	IMPROVEMENTS
Backup Water Supply and Water System Resiliency MWRA has 5 years of available supply in storage. Both the MWRA and BWSC completed multi-hazard Risk and Resilience Assessments and Emergency Response Plans in 2020.	None at this time.
Pursue Inclusive Hiring and Living Wages for Resilience Projects Living wages promote economic empowerment, wellbeing, and the ability to recover from adverse events. The City support employees through this practice.	None at this time.
Prioritize Use of Minority- and Women-Owned Businesses for Resilience Projects Prioritization of MWBE hiring ensures that more diverse voices are included in project development and helps MWBEs achieve ongoing economic success. In 2019, an Executive Order established the Equitable Procurement Procedures. This was followed by an Executive Order in 2021 calling for establishing contracting goals, tracking metrics, and instituting a Supplier Diversity Program.	None at this time.
Housing Authority Projects All BHA capital projects aim to incorporate resiliency. For example, when buildings undergo roof reconstruction projects the insulation is replaced with material with a higher insulating value to reduce heat loss. New heating equipment is replaced with efficiency boilers to reduce fossil fuel consumption. In 2021, two large conversion projects are in progress (Doris Bunte and St. Botolph), which will include energy saving measures and stormwater improvements. Other improvements regularly involve energy efficient heating, ventilating and air conditioning upgrades, envelope improvements, low flow toilets, and aerators to reduce water consumption.	None at this time.

Flood-Related Hazard Mitigation Measures

Boston has completed substantial planning efforts, initiatives, and projects to address projected future risks from sea level rise/storm surge and stormwater flooding. Given the coastal geography of Boston, flood-related hazard mitigation measures are an imperative component of policies, plans, and regulations for protecting residents.

FLOOD-RELATED MITIGATION MEASURE	IMPROVEMENTS
Participation in the NFIP Boston participates in the National Flood Insurance Program (NFIP). The NFIP is a Federal program administered by FEMA enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for State and community floodplain management regulations that reduce future flood damages. The City complies with the NFIP by enforcing floodplain regulations and maintaining up-to-date floodplain maps. The FEMA Flood Insurance Rate Maps (FIRMs) were last updated in 2016. NFIP uses a Community Rating System (CRS) to award communities that go beyond the minimum standards with lower flood insurance premiums for property owners. The incentives are awarded upon a credit system for various activities. Points are awarded to communities that prepare, adopt, implement, and update a comprehensive flood hazard mitigation plan using a standard planning process. Boston is not currently eligible to participate in the CRS Program (as of May 2021).	Update Floodplain Overlay District language per the state's requirements to remain in compliance with NFIP standards and update FEMA flood maps. Take necessary steps to enroll in the Community Rating System.
Boston Coastal Flood Resilience Design Guidelines The Coastal Flood Resilience Design Guidelines document is a resource to help Boston property owners and developers make informed, forward-looking decisions about flood protection for existing buildings and new construction.	None at this time.

FLOOD-RELATED MITIGATION MEASURE	IMPROVEMENTS
Regulations to Support Flood Mitigation, Resilience, and Adaptation The City of Boston is dedicated to integrating flood mitigation measures into ordinances that regulate future development, building standards, and protect open space. The following regulations are currently active. • Coastal Flood Resilience Zoning Overlay: The BPDA has implemented a new Coastal Flood Resilience Overlay District (CFROD), Article 25A, and related updates to existing zoning articles. The CFROD and zoning map relates to areas of the City of Boston anticipated to be flooded with a 1% chance storm event in 2070 with 40-inches of sea level rise. CRROD formalizes the implementation of the Coastal Resiliency Guidelines and establish sea level rise design flood elevations for new construction and retrofits. • Article 25 – Flood Hazards District: The purpose of this article is to promote the health and safety of the occupants of land against the hazards of flooding, to preserve and protect the streams and other water courses in the city and their adjoining lands, to protect the community against detrimental use and development, and to minimize flood losses. • Article 80: The Article 80 review process may include, but is not limited to, review of a project's impacts on transportation, public realm, the environment, and historic resources.	Make updates to regulations to continue to incorporate climate change and best practices.
MBTA Climate Vulnerability Assessments and Adaptations The following assessments and projects are currently underway or completed (2021): Orange Line Vulnerability Assessment (in progress); Blue Line Vulnerability Assessment (complete); Red Line Vulnerability Assessment (in progress); System Assessment (in progress); System-wide Assessment (in progress); Blue Line Station flood protective barrier installation (completed).	Ongoing.

FLOOD-RELATED MITIGATION MEASURE	IMPROVEMENTS
Operation and Maintenance The Public Works and BWSC both regularly conduct operation and maintenance procedures that reduce flooding. For example, PWD has a regular street sweeping schedule that reduces stormwater flooding due to clogged drainage infrastructure. BWSC also completes catch basin cleaning and other maintenance needs on the stormwater system. Seawalls, tide gates, and other flood mitigation structures are inspected on a regular basis. Many departments digitally track operation and maintenance.	None at this time.
Water Quality Improvements BWSC implements continual programmatic steps to improve water quality during large storm events, including the removal of infiltration and inflow sources, maintaining and enforcing the Erosion and Sediment Control Plan, conducting public information campaigns, and removing Combined- Sewer Overflows (CSOs).	None at this time.
Ordinance Protecting Local Wetlands and Promoting Climate Change Adaptation in the City The ordinance regulates wetland resource areas beyond those covered by the WPA, including new Coastal and Inland Flood Resilience Zones, a potential 200-foot Extended Riverfront Area, a 25-foot Waterfront Area within certain Buffer Zones, and a broader definition of "Vernal Pool" and incorporates flood projections to enhance climate resilience measures.	The next phase of work is to map new resources and adopt performance standards.
DCR Dam Safety Regulations and Inspections All jurisdictional dams are subject to the Division of Conservation and Recreation's dam safety regulations (302 CMR 10.00). The dams must be inspected regularly, and reports filed with the DCR Office of Dam Safety.	None at this time.

Winter Storm-Related Hazard Mitigation Measures

Winter storms and extreme cold weather present the greatest threat to Boston's economically vulnerable residents and those with insecure housing. Boston has a variety of programs through OEM, the State, and the Environment Department that seek to house individuals during low temperatures, repair or retrofit homes to promote energy savings, and provide financial support for heating bills. Given the climate of Boston, emergency response programs such as these are a key component of winter-related hazard mitigation measures.

WIND-RELATED MITIGATION MEASURE	IMPROVEMENTS
Street Outreach Team The Street Outreach Team travels around the city by van to ensure that individuals experiencing homelessness and other vulnerable residents are not exposed to extreme temperatures and inclement weather. They take those who need shelter or are having a medical emergency to an emergency shelter or medical facility.	None at this time.
Low Income Home Energy Assistance Program Known commonly as Fuel Assistance, the Low-Income Home Energy Assistance Program (LIHEAP) provides eligible households with help in paying a portion of winter heating bills.	None at this time.
Emergency Home Repairs Income eligible homeowners and residents over age 60 can receive assistance with winter emergencies and repairs, such as fixing storm damage, leaking roofs, furnaces and leaking/frozen pipes. Grants are awarded up to $5,000.	None at this time.
Mayor's Senior Save Program The Mayor's Seniors Save program helps income eligible Bostonians over the age of 60 replace old, inefficient heating systems with a new heating system.	None at this time.

MEASURE	IMPROVEMENTS
Winter Weather Preparation and Response Prior to winter weather events, PWD pre-treats streets when ice is anticipated. PWD has a snowplowing strategy in place, which includes coordinating with other City agencies on locations where piling snow is acceptable. PWD also utilizes GPS software to track snow removal and relay information. Parking bans and sidewalk clearing requirements are also in effect.	Identify more locations to pile snow.

Brushfire Hazard Mitigation Measures

The risk of brushfire in Boston is not as prevalent as the Western United States due to Boston's wet climate, density of development, and proximity to waterbodies. However, there are still inherent fire risks that come from human everyday activities, construction types, hazardous materials, and land management practices. The Boston Fire Department has hazard mitigation measures in place to reduce the risk of brushfires from spreading.

BRUSHFIRE MITIGATION MEASURE	IMPROVEMENTS
Fire Prevention The Fire Prevention Division, under the Boston Fire Department, issues permits, completes inspections, conducts outreach, issues licenses, registrations, and certificates and completes inspection requests. This includes smoke and carbon monoxide detector compliance for the sale or transfer of residential property, environmental property searches, and obtaining fire reports.	Expand education and outreach programs.

Heat-Related Hazard Mitigation Measures

Boston employs a number of emergency response practices, studies, and initiatives to help minimize the negative impact of extreme heat on the public health and wellbeing of Bostonians, including a current Boston Heat Resilience Study, which will result in a suite of future actions to mitigate the impacts of extreme heat on Boston's most vulnerable communities. Existing citywide heat-related mitigation measures include the following.

HEAT-RELATED MITIGATION MEASURE	IMPROVEMENTS
Boston Emergency Heat Action Plan Boston's Heat Emergency Action Plan outlines the City's response to heat waves and extreme temperatures that threaten the public health and safety of Boston residents. The Plan details emergency communication strategies, cooling center system, and outreach and response to residents experiencing homelessness.	Consultants have been hired to update plan.
Boston Heat Resilience Study The study includes a heat vulnerability assessment and focuses on areas where heat islands overlap with historically underserved communities. The study will provide creative and community-driven solutions to reduce urban heat island impacts, enhance public awareness of heat health risks, and increase human comfort.	Consultants hired. Ongoing (2021).
Natural Hazard Preparation Guides OEM publishes a 'Prepare for Heat Guide' that provides information about how to cool down during a heat wave, the location of cooling centers, parks, and water-features, emergency information, contacts, and shelter information, in addition to tips about how to prepare or respond to extreme heat. Public Works also produces a 'Winter Weather Guide.'	Update when new resources become available.
Boston Center for Youth and Families (BCYF) Cooling Centers Many BCYF locations are cooling centers, which decreases the likelihood of heat stress.	Ensure that Cooling Centers are equipped with back-up generators or other forms of emergency power.

HEAT-RELATED MITIGATION MEASURE	IMPROVEMENTS
BWSC Water Truck Water distribution is BWSC's main responsibility to the residents of Boston. The Water Truck is an interactive way for residents and visitors to enjoy Boston's award-winning tap water. The truck features six taps, four water bubblers, and two doggy bowls and can hold 725 gallons of water. The insulated truck keeps water cool and can be refilled at any drinkable water station.	None at this time.
Prevent Outbreaks of West Nile Virus and Eastern Equine Encephalitis Every summer the Suffolk County Mosquito Control Commission hires temporary workers to drop larvicide in catch basins throughout the city.	None at this time.

Pandemic-Related Hazard Mitigation Measures

Given the 2020-2021 COVID-19 pandemic, pandemic-related hazard mitigation measures are of particular importance for maintaining public health and life safety. The 2014 Hazard Mitigation Plan outlined the following measures, which have been adopted. In addition, many other emergency response and public health practices have been implemented to limit the spread of COVID-19 in Boston and around the globe. These adopted measures will likely be ongoing in order to progress towards herd immunity to COVID-19 and reduce the spread of other infectious disease.

PANDEMIC-RELATED MITIGATION MEASURE	IMPROVEMENTS
Health in All Policies This initiative ensures that equitable health impacts and climate change considerations are factored into City decision-making.	Expand coordination with community and health partners. Incorporate lessons learned from COVID-19 pandemic.
Public Education Boston Public Health Commission (BPHC) distributes fact sheets and hosts educational sessions on ways to reduce health risks.	Expand education and outreach programs. Incorporate lessons learned from COVID-19 pandemic.

PANDEMIC-RELATED MITIGATION MEASURE	IMPROVEMENTS
Data Surveillance BPHC completes surveillance of multiple data streams for new or emerging infectious diseases that pose a threat to public health. Information is provided to partners and the public so they can take appropriate steps to reduce spread of disease. OEM also tracks PPE practices and usage rates to inform proactive planning and ordering.	Incorporate lessons learned from COVID-19 pandemic.
Coordination with Healthcare Providers Information and clinical guidance is provided to healthcare providers. BPHC sends out health alerts. Vaccine distribution is completed on a limited basis and in partnership with healthcare contacts.	Incorporate lessons learned from COVID-19 pandemic.

above and right: 2020 pandemic response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SIX: Implementation Progress on Boston's 2014 Natural Hazard Mitigation Plan

Significant progress has been made on the 2014 Boston Natural Hazard Mitigation Plan (NHMP). Hazard mitigation is a priority, not only among emergency management and environmentally focused departments, but citywide.

The City is making a concerted effort to adapt its infrastructure, built, and natural environments, while at the same time supporting its communities in preparing for the impacts of climate change through programs that support social and economic resilience. Several resources were used to track progress on the actions identified in 2014 NHMP and to determine if any actions that were not completed are still a priority. These sources included interviewing the Executive Steering Committee (ESC) and Local Hazard Mitigation Team (LHMT), research, and outreach to other agencies.

The decision regarding whether to carry forward mitigation measures was based on the continued relevance or effectiveness of the action. Certain priority actions, while incomplete, have been addressed through other implemented mitigation measures, and are no longer needed. If the action is still a priority, the project team assessed barriers to prior implementation, in order to better understand how to facilitate completion of the measure. Table 6-1 summarizes the status of the mitigation measures.

Incomplete actions that are still a priority are also noted in Chapter 7 and include information regarding the responsible department for implementation, potential funding mechanisms to facilitate implementation, and a detailed description of the action. In many cases, incompleted actions had partially progressed and were updated to reflect this in Chapter 7. Seventeen out of fifty-three actions were completed in their entirety.

Table 6 1. Status of Mitigation Measures from the 2014 NHMP

ID	MITIGATION MEASURE	2021 STATUS UPDATE	INCLUSION IN 2021 PLAN
1	Muddy River restoration and flood control	Incomplete: Many projects have been designed and constructed to reduce flooding, but a portion of the flood control system is still under construction	Yes
2	Storrow Drive reconstruction and drainage improvements	Incomplete: There have been a few projects, including the east bound bridge replacement, but no full scale reconstruction effort has taken place	Yes
3	Replace the Charlestown underpass by replacing the tunnel with an urban boulevard and installing drainage improvements	Incomplete: The reconstruction of Rutherford Avenue has begun, but has not been fully completed	Yes
4	Dredging to address Canterbury Brook flooding in Mattapan	Completed	No
5	Morrissey Boulevard rehabilitation, including tidal flooding and drainage improvements	Incomplete: Tide gates were installed on Morrissey Boulevard and a study to improve mobility and resiliency is currently in progress (2021)	Yes: Update to reflect progress and next steps
6	Longwood Medical Area drainage improvements	Completed	No

Table 6 1. Status of Mitigation Measures from the 2014 NHMP

ID	MITIGATION MEASURE	2021 STATUS UPDATE	INCLUSION IN 2021 PLAN
7	Floodproof the basement and elevate the utilities for Engine 20 in Dorchester	Completed	No
8	Assess the vulnerability of Central Artery and Mass Pike to riverine and coastal flooding, particularly with climate change, in order to develop mitigation measures	Completed: The Central Artery/ Tunnel Vulnerability and Adaptation Assessment was completed in June 2015 and created the hydrodynamic Boston Harbor Flood Risk Model (BH-FRM) to identify risk and depth of water resulting from storm surge induced coastal flooding under current and future sea levels	Yes: Update action to address the findings of the assessment
9	Assess the vulnerability of the MBTA system to coastal and riverine flooding, heat waves, and climate change in order to develop mitigation measures	Incomplete: The MBTA has begun or completed a vulnerability assessment of several transit lines. Protective barriers have been installed at Aquarium Station.	Yes: Update action to include implementation of assessments
10	Assess vulnerability of the electrical grid, particular major distribution lines and substations, to natural hazards likely to be increased by climate change in order to develop mitigation measures	Completed	Yes: Update action to focus on implementation of assessment

Table 6 1. Status of Mitigation Measures from the 2014 NHMP

ID	MITIGATION MEASURE	2021 STATUS UPDATE	INCLUSION IN 2021 PLAN
11	Assess stormwater management drainage system in order to recommend improvements to storm drains at the Uphams Corner, McKim and Lower Mills Branch Libraries	Incomplete	No: Additional outreach will be completed to better understand this concern. The action will be added if necessary upon investigation.
12	Assess Boston Marine Industrial Park stormwater management system and implement improvements	Incomplete: BWSC is currently designing improvements	Yes
13	Construct a large drain on the easement on Lawrence Street in Roxbury	Completed: BWSC constructed a 54-inch storm drain to eliminate flooding problems	No
14	Assessment of mast arms for wind vulnerability at signalized intersections on state major arterials and roadways	Incomplete	No
15	Public education on hurricane and tornado awareness, using Red Cross Tornado app for smart phones	Incomplete	Yes: Broaden to increase outreach beyond the app
16	New street tree planting standards on spacing and soil volume to increase wind resilience	Incomplete	Yes: Combine several priorities related to tree canopy protection to streamline action list
17	Purchase Android- based mobile GPS Tablets for ISD inspectors	Incomplete	Yes

Table 6 1. Status of Mitigation Measures from the 2014 NHMP

ID	MITIGATION MEASURE	2021 STATUS UPDATE	INCLUSION IN 2021 PLAN
18	Conduct study to identify necessary retrofits in unreinforced masonry buildings to improve earthquake resilience of municipal buildings	Incomplete	Yes: Include in broader action on increasing the resilience of municipal assets
19	Utilize QuakeSmart Program materials and and USGS ShakeAlert® Earthquake Early Warning System	Incomplete	Yes: Broaden to increase outreach beyond these resources
20	Purchase Department of Homeland Security's Finding Individuals for Disaster and Emergency Response (DHS FINDER) for BFD	Incomplete	Yes
21	Increase public education on earthquakes using Red Cross Earthquake App for iPhones and Android Smart Phones and participate in annual Northeast SHAKEOUT	Incomplete	Yes: Broaden to increase outreach beyond the app
22	Moon Island seawall rehabilitation to mitigate coastal hazards	Incomplete	Yes
23	Stabilize bank or establish new bank at Columbia Point to mitigate coastal hazards	Completed: The Harborwalk/ bank between JFK Library and Harborpoint Apartments was stabilized. Erosion was occurring because it did not have the same type of revetment that the rest of Columbia Point had	No

Table 6 1. Status of Mitigation Measures from the 2014 NHMP

ID	MITIGATION MEASURE	2021 STATUS UPDATE	INCLUSION IN 2021 PLAN
24	Long term solution to stabilize bank at East Eagle Street to mitigate coastal hazards	Completed: The 300-foot section of eroding bank along East Eagle Street and the Chelsea River has been addressed	No
25	Assess feasibility of strengthening seawalls and/or adding vegetation for shoreline stabilization along Morrissey Blvd to mitigate coastal hazards	Incomplete: Climate Ready Boston - Dorchester explored solutions for Morrissey Blvd and a feasibility study and preliminary designs were completed in 2015-2016	Yes: Update action to focus on implementation
26	Stabilize coastal bank along the eastern side of Long Island, adjacent to the Public Health Commission's campus to mitigate coastal hazards	Incomplete	Yes
27	Assess Boston Harbor waterfront for additional sea and flood wall protection to mitigate coastal hazards	Completed: UMass Boston Sustainable Solutions Lab assessed feasibility of harborwide barrier systems. Climate Ready Boston and Coastal Resilient Solutions reports have evaluated flood pathways and flood protection systems	Yes: Update action to focus on implementation of assessment
28	Assess impact of tidal flooding at McCormack and Dever schools, 315 Mt. Vernon Street, Columbia Point, Dorchester to develop mitigate measures	Completed: An informal assessment of the site's vulnerabilities was completed by the insurance company	Yes: Update action to focus on implementation of assessment
29	Tree planting program to mitigate extreme heat and stormwater impacts to mitigate extreme heat	Completed: The City has an annual tree planting program. In 2020-2021 the City began drafting an Urban Forest Plan, hired an arborist, and planted additional trees	No: This will be captured in the existing capabilities and capacity section of the NHMP

Table 6 1. Status of Mitigation Measures from the 2014 NHMP

ID	MITIGATION MEASURE	2021 STATUS UPDATE	INCLUSION IN 2021 PLAN
30	Cool Roofs Program – explore incentives and install green and white roofs to mitigate extreme heat	Incomplete: Environment Department explored a pilot project, but did not implement	No: Heat resilience strategies will be updated upon the completion of the Heat Resiliency Study
31	Assess feasibility of National Fire Protection Agency FireWise Program for urban environmental education of homeowners on reducing brush and mulch fires	Incomplete	Yes
32	Enhance the BFD Fire Prevention Programs	Incomplete	Yes
33	Enhance the Boston Fire Life Safety Plan Program	Incomplete	Yes
34	Hire a LEPC Tier II Manager	Incomplete	Yes
35	Inventory equipment vulnerable to solar storm electromagnetic pulses (EMPs)	Incomplete	Yes: Amend to conduct a study on the vulnerability of the City to EMPs
36	Build Faraday Cages to store and protect redundant radio and communication equipment, laptops, and batteries	Incomplete	Yes: Amend to conduct a study on the vulnerability of the City to EMPs

Table 6 1. Status of Mitigation Measures from the 2014 NHMP

ID	MITIGATION MEASURE	2021 STATUS UPDATE	INCLUSION IN 2021 PLAN
37	Prevent outbreaks of West Nile Virus and Eastern Equine Encephalitis by treating catch basins with mosquito larvicides	Completed: This will be captured in the existing capabilities and capacity section of the NHMP	No
38	Assess the risk of water-reactive chemicals stored in flood-prone buildings to mitigate flood hazards	Incomplete: BFD does address this concern with those who store hazardous chemicals in at risk areas, to ensure the chemicals would not present a greater hazard when environmental factors are considered	Yes
39	Monitor outbreak of invasive species and eradicate Asian Longhorned Beetle treating host trees with imidacloprid	Completed: This will be captured in the existing capabilities and capacity section of the NHMP	No
40	Participate in the FEMA Flood Insurance Program Community Rating System	Incomplete	Yes
41	Update Storm Ready Certification with National Weather Service	Incomplete	Yes
42	Adopt a tree retention ordinance to preserve existing trees or equally compensate for the loss of the tree's caliper	Incomplete	Yes: Combine several priorities related to tree canopy protection to streamline action list
43	Complete community preparedness workshops and outreach through OEM	Completed	No: This will be captured in the existing capabilities and capacity section of the NHMP

Table 6 1. Status of Mitigation Measures from the 2014 NHMP

ID	MITIGATION MEASURE	2021 STATUS UPDATE	INCLUSION IN 2021 PLAN
44	Establish a multi-cultural and multi-language public awareness program on natural hazards and mitigation	Incomplete: OEM setup AlertBoston, which sends communications in multiple languages	Yes: Continue to expand outreach
45	Conduct a survey of emergency generators at critical infrastructure facilities, municipal buildings, shelters and youth hostels	Incomplete: The OEM has completed a survey of emergency shelters, but not of other critical facilities	Yes
46	Evaluate feasibility of mobilizing passenger ferries for evacuation	Incomplete	Yes
47	Convene a Cabinet level Climate Preparedness Taskforce to review current activities and policies and provide guidance for further development	Incomplete: MAPC has convened the Metro Mayors Climate Preparedness Taskforce, but a Boston focused group could be warranted	Yes
48	Identify ways for institutions and businesses to reduce their vulnerability to climate change and for the City of Boston to support those efforts	Incomplete	Yes
49	Survey the preparedness of existing buildings and other assets (e.g. MBTA stations for climate change)	Completed: Climate Ready Boston assessed city-owned assets for climate change	No

Table 6 1. Status of Mitigation Measures from the 2014 NHMP

ID	MITIGATION MEASURE	2021 STATUS UPDATE	INCLUSION IN 2021 PLAN
50	Include climate change preparedness in Article 80 Development Review to enhance flood mitigation	Incomplete: The Climate Resilient Design Guidelines are used to mitigation risks associated with sea level rise and storm surge, but there is not a standard for riverine or stormwater flooding	Yes: Combine several priorities related to regulations to streamline action list
51	Adopt a Wetlands Ordinance that includes sea-level rise and develop new floodplain maps that incorporate projected climate change to mitigate flood hazards	Incomplete: A new Wetlands Ordinance was adopted in 2019 to address climate change impacts, but the next phase is to map new resources and adopt performance standards	Yes: Combine several priorities related to regulations to streamline action list
52	Develop guidelines and prioritization for better enforcement of flood proofing standards to mitigate flood hazards	Incomplete: The Climate Resilient Design Guidelines are used to mitigation risks associated with sea level rise and storm surge, but there is not a standard for riverine or stormwater flooding	Yes: Combine several priorities related to regulations to streamline action list
53	Review emergency operation planning for storms and flooding	Completed: The Emergency Operation Plan is reviewed annually	No: This will be captured in the existing capabilities and capacity section of the NHMP

SEVEN: IDENTIFICATION OF HAZARD MITIGATION AND CLIMATE ADAPTATION STRATEGIES

Boston is actively committed to reducing the adverse impacts of natural hazards. While a diverse array of programs, projects, and policies have been implemented already, there are still significant actions to be taken to mitigate the increasing risks climate change poses to the built and natural environments. Chapter 7 details a priority list of actions to be advanced in the immediate and long-term. Implementation of these actions often reduces risk, while also providing valuable co-benefits to the health and wellbeing of Boston's residents.

7.1 Action Development

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

- Hazard and climate change risk assessment
- Existing measures and the capacity to mitigate and respond to hazardous events
- Progress on the 2014 NHMP
- Input from stakeholders and the community

An important aspect of hazard mitigation is the continuation and improvement of existing initiatives that reduce risk and increase the preparedness of residents. Chapter 5 includes an extensive list of existing mitigation measures and operational capabilities that may need improvements based on new data and best practices. These improvements, while qualifying as future priority actions, are listed within Chapter 5, unless they relate directly to a newly identified action, in which case they are directly referenced within this chapter.

Each mitigation measure is paired with an estimated cost, projected year of completion, and implementation responsibility. These considerations also informed the prioritization of the mitigation measures along with other metrics described herein. A summary of the priority actions is available in Table 7-1, however, additional information is available in section 7.2.1. Each action has been assigned an identification number (ID) to match each action in the table summary with its detailed description. The detailed description includes the following information for each action.

General Objective – The general objective of the priority action refers to the hazard or hazards the action intends to mitigate. The objective is an overarching aim related to one or several mitigation actions. The general objective may be achieved through a variety or combination of mitigation actions.

Action Description - A description of a hazard mitigation or climate adaption measure with details, such as specific location, strategy, or technique to be used to work towards fulfilling the general objective.

Hazard Addressed - Priorities may mitigate single or multiple as indicated. All hazards assessed as a part of this plan in Chapter 4 were considered when developing the priority list.

Implementation Responsibility – Most hazard mitigation and climate adaptation measures will require a multi-department approach where several City departments share responsibility. This determination is at the discretion of the governing body of the community. The designation of implementation responsibility in the table was assigned based on general knowledge of the responsibilities of each municipal department. In addition, some action items require extensive involvement with the Commonwealth of Massachusetts departments or private entities. In those cases, the relevant entities have been listed in addition to a municipal department. For a listing of abbreviations related to municipal and state agency names, see the Appendix G.

Mitigating natural hazards is not strictly local issue. For example, the drainage systems that serve communities are often complex systems of storm drains, roadway infrastructure, pump stations, dams, and other facilities owned and operated by a wide variety of agencies, including the Massachusetts Department of Transportation (MassDOT), Massachusetts Emergency Management Association (MEMA), Massachusetts Water Resources Authority (MWRA), Massachusetts Bay Transportation Authority (MBTA), Massachusetts Port Authority (MassPort), Division of Capital Asset Management and Maintenance (DCAMM), United States Army Corp of Engineers (USACE), United States Department of Agriculture (USDA), Massachusetts Department of Conservation and Recreation (DCR), and the University of Massachusetts-Boston (UMass). The planning, construction, operation, and maintenance of these structures are integral to the hazard mitigation and climate adaptation efforts of communities. The City will strive to share and obtain vulnerability data in coordination with state and regional agencies with land ownership in the City. Like communities, state agencies also operate with budgetary and staffing constraints. Similar to municipalities, they must make decisions about numerous competing priorities. In order to implement many of the mitigation measures identified by the City, all parties will need to work together towards a mutually beneficial solution. Regional entities will also be key partners in implementing measures from this plan.

Status – The status of an action indicates if departments have already started advancing the general objective. For example, a project may have completed the design, but has yet to be constructed and therefore would have a status of "In Progress."

Year to Completion – The time frame indicates the projected completion of the general objective. In many cases, several steps will need to be completed to realize the full benefits. The time frame for completion is based upon the complexity of the measure, the overall priority of the measure, and the general assumption of funding availability. The identification of time frames is not meant to prevent a community from actively seeking out and taking advantage of funding opportunities as they arise, but they may also shift as priorities change with new leadership, emerging concerns, and community input.

Estimated Cost –All costs are estimates and would need to be updated at the time of design and construction. When applicable, costs have been divided between preliminary assessments and the cost of construction.

Potential Funding Sources – The identification of potential funding sources is preliminary and may vary depending on numerous factors. These factors include, but are not limited to, if a mitigation measure is conceptual or has been studied, evaluated, or designed. In most cases, the measure will require a combination of funding sources. 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. The City's General Fund or Capital Budget are considered a default potential funding source unless the City

pursues additional funding. 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 become available through private foundations or upon federally declared disaster declarations, as is the case with FEMA's FMA and HMGP grants. State revolving funds and other no- or low-interest loans may also be of interest. An evolving list of funding opportunities can be found on the *Community Grant Finder webpage.* For a listing of abbreviations related to funding sources, see the Appendix G.

Action Prioritization - A prioritization designation of high, medium, or low priority was assigned to each mitigation measure. This designation was based on the culumative rating in the ten categories:

- **Life Safety** - Will this action protect lives and prevent injury?
- **Property Protection** - Will this action eliminate or reduce damage to structures and infrastructure?
- **Technical** - Is the mitigation action technically feasible?
- **Political** - Does the public support the mitigation action?
- **Legal** -Does the City have the authority to implement the action?
- **Environmental** - Will the action protect and preserve Boston's natural resources?
- **Social** - Will the action have a positive impact on the community and vulnerable populations?
- **Administrative** - Does the City have the capabilities to implement and maintain the action?
- **Local Champion** - Is there a strong advocate for the project with the City?
- **Other Community Objectives** - Does the action advance other objectives in Boston, such as capital improvement, economic development, environmental quality, or open space preservation?

Each mitigation measure received a score of 1-5 based upon how well it conformed to each goal. A rating of 1 did not meet the category goal, and a rating of 5 fully aligned with the goal. The total score informed the mitigation strategy prioritization.

PRIORITIZATION DESIGNATION		
Low (L)	**Medium (M)**	**High (H)**
24 to 30 points	31 to 37 points	38 to 45 points

Table 7-1. Summary of Hazard Mitigation and Climate Adaptation Actions				
ID	Action	Year of Completion	Responsibility	Priority
A1	Physical Adaptations and Operational Changes to the MBTA Stations and Service Lines to Address Climate Impacts	2030	MBTA	H
A2	Adapt Morrissey Boulevard for Flood Resilience	2030	DCR, MassDOT, BPDA	H
A3	Sector-wide Vulnerability Assessment of Information Technology and Communication Infrastructure	2025	DoIT, OEM	M
A4	Sector-wide Vulnerability Assessment and Capacity Building Effort for Health Care Systems	2025	BPHC	M
A5	Identify, Support, and Promote Programs, Policies, or Other Actions for Institutions and Businesses to Reduce Their Vulnerability to Climate Change and for the City of Boston to Support Those Efforts	2025	Department of Economic Development, Environment Department	M
A6	Introduce Hazard Mitigation and Resiliency Into Regulations and Ordinances at the Local Level and Advocate for Changes at the State Level	2023	BPDA, Environment Department, Parks and Recreation	H
A7	Emergency Notification System Upgrades for Increased Access	2023	OEM	H
A8	Assess Back-up Energy Options at Critical Facilities	2023	OEM, BPDA, Environment Department	M
A9	Citywide Energy Demands Assessment Update and Reduce Stress on Grid Demand During Peak Usage	2030	BPDA, Environment Department	H
A10	Emergency Evacuation Route Improvements and Outreach	2022	OEM	H
A11	Emergency Shelter Assessment and Improvements	2025	OEM	H
A12	Feasibility Assessment of District Energy Solutions for Large Scale Developments	2025	BPDA, Environment Department, BPHC	H
A13	Implement the Findings of the Tunnel Vulnerability Assessment and Flood Mitigation Feasibility Study	2040	MassDOT	H

Table 7-1. Summary of Hazard Mitigation and Climate Adaptation Actions				
ID	Action	Year of Completion	Responsibility	Priority
A14	Public Housing Vulnerability Assessments and Adaptations	2025	Boston Housing Authority	H
A15	Boston Public Schools Green Infrastructure and Outreach	2025	Boston Public Schools	M
A16	Engage Across the Greater Boston Region to Develop Additional Regional Climate Adaptation and Resilience Measures Critical to Boston's Resilience	2026	Environment Department	M
A17	Evaluate Incentives and Finance Tools to Promote Resiliency in Buildings, Installation of Green Infrastructure, and Tree Management	2025	ISD, BPDA, Environment Department, Parks and Recreation	H
A18	Deliver Community Leadership Development and Engagement Programs That Build Community Capacity Around Climate Actio	2025	Environment Department	M
A19	Develop a Green Infrastructure Location Plan for Public Lands and Public Right of Way	2025	Public Works, Department of Transportation Environment Department, BWSC	H
A20	Implement Resilient Solutions Identified through Climate Ready Boston and Continue to Develop Strategies that Integrate Various Hazards	2030	BPDA, Environment	H
A21	Improve Resiliency of Boston Police Department Facilities	2025	Boston Police Department	L
A22	Franklin Park Action Plan and Resilience	2025	Parks and Recreation	H
A23	Identify Resilience Focused Workforce Development Pathways	2025	Mayor's Office of Economic Development	L
A24	Advocate for State Building Code Amendments to Promote Climate Readiness	2022	BPDA, Environment Department, ISD	L
A25	Continue to Develop a Resilience Assessment and Education Program for Property Owners and Tenants	2024	ISD, Environment Department	H
A26	Expand Back-up Power of Private Buildings that Serve Vulnerable Populations	2025	OEM, Community Organizations and Non-profits	M

Table 7-1. Summary of Hazard Mitigation and Climate Adaptation Actions				
ID	Action	Year of Completion	Responsibility	Priority
A27	Continue to Pursue Boston's Admission to National Flood Insurance Program (NFIP) Community Rating System	2023	Environment Department	L
A28	Develop a Sustainable Operating Model for Green Infrastructure on Public Land and Rights of Way	2023	Public Works	M
A29	Conduct a Comprehensive Wetlands Inventory and Develop a Wetlands Protection Action Plan	2025	Environment Department	M
A30	Prepare Parks and Outdoor Facilities for Climate Change	2025	Parks and Recreation	H
A31	Convene a Cabinet level Climate Preparedness Taskforce	2023	Mayor's Office	M
A32	Develop and Deploy an Environmental Sensors Strategy to Track Performance Against Climate Goals Across the City	2025	Environment Department, MONUM	H
A33	Storrow Drive Reconstruction and Drainage Improvements	2030	DCR	H
A34	Implement Recommended Actions in Boston's Citywide Heat Resiliency Study	2022	Environment Department, Parks, BPHC, OEM	H
A35	Muddy River Flood Control	2023	Army Corp of Engineers, DCR, Parks and Recreation, Town of Brookline	H
A36	Utilize Community Advisory Boards, District and Sub-District Working Groups, and Other Structures to Build Long-Term Partnerships for Climate Action	2025	BPDA, Environment Department	M
A37	Establish Flood Protection Overlay Districts	2025	BPDA, Environment Department	H
A38	Continue to Refine a Consistent Evaluation Framework for Prioritizing Climate Resilience and Adaptation Implementation	2023	BPDA, Environment Department	H
A39	Establish an Infrastructure Coordination Committee	2023	Mayor's Office and Governor's Office	L

Table 7-1. Summary of Hazard Mitigation and Climate Adaptation Actions				
ID	Action	Year of Completion	Responsibility	Priority
A40	Develop Design Guidelines for Green Infrastructure on Public and Private Property	2023	Parks and Recreation, Environment Department	H
A41	Implement an Action Plan to Enhance Boston's Urban Tree Canopy and Protect Residents From the Impacts of Extreme Heat	2030	Parks and Recreation, Environment Department	H
A42	Adapt Municipal Facilities for Climate Change Impacts	2025	Multiple Agencies	M
A43	Evaluate and Advocate for Reforms in the NFIP	2023	Multiple Agencies	L
A44	Improve Food Access and Supply Chain Resiliency	2030	Mayor's Office of Food Access, OEM	M
A45	Expand Citywide Climate Readiness Education, Engagement, and Leadership Development Campaigns	2024	Environment Department, OEM	H
A46	Building Resiliency around the Fort Point Channel Area	2030	BPDA, Parks and Recreation, BWSC	H
A47	East Boston Coastal Resilience Barrier	2027	BPDA	H
A48	Construct Boston Marine Industrial Park Stormwater Management System Stormwater Improvements	2024	BPDA	H
A49	Moon Island Seawall Rehabilitation to Mitigate Coastal Hazards	2024	Property Management Department, Neighborhood Development, BFD, Public Facilities	H
A50	Stabilize Coastal Bank Along the Eastern Side of Long Island	2025	Property Management Department, DCR	H
A51	Update Storm Ready Certification with National Weather Service	2023	OEM	H
A52	Evaluate Feasibility of Mobilizing Passenger Ferries for Evacuation	2023	OEM	L

Table 7-1. Summary of Hazard Mitigation and Climate Adaptation Actions				
ID	Action	Year of Completion	Responsibility	Priority
A53	**Conduct a Study on the Vulnerability of the City Solar Storm Electromagnetic Pulses**	2030	OEM	M
A54	Rutherford Ave/Charlestown Underpass – Replace Tunnel With Urban Boulevard and Drainage Improvements	2030	Transportation Department	H
A55	Purchase Android- based mobile GPS Tablets for ISD Inspectors	2022	ISD & DoIT	M
A56	Build Capacity of Fire Prevention Division	2025	BFD	M
A57	Assess the Risk of Water-Reactive Chemicals Stored in Flood-Prone Buildings to Mitigate Flood Hazards	2025	BFD HAZMAT and BFD LEPC	M
A58	Address Vulnerabilities to Tidal Flooding at McCormack and Dever schools, (315 Mt. Vernon Street, Columbia Point, Dorchester)	2035	Property Management Department	H

7.2.1 Prioritized Action Details

A1. Physical Adaptations and Operational Changes to the MBTA Stations and Service Lines to Address Climate Impacts

Description	The MBTA has begun conducting climate change vulnerability assessments for each of its lines and implementing flood protection measures. Improvements should be made to transit lines, operational facilities, and stations/stops to improve resiliency during winter storms, extreme heat, and stormwater and coastal flooding.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	MBTA
Cost	$25-$50 Million
Status	In Progress
Time to Completion	2030
Funding Source	BRIC, Chapter 90 Program

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	3
	Political	5
	Legal	1
	Environmental	5
	Social	5
	Administrative	3
	Local Champion	3
	Other Community Objectives	5
Prioritization		**35**

A2. Adapt Morrissey Boulevard for Flood Resilience

Description	Several different initiatives have occurred along Morrissey Boulevard since the last NHMP. Climate Ready Boston - Dorchester explored flood mitigation solutions for Morrissey Boulevard. A Redesign Study and Preliminary Designs for a portion of the street was completed in 2015-2016. MassDOT in partnership with the City are not conducting a coordinated hazard mitigation efforts. Physical adaptations and improvement could include, such as road reconstruction, bank stabilization, seawalls repair and upgrades.
Priority	H
Hazard Addressed	Coastal
Implementation Responsibility	DCR, MassDOT, BPDA
Cost	$25 Million
Status	In Progress
Time to Completion	2030
Funding Source	BRIC, Chapter 90 Program

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	3
	Political	5
	Legal	1
	Environmental	5
	Social	5
	Administrative	5
	Local Champion	5
	Other Community Objectives	5
Prioritization		**39**

A3. Sector-wide Vulnerability Assessment of Information Technology and Communication Infrastructure

Description	Protection of municipal Information Technology infrastructure is critical to data protection, cybersecurity, and continuity of critical services and industries. Protection of communication infrastructure, such as fiber-optic lines is critical to data protection, cybersecurity, and continuity of critical services and industries.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	DoIT, OEM
Cost	Staff Time
Status	Not Started
Time to Completion	2025
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	5
	Political	5
	Legal	5
	Environmental	3
	Social	3
	Administrative	1
	Local Champion	3
	Other Community Objectives	4
Prioritization		**31**

A4. Sector-wide Vulnerability Assessment and Capacity Building Effort for Health Care Systems

Description	Enhance the resiliency of healthcare systems by understanding their vulnerability to climate hazards, coordinate across systems to ensure adequate emergency response in inclement events, build capacity through the creation of a response network.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	BPHC
Cost	Staff Time
Status	Not Started
Time to Completion	2025
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	3
	Technical	5
	Political	3
	Legal	2
	Environmental	3
	Social	5
	Administrative	1
	Local Champion	3
	Other Community Objectives	3
Prioritization		**30**

A5. Identify, Support, and Promote Programs, Policies, or Other Actions for Institutions and Businesses to Reduce Their Vulnerability to Climate Change

Description	Private enterprises provide critical services for the community. The City of Boston will identify, support, and promote programs that reduce the vulnerability across sectors. For example, the City could launch a grant program for small businesses to support their implementation of hazard mitigation measures that support the continuity of their business, promotes economic success, and reduces their environmental impact.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	Department of Economic Development, Environment Department
Cost	Staff Time
Status	In Progress
Time to Completion	2025
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	2
	Property Protection	4
	Technical	2
	Political	4
	Legal	3
	Environmental	2
	Social	5
	Administrative	2
	Local Champion	4
	Other Community Objectives	4
Prioritization		**28**

A6. Introduce Hazard Mitigation and Resiliency Into Regulations and Ordinances at the Local Level and Advocate for Changes at the State Level

Description	Boston has been actively introducing regulations that support clean energy, carbon emissions reductions, climate mitigation, and resiliency. This effort should continue across all City agencies. The City recently adopted a new wetland ordinance, but the next phase of work will include mapping new resources and adopting performance standards. The City also developed the Climate Resilient Design Guidelines for sea level rise and storm surge, but does not include riverine or stormwater flooding. New street tree planting standards on spacing and soil volume to increase wind resilience. Adopt a tree retention ordinance to preserve existing trees or equally compensate for the loss of the tree's caliper (mitigation for both flooding and extreme heat).
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	BPDA, Environment Department, Parks and Recreation
Cost	$80,000 per Regulatory Update
Status	In Progress
Time to Completion	2023
Funding Source	Staff Time, MVP, EEA Planning Assistance Grant

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	5
	Technical	4
	Political	4
	Legal	3
	Environmental	5
	Social	3
	Administrative	3
	Local Champion	4
	Other Community Objectives	4
Prioritization		**34**

A7. Emergency Notification System Upgrades for Increased Access

Description	Make system and operational updates to the emergency response text service to promote access and equitable user-experience. Emergency messages should be translated into multiple languages and available through Wi-Fi-based messaging services (such as WhatsApp).
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	OEM
Cost	Staff Time
Status	In Progress
Time to Completion	2023
Funding Source	Staff Time, City Funds

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	2
	Technical	5
	Political	5
	Legal	5
	Environmental	2
	Social	5
	Administrative	5
	Local Champion	5
	Other Community Objectives	2
Prioritization		**38**

A8. Assess Back-up Energy Options at Critical Facilities

Description	Ensure all critical facilities have adequate back up power for continuity of services by developing microgrid systems with renewable energy sources. Conduct an assessment of emergency generators and transfer switches at critical infrastructure facilities, municipal buildings, and youth hostels. An assessment has already been completed for emergency shelters.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	OEM, BPDA, Environment Department
Cost	Staff Time for Assessment, $150K for Feasibility Assessment, $500K for Pilot Microgrid Installation
Status	In Progress
Time to Completion	2023
Funding Source	Staff Time, BRIC, DOER

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	5
	Political	5
	Legal	5
	Environmental	3
	Social	3
	Administrative	3
	Local Champion	3
	Other Community Objectives	2
Prioritization		**33**

A9. Citywide Energy Demands Assessment Update and Reduce Stress on Grid Demand During Peak Usage

Description	Update the 2016 Boston Community Energy Study Demand map for current needs and usage. Support installation of battery storage in the City's largest buildings to reduce demands during peak usage, also ensuring energy resilience.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	BPDA, Environment Department
Cost	$200K for Assessment, $1M for Battery Backup Systems
Status	Not Started
Time to Completion	2030
Funding Source	DOER, Green Communities

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	4
	Political	5
	Legal	5
	Environmental	4
	Social	3
	Administrative	3
	Local Champion	5
	Other Community Objectives	3
Prioritization		**35**

A10. Emergency Evacuation Route Improvements and Outreach

Description	Install energy storage for emergency evacuation lighting or other route marking mechanisms, conduct outreach to increase awareness of routes and conduct mobility studies to assess route effectiveness.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	OEM
Cost	$500K
Status	In Progress
Time to Completion	2022
Funding Source	EMPG

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	2
	Technical	5
	Political	5
	Legal	5
	Environmental	2
	Social	5
	Administrative	4
	Local Champion	5
	Other Community Objectives	2
Prioritization		**38**

A11. Emergency Shelter Assessment and Improvements

Description	Many of Boston Public Schools, BCYF centers, and other emergency shelters do not have air conditioning, backup generators, or transfer switches. These upgrades are necessary to ensure heating and cooling stations are available to residents throughout the city.
Priority	H
Hazard Addressed	Heat
Implementation Responsibility	OEM
Cost	Staff Time - Assessment; Varied - Implementation
Status	Not Started
Time to Completion	2025
Funding Source	Staff Time - Assessment; EMPG, BRIC - Implementation

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	5
	Political	5
	Legal	5
	Environmental	4
	Social	5
	Administrative	3
	Local Champion	5
	Other Community Objectives	3
Prioritization		**42**

A12. Feasibility Assessment of District Energy Solutions for Large Scale Developments

Description	Smart utility measures, such as microgrids, should be installed at the district scale. Complete the feasibility assessment for energy resilience measures at Mattapan's BPHC site and apply lessons learned to other city-owned facilities.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	BPDA, Environment Department, BPHC
Cost	$200K for Assessment, $500K for Installations
Status	Not Started
Time to Completion	2025
Funding Source	DOER, Green Communities

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	4
	Political	5
	Legal	5
	Environmental	4
	Social	3
	Administrative	3
	Local Champion	5
	Other Community Objectives	3
Prioritization		**35**

A13. Implement the Findings of the Tunnel Vulnerability Assessment and Flood Mitigation Feasibility Study

Description	The Central Artery/Tunnel Vulnerability and Adaptation Assessment was completed in June 2015, which evaluated the feasibility of flood mitigation measures to protect tunnel access. The findings of this vulnerability assessment should be implemented in order to achieve the intended hazard mitigation goals.
Priority	H
Hazard Addressed	Coastal
Implementation Responsibility	MassDOT
Cost	$1M
Status	In Progress
Time to Completion	2040
Funding Source	BRIC, Chapter 90 Program, STBG

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	4
	Political	5
	Legal	1
	Environmental	4
	Social	3
	Administrative	4
	Local Champion	4
	Other Community Objectives	3
Prioritization		**35**

A14. Public Housing Vulnerability Assessments and Adaptations

Description	Assess the vulnerability of the City's public housing portfolio. Implement adaptation measures that align with planned capital improvements and the maintenance schedule.
Priority	H
Hazard Addressed	Coastal, Heat
Implementation Responsibility	Boston Housing Authority
Cost	$500K
Status	Not Started
Time to Completion	2025
Funding Source	BRIC, HUD-CDBG

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	4
	Political	4
	Legal	3
	Environmental	3
	Social	5
	Administrative	2
	Local Champion	3
	Other Community Objectives	4
Prioritization		**34**

A15. Boston Public Schools Green Infrastructure and Outreach

Description	Work with the Boston Public School system to install on-site green infrastructure projects that can also be used as an teaching tool for youth education and outreach.
Priority	M
Hazard Addressed	Stormwater, Heat
Implementation Responsibility	Boston Public Schools
Cost	$750K
Status	Not Started
Time to Completion	2025
Funding Source	MAPC Community Resilience Grants, MVP

Evaluation Criteria Scoring (1-5)	Life Safety	1
	Property Protection	2
	Technical	5
	Political	4
	Legal	5
	Environmental	5
	Social	5
	Administrative	2
	Local Champion	3
	Other Community Objectives	4
Prioritization		**32**

A16. Engage Across the Greater Boston Region to Develop Additional Regional Climate Adaptation and Resilience Measures Critical to Boston's Resilience

Description	The City of Boston is engaging with regional partners to deliver additional studies and other partnerships that can support regional climate adaptation and resilience that meets the objectives of Climate Ready Boston. The Environment Department may also reengage with the Greater Boston Research Advisory Group (GBRAG) to continue to refine climate projections and discuss recent advancements in climate science.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	Environment Department
Cost	Staff Time - Collaboration; Varied - Implementation of Actions
Status	In Progress
Time to Completion	2025
Funding Source	Staff Time - Collaboration; MVP, BRIC, MAPC - Implementation

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	4
	Technical	4
	Political	4
	Legal	3
	Environmental	4
	Social	3
	Administrative	3
	Local Champion	3
	Other Community Objectives	4
Prioritization		**36**

A17. Evaluate Incentives and Finance Tools to Promote Resiliency in Buildings, Installation of Green Infrastructure, and Tree Management

Description	Financing is a common hurdle for implementation of building retrofits for energy and resilience. Identifying available grants and subsidies and conducting outreach to property owners can enable them to retrofit their buildings. Conduct detailed studies to promote green infrastructure strategies and tree planting, protection, and maintenance.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	ISD, BPDA, Environment Department, Parks and Recreation
Cost	$1M
Status	In Progress
Time to Completion	2025
Funding Source	DOER, DOE Loan Program Office, 604b, Community Forest Grant Program

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	5
	Political	4
	Legal	5
	Environmental	5
	Social	5
	Administrative	4
	Local Champion	3
	Other Community Objectives	5
Prioritization		**37**

A18. Deliver Community Leadership Development and Engagement Programs That Build Community Capacity Around Climate Action

Description	Increase involvement of community leaders in climate planning efforts. Conduct a study identifying barriers to meaningful participation.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	Environment Department
Cost	$150K
Status	In Progress
Time to Completion	2025
Funding Source	MAPC Community Resilience Grants, MVP

Evaluation Criteria Scoring (1-5)	Life Safety	1
	Property Protection	2
	Technical	5
	Political	5
	Legal	5
	Environmental	2
	Social	5
	Administrative	4
	Local Champion	3
	Other Community Objectives	5
Prioritization		**32**

A19. Develop a Green Infrastructure Location Plan for Public Lands and Public Right of Way

Description	BWSC has completed an opportunities assessment for green infrastructure at the subbasin level, but does not have plans for green infrastructure installations for specific streets. BWSC can make recommendations for green infrastructure improvements during other capital improvement projects in the public right-of-way. BWSC has also identified 10 green infrastructure sites for pilot projects. Some of the parcels are not owned by the City and efforts are being coordinated to pursue these projects. A study to more specifically determine other future ideal locations for the implementation of green infrastructure may be warranted.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	Public Works, Department of Transportation Environment Department, BWSC
Cost	$250K
Status	Not Started
Time to Completion	2025
Funding Source	604b Grant Program; MVP; Community Forest Grant Program

Evaluation Criteria Scoring (1-5)	Life Safety	1
	Property Protection	2
	Technical	5
	Political	5
	Legal	5
	Environmental	5
	Social	3
	Administrative	4
	Local Champion	5
	Other Community Objectives	4
Prioritization		**35**

A20. Implement Resilient Solutions Identified through Climate Ready Boston and Continue to Develop Strategies that Integrate Various Hazards

Description	District-scale or neighborhood level solutions protect many properties at once and may provide co-benefits to the public realm. The City should continue ongoing efforts to implement Climate Ready Boston neighborhood level plans for climate adaptation, specifically coastal adpatation strategies identified for implementation within the 2030 planning horizon. Additional studies may need to be conducted to integrate the coastal resiliency efforts, stormwater management, and groundwater monitoring into an unified approach to develop protection solutions. Managed retreat should be considered as a possible option by identify funding mechanisms, case studies, community participation models, and potential 'receiving' areas for residents. Flooding, heat, and other natural hazard studies and assessments should be updated periodically.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	BPDA, Environment Department
Cost	$2M ($400K per year)
Status	Planned
Time to Completion	2030
Funding Source	MVP, CZM Coastal Resiliency, BRIC, DOE Loan Program Office

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	4
	Political	4
	Legal	3
	Environmental	4
	Social	5
	Administrative	3
	Local Champion	3
	Other Community Objectives	5
Prioritization		**38**

A21. Improve Resiliency of Boston Police Department Facilities

Description	Frontage Road Boston Police Department building is vulnerable to flooding and the equipment room and generator are below the Design Flood Elevation or DFE.
Priority	L
Hazard Addressed	Flooding
Implementation Responsibility	Boston Police Department
Cost	$200K per Structure
Status	Not Started
Time to Completion	2025
Funding Source	CZM Coastal Resiliency and MVP

Evaluation Criteria Scoring (1-5)	Life Safety	1
	Property Protection	3
	Technical	4
	Political	3
	Legal	5
	Environmental	3
	Social	3
	Administrative	3
	Local Champion	4
	Other Community Objectives	1
Prioritization		**29**

A22. Franklin Park Action Plan and Resilience

Description	Boston Parks and Recreation Department has launched a new master plan for Franklin Park in May 2020. The City committed approximately $28 million to revitalize Franklin Park.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	Parks and Recreation
Cost	$28 million
Status	In Progress
Time to Completion	2025
Funding Source	City Funds, MassTrails, Community Forest Grant Program

Evaluation Criteria Scoring (1-5)	Life Safety	1
	Property Protection	3
	Technical	5
	Political	5
	Legal	5
	Environmental	5
	Social	3
	Administrative	5
	Local Champion	5
	Other Community Objectives	4
Prioritization		**34**

A23. Identify Resilience Focused Workforce Development Pathways

Description	Create new public sector jobs that support the implementation of resilience projects and programs.
Priority	L
Hazard Addressed	Multi
Implementation Responsibility	Mayor's Office of Economic Development
Cost	Staff Time
Status	Not Started
Time to Completion	2025
Funding Source	Staff Time, City Funds

Evaluation Criteria Scoring (1-5)	Life Safety	1
	Property Protection	2
	Technical	5
	Political	3
	Legal	3
	Environmental	2
	Social	3
	Administrative	3
	Local Champion	3
	Other Community Objectives	4
Prioritization		**25**

A24. Advocate for State Building Code Amendments to Promote Climate Readiness

Description	Advocate for changes in the Massachusetts State Building Code that will facilitate the implementation of greater climate adaptation and hazard mitigation measures.
Priority	L
Hazard Addressed	Multi
Implementation Responsibility	BPDA, Environment, ISD
Cost	Staff Time
Status	Not Started
Time to Completion	2022
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	4
	Technical	3
	Political	2
	Legal	1
	Environmental	3
	Social	3
	Administrative	2
	Local Champion	1
	Other Community Objectives	2
Prioritization		**22**

A25. Continue to Develop a Resilience Assessment and Education Program for Property Owners and Tenants

Description	Continue to develop a Resilience Assessment and Education program for property owners and tenants to educate and support integration of operations, management, and investment approaches that can deliver climate ready buildings. The Resilience Audit Program would function similarly to the Energy Audit Program. Homeowners would be able to have their home assessed for free for potential resiliency improvements.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	ISD, Environment Department
Cost	$500K
Status	In Progress
Time to Completion	2024
Funding Source	MVP, DOE Loan Program Office

Evaluation Criteria Scoring (1-5)	Life Safety	2
	Property Protection	4
	Technical	5
	Political	4
	Legal	4
	Environmental	4
	Social	3
	Administrative	5
	Local Champion	5
	Other Community Objectives	4
Prioritization		**36**

A26. Expand Back-up Power of Private Buildings that Serve Vulnerable Populations

Description	Many private facilities, such as community-based organizations, serve essential functions for vulnerable populations. Providing these buildings with back-up power enables them to support these populations during a climate-related event.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	OEM, Community Organizations and Non-profits
Cost	$1M
Status	Not Started
Time to Completion	2025
Funding Source	DOE Loan Program Office, DOER

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	5
	Technical	4
	Political	4
	Legal	1
	Environmental	3
	Social	5
	Administrative	2
	Local Champion	2
	Other Community Objectives	4
Prioritization		**30**

A27. Continue to Pursue Boston's Admission to the NFIP Community Rating System

Description	The NFIP Community Rating System reduces premiums for communities based on proactive actions taken to support flood mitigation and resilience.
Priority	L
Hazard Addressed	Flooding
Implementation Responsibility	Environment Department
Cost	Staff Time
Status	In Progress
Time to Completion	2023
Funding Source	Staff Time, MVP or CZM to Implement Steps Required for Eligibility

Evaluation Criteria Scoring (1-5)	Life Safety	2
	Property Protection	3
	Technical	5
	Political	3
	Legal	5
	Environmental	3
	Social	3
	Administrative	3
	Local Champion	2
	Other Community Objectives	1
Prioritization		**29**

A28. Develop a Sustainable Operating Model for Green Infrastructure on Public Land and Rights of Way

Description	Proper maintenance of green infrastructure is critical to ensure that species survive after planting. Without proper maintenance, green infrastructure cannot operate optimally.
Priority	M
Hazard Addressed	Heat, Stormwater
Implementation Responsibility	Public Works
Cost	$100K
Status	Not Started
Time to Completion	2023
Funding Source	604b Grant Program

Evaluation Criteria Scoring (1-5)	Life Safety	2
	Property Protection	2
	Technical	4
	Political	5
	Legal	5
	Environmental	5
	Social	3
	Administrative	4
	Local Champion	3
	Other Community Objectives	3
Prioritization		**33**

A29. Conduct a Comprehensive Wetlands Inventory and Develop a Wetlands Protection Action Plan

Description	The development of a Wetlands Protection Action Plan will help ensure that Boston's critical natural systems are protected from future development, environmental pollution, sea level rise, and storm surge flooding.
Priority	M
Hazard Addressed	Coastal
Implementation Responsibility	Environment Department
Cost	$100K
Status	In Progress
Time to Completion	2025
Funding Source	MVP, EEA Planning Assistance Grant

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	2
	Technical	3
	Political	3
	Legal	5
	Environmental	5
	Social	3
	Administrative	2
	Local Champion	5
	Other Community Objectives	3
Prioritization		**31**

A30. Prepare Parks and Outdoor Facilities for Climate Change

Description	Many of Boston's parks and park facilities are located in the coastal zone. These facilities may need to be retrofitted or adapted to ensure their protection against flooding and continuity of services provided to the public. Parks can be designed to provide urban heat island relief and flood storage. Moakley Park is one example that is currently in design.
Priority	H
Hazard Addressed	Coastal
Implementation Responsibility	Parks and Recreation
Cost	$25M-$50M
Status	Not Started
Time to Completion	2025
Funding Source	BRIC, MVP, CZM Coastal Resiliency

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	4
	Technical	3
	Political	4
	Legal	5
	Environmental	5
	Social	5
	Administrative	3
	Local Champion	5
	Other Community Objectives	5
Prioritization		**38**

A31. Convene a Cabinet level Climate Preparedness Taskforce

Description	Increase accountability and coordination throughout the departments by creating a Climate Preparedness Taskforce to review current activities and policies and provide guidance for further development.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	Mayor's Office
Cost	Staff Time
Status	Not Started
Time to Completion	2023
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	5
	Political	5
	Legal	5
	Environmental	3
	Social	3
	Administrative	3
	Local Champion	3
	Other Community Objectives	4
Prioritization		**33**

A32. Develop and Deploy an Environmental Sensors Strategy to Track Performance Against Climate Goals Across the City

Description	The City of Boston has established metrics for performance of infrastructure and the public realm against climate risks. To build upon those metrics, we will integrate a sensor deployment strategy to measure impacts of flood infrastructure, heat infrastructure, green infrastructure, and other priorities at more frequent intervals to inform policy, prioritization, and response strategies.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	Environment Department, MONUM
Cost	Staff Time
Status	Not Started
Time to Completion	2025
Funding Source	Staff Time, City Funds

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	5
	Political	5
	Legal	5
	Environmental	3
	Social	3
	Administrative	3
	Local Champion	3
	Other Community Objectives	4
Prioritization		**38**

A33. Storrow Drive Reconstruction and Drainage Improvements

Description	Storrow Drive is vulnerable to flooding due to its low elevation. The road needs improvements to reduce the impacts of flooding.
Priority	H
Hazard Addressed	Coastal, Stormwater
Implementation Responsibility	DCR
Cost	$500M-$1B
Status	Not Started
Time to Completion	2030
Funding Source	BRIC, Chapter 90 Program, STBG

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	5
	Political	4
	Legal	1
	Environmental	3
	Social	4
	Administrative	2
	Local Champion	4
	Other Community Objectives	5
Prioritization		**33**

A34. Implement Recommended Actions in Boston's Citywide Heat Resiliency Study

Description	Boston's Heat Emergency Action Plan ensures Bostonians are aware of and have access to cooling centers, are not isolated in a home without air conditioning, and can seek adequate health care if experiencing heat stress. The City of Boston is currently conducting a citywide heat resiliency study, which will generate recommendations for solutions to address heat risk.
Priority	H
Hazard Addressed	Heat
Implementation Responsibility	Environment Department, Parks, BPHC, OEM
Cost	Staff Time, $280K
Status	In Progress
Time to Completion	2022
Funding Source	Staff Time, MVP

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	2
	Technical	5
	Political	5
	Legal	5
	Environmental	3
	Social	5
	Administrative	5
	Local Champion	5
	Other Community Objectives	5
Prioritization		**40**

A35. Muddy River Flood Control

Description	Complete the ongoing construction (June 2021) to provide flood mitigation.
Priority	H
Hazard Addressed	Flood
Implementation Responsibility	Army Corp of Engineers, DCR, Parks and Recreation, Town of Brookline
Cost	$5M
Status	In Progress
Time to Completion	2023
Funding Source	Army Corp of Engineers

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	4
	Political	5
	Legal	1
	Environmental	3
	Social	5
	Administrative	5
	Local Champion	5
	Other Community Objectives	5
Prioritization		**38**

A36. Utilize Community Advisory Boards, District and Sub-District Working Groups, and Other Structures to Build Long-Term Partnerships for Climate Action

Description	Community partners have essential knowledge that is invaluable to the development and implementation of adaptation strategies that protect residents. Partners could include community organizations, cultural institutions, universities, and other private entities.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	BPDA, Environment Department
Cost	$200K
Status	In Progress
Time to Completion	2025
Funding Source	MAPC - Advancing Resilience, MVP

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	5
	Political	4
	Legal	5
	Environmental	2
	Social	5
	Administrative	3
	Local Champion	2
	Other Community Objectives	4
Prioritization		**32**

A37. Establish Flood Protection Overlay Districts

Description	Flood Protection Overlay Districts will ensure future development is adapted to flood risks and aligns with district flood protection goals.
Priority	H
Hazard Addressed	Coastal
Implementation Responsibility	BPDA, Environment Department
Cost	$200K
Status	In Progress
Time to Completion	2025
Funding Source	City Funds, Land Use Planning Assistance Grants

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	3
	Political	3
	Legal	5
	Environmental	5
	Social	5
	Administrative	4
	Local Champion	5
	Other Community Objectives	5
Prioritization		**40**

A38. Determine a Consistent Evaluation Framework for Flood Defense Prioritization

Description	Establishing a consistent evaluation framework will make prioritization more efficient, uniform, and logical, while also emphasizing equity and environmental justice communities.
Priority	H
Hazard Addressed	Coastal, Stormwater
Implementation Responsibility	BPDA, Environment Department
Cost	$250K
Status	In Progress
Time to Completion	2023
Funding Source	City Funds, Land Use Planning Assistance Grants

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	4
	Technical	4
	Political	4
	Legal	5
	Environmental	3
	Social	5
	Administrative	4
	Local Champion	3
	Other Community Objectives	4
Prioritization		**35**

A39. Establish an Infrastructure Coordination Committee

Description	An Infrastructure Coordination Committee will support an integrated effort to collaborate across projects to promote resilience between the local and state agencies.
Priority	L
Hazard Addressed	Multi
Implementation Responsibility	Mayor's Office and Governor's Office
Cost	Staff Time
Status	In Progress
Time to Completion	2023
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	1
	Property Protection	2
	Technical	5
	Political	3
	Legal	5
	Environmental	2
	Social	3
	Administrative	3
	Local Champion	1
	Other Community Objectives	1
Prioritization		**25**

A40. Develop Design Guidelines for Green Infrastructure on Public and Private Property

Description	Design guidelines can help ensure that private property owners are properly installing green infrastructure. Proper installation is essential for critical function. The guidelines should also include maintenance procedures.
Priority	H
Hazard Addressed	Heat, Stormwater
Implementation Responsibility	Parks and Recreation, Environment Department
Cost	$100K
Status	In Progress
Time to Completion	2023
Funding Source	EEA Planning Assistance Grant

Evaluation Criteria Scoring (1-5)	Life Safety	2
	Property Protection	3
	Technical	5
	Political	5
	Legal	5
	Environmental	5
	Social	3
	Administrative	5
	Local Champion	4
	Other Community Objectives	3
Prioritization		**37**

A41. Implement an Action Plan to Enhance Boston's Urban Tree Canopy and Protect Residents From the Impacts of Extreme Heat

Description	Implement the recommendations of the (2021) Urban Forest Masterplan, which evaluates the current tree cover and strategies to enhance tree canopy coverage and public health.
Priority	H
Hazard Addressed	Heat, Stormwater
Implementation Responsibility	Parks and Recreation, Environment Department
Cost	$150K
Status	In Progress
Time to Completion	2022
Funding Source	City Funds

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	1
	Technical	4
	Political	5
	Legal	5
	Environmental	5
	Social	3
	Administrative	5
	Local Champion	5
	Other Community Objectives	5
Prioritization		**38**

A42. Adapt Municipal Facilities for Climate Change Impacts

Description	Municipal departments should implement climate adaptation improvements to their facilities to ensure continuity of services. This effort should include conducting a study to retrofit unreinforced masonry buildings to improve earthquake resilience.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	Multiple Agencies
Cost	$500K
Status	In Progress
Time to Completion	2025
Funding Source	Chapter 90 Program, BRIC, DOE Loan Program Office

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	5
	Technical	3
	Political	3
	Legal	5
	Environmental	3
	Social	3
	Administrative	2
	Local Champion	2
	Other Community Objectives	3
Prioritization		**30**

A43. Evaluate and Advocate for Reforms in the NFIP

Description	A large percentage of Boston residents are in areas where flood insurance is needed. Reform of the NFIP could enable residents to more equitably and affordably access flood insurance. The City should work with FEMA to evaluate and advocate for reforms that will result in higher insurance coverage rates.
Priority	L
Hazard Addressed	Flooding
Implementation Responsibility	Multiple Agencies
Cost	Staff Time
Status	Not Started
Time to Completion	2023
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	5
	Political	3
	Legal	5
	Environmental	2
	Social	3
	Administrative	2
	Local Champion	1
	Other Community Objectives	1
Prioritization		**27**

A44. Improve Food Access and Supply Chain Resiliency

Description	Strengthen partnership with food banks developed during the COVID-19 pandemic. Incentivize new stores that provide groceries and other staples in food deserts. Identify locations for new community gardens. Explore how to improve the resiliency of supply chains for community necessities, like food and water.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	Mayor's Office of Food Access, OEM
Cost	$100K
Status	In Progress
Time to Completion	2030
Funding Source	Senior SAFE, MassWorks, MVP, Urban Agriculture Program

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	2
	Technical	3
	Political	4
	Legal	5
	Environmental	2
	Social	5
	Administrative	3
	Local Champion	5
	Other Community Objectives	3
Prioritization		**33**

A45. Expand Citywide Climate Readiness Education, Engagement, and Leadership Development Campaigns

Description	Outreach is critical to increase the awareness of residents to both their climate risks and potential actions they can take to prepare. Outreach should focus on social vulnerable populations in particular. Interactive, visually compelling, and translated materials are key. Messages could include information on preparedness, evacuation routes, and steps the City is taking to mitigate hazards or progress on the NHMP. OEM will work to increase public education on hurricane, tornado, earthquake awareness. OEM will also participate in the annual Northeast SHAKEOUT, utilize the QuakeSmart Program's materials or other source, and and incorporate the USGS ShakeAlert® Earthquake Early Warning System or something similiar into programming.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	Environment Department, OEM
Cost	$150K
Status	In Progress
Time to Completion	2024
Funding Source	MVP

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	5
	Political	5
	Legal	5
	Environmental	3
	Social	5
	Administrative	5
	Local Champion	5
	Other Community Objectives	3
Prioritization		**39**

A46. Building Resiliency around the Fort Point Channel Area

Description	Two ongoing projects are exploring design and funding for the Fort Point Channel area. A FEMA PDM Grant has been submitted by the BPDA and Parks and Recreation Department to design and construct a vegetated berm or coastal barrier to provide flood protection. FEMA has authorized the project for further review and an environmental assessment is being completed. BWSC is conducting a study to add additional storage capacity in the Fort Point Channel to reduce stormwater flooding. The two projects are coordinated but occurring independently to address different hazards. BWSC previously installed a tide gate in this area.
Priority	H
Hazard Addressed	Flooding
Implementation Responsibility	BPDA, Parks and Recreation- Flood Barrier; BWSC-Stormwater Storage
Cost	$20M-Flood Barrier
Status	In Progress
Time to Completion	2030
Funding Source	BRIC

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	4
	Political	5
	Legal	5
	Environmental	4
	Social	3
	Administrative	3
	Local Champion	3
	Other Community Objectives	2
Prioritization		**37**

A47. East Boston Coastal Resilience Barrier

Description	Finalize the design for the East Boston Coastal Resilience Strategies for the Carlton Wharf and Lewis Mall Flood pathways.
Priority	H
Hazard Addressed	Flooding
Implementation Responsibility	BPDA
Cost	$1M
Status	In Progress
Time to Completion	2027
Funding Source	CZM Coastal Resiliency and MVP for Design, BRIC for Construction

Evaluation Criteria Scoring (1-5)	Life Safety	5
	Property Protection	5
	Technical	5
	Political	5
	Legal	5
	Environmental	4
	Social	5
	Administrative	3
	Local Champion	4
	Other Community Objectives	2
Prioritization		**41**

A48. Construct Boston Marine Industrial Park Stormwater Management System Improvements

Description	Finalize the design and construct stormwater improvements to reduce flooding.
Priority	H
Hazard Addressed	Flooding
Implementation Responsibility	BPDA
Cost	$1.5-2M
Status	In Progress
Time to Completion	2024
Funding Source	MVP

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	5
	Technical	5
	Political	4
	Legal	5
	Environmental	5
	Social	5
	Administrative	4
	Local Champion	4
	Other Community Objectives	4
Prioritization		**41**

A49. Moon Island Seawall Rehabilitation to Mitigate Coastal Hazards

Description	There are multiple ongoing projects to improve the resilience of Moon Island. The Streets Division is working on the causeway and street reconstruction project. The Fire Department is also assessing the emergency egress. Moon Island Seawall Rehabilitation design has begun through the Public Facilities Department.
Priority	H
Hazard Addressed	Flooding
Implementation Responsibility	Property Management Department, Neighborhood Development, BFD, Public Facilities
Cost	$1.5M
Status	In Progress
Time to Completion	2024
Funding Source	CZM Coastal Resiliency

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	5
	Technical	4
	Political	4
	Legal	3
	Environmental	4
	Social	4
	Administrative	4
	Local Champion	5
	Other Community Objectives	3
Prioritization		**36**

A50. Stabilize Coastal Bank Along the Eastern Side of Long Island

Description	Coastal erosion is encroaching on a non-operational electric substation adjacent to the Public Health Commission's campus. Design and construct bank stabilization and protection measures against sea level rise and coastal surge to protect muncipal assets.
Priority	H
Hazard Addressed	Flooding
Implementation Responsibility	Property Management Department, DCR
Cost	$7,000 to $10,000 per linear foot, likely $1M
Status	In Progress
Time to Completion	2025
Funding Source	CZM Coastal Resiliency

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	5
	Technical	4
	Political	4
	Legal	3
	Environmental	4
	Social	4
	Administrative	4
	Local Champion	5
	Other Community Objectives	3
Prioritization		**36**

A51. Update Storm Ready Certification with National Weather Service

Description	StormReady certification ensures that plans are in place to handle all types of extreme weather. The program encourages communities to take a new, proactive approach to improving local hazardous weather operations by providing emergency managers with clear-cut guidelines on how to improve their hazardous weather operations.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	OEM
Cost	Staff Time
Status	In Progress
Time to Completion	2023
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	3
	Technical	5
	Political	3
	Legal	5
	Environmental	3
	Social	4
	Administrative	4
	Local Champion	5
	Other Community Objectives	3
Prioritization		**26**

A52. Evaluate Feasibility of Mobilizing Passenger Ferries for Evacuation

Description	Ferries may be feasible option for evacuation of residents prior to a known hazard to support other forms of evacuation.
Priority	L
Hazard Addressed	Multi
Implementation Responsibility	OEM
Cost	Staff Time
Status	In Progress
Time to Completion	2023
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	2
	Technical	5
	Political	2
	Legal	2
	Environmental	3
	Social	3
	Administrative	2
	Local Champion	3
	Other Community Objectives	3
Prioritization		**33**

A53. Conduct a Study on the Vulnerability of the City Solar Storm Electromagnetic Pulses (EMPs)

Description	OEM could conduct a study to learn more about the City's vulnerability to this hazard, which could include creating an inventory of critical equipment vulnerable to EMPs. Faraday Cages could be a possible solution to protecting equipment from electromagnetic fields and would increase the resiliency of the communication network.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	OEM
Cost	Cage without redundant equipment -$40K - $50K; Cages with equipment- $500,000
Status	In Progress
Time to Completion	2030
Funding Source	City Funds, EMPG

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	3
	Technical	5
	Political	2
	Legal	5
	Environmental	3
	Social	3
	Administrative	5
	Local Champion	3
	Other Community Objectives	3
Prioritization		**38**

A54. Rutherford Ave/Charlestown Underpass – Replace Tunnel With Urban Boulevard and Drainage Improvements

Description	Finish the current construction on Rutherford Ave and assess area for future resiliency improvements.
Priority	H
Hazard Addressed	Multi
Implementation Responsibility	Boston Transportation Department
Cost	$100 M
Status	In Progress
Time to Completion	2030
Funding Source	Federal Highway Administration

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	4
	Technical	5
	Political	4
	Legal	5
	Environmental	3
	Social	5
	Administrative	3
	Local Champion	5
	Other Community Objectives	4
Prioritization		**33**

A55. Purchase Android- based Mobile GPS Tablets for ISD Inspectors

Description	Purchase tablets to streamline assessments and resiliency audits of buildings.
Priority	M
Hazard Addressed	Multi
Implementation Responsibility	ISD, DoIT
Cost	$30,000 (60 units * 500)
Status	Not Started
Time to Completion	2022
Funding Source	City Funds

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	4
	Technical	5
	Political	2
	Legal	5
	Environmental	3
	Social	4
	Administrative	4
	Local Champion	3
	Other Community Objectives	3
Prioritization		**33**

A56. Build Capacity of Fire Prevention Division

Description	Purchase an DHS FINDER. Assess feasibility of National Fire Prevention Association's FireWise Program for urban environmental education of homeowners on reducing brush and mulch fires. Enhance Fire Prevention Programs. Develop a Fire Life Safety Plan Program. Hire a LEPC Tier II Manager
Priority	M
Hazard Addressed	Fire
Implementation Responsibility	BFD
Cost	Staff Time
Status	Not Started
Time to Completion	2025
Funding Source	Staff Time

Evaluation Criteria Scoring (1-5)	Life Safety	3
	Property Protection	3
	Technical	5
	Political	3
	Legal	5
	Environmental	3
	Social	5
	Administrative	3
	Local Champion	3
	Other Community Objectives	4
Prioritization		**33**

A57. Assess the Risk of Water-Reactive Chemicals Stored in Flood-Prone Buildings to Mitigate Flood Hazards

Description	Assess the risk of both regulated chemical storage facilities (such as permitting underground storage tanks) and unregulated facilities (such as salons, dry cleaners, and other small businesses with chemicals) for risk to flooding and examine the storage practices. Provide recommendations for improvements. The Boston Fire Department works with businesses and individuals that store hazardous chemicals to ensure they will not present a greater hazard when environmental factors are considered.
Priority	M
Hazard Addressed	Flooding
Implementation Responsibility	BFD HAZMAT and BFD LEPC
Cost	Staff Time
Status	Not Started
Time to Completion	2025
Funding Source	Staff Time, HMEP Grant

Evaluation Criteria Scoring (1-5)		
	Life Safety	3
	Property Protection	3
	Technical	3
	Political	4
	Legal	3
	Environmental	5
	Social	5
	Administrative	4
	Local Champion	3
	Other Community Objectives	4
Prioritization		**33**

A58. Address Vulnerabilities to Tidal Flooding at McCormack and Dever Schools

Description	Complete recommendations identified in the informal assessment conducted by the insurance company to reduce risk to flooding, such as elevating critical infrastructure and addressing nearby flood pathway.
Priority	H
Hazard Addressed	Flooding
Implementation Responsibility	Property Management Department
Cost	$1M
Status	In Progress
Time to Completion	2035
Funding Source	BRIC

Evaluation Criteria Scoring (1-5)	Life Safety	4
	Property Protection	4
	Technical	5
	Political	5
	Legal	5
	Environmental	3
	Social	5
	Administrative	4
	Local Champion	3
	Other Community Objectives	5
Prioritization		**38**

EIGHT: PLAN ADOPTION AND MAINTENANCE

8.1 Plan Adoption

The City of Boston's 2021 NHMP was adopted by the City Council on [ADD DATE]. See Appendix E for supporting documentation. The plan was approved by FEMA on [ADD DATE] for a five-year period and will expire on [ADD DATE].

8.2 Plan Implementation and Maintenance

The ESC will use the improvements to existing mitigation measures identified in Chapter 5 and the hazard mitigation interventions identified in Chapter 7 as their action plan to improve the City's resilience to hazards. The departments and agencies responsible for implementation were identified for each hazard mitigation measure improvement or intervention in the previous chapters and will be responsible for championing the NHMP's implementation. Coordination with other City entities, the Metropolitan Area Planning Council, adjacent communities, local organizations, businesses, watershed groups, and state agencies will be essential for successful implementation and continual updates of the plan.

To track progress, OEM will coordinate quarterly check-ins. In the first two quarters of each subsequent year after the plan's approval, OEM will send out notices to the ESC and other partners responsible for plan implementation. The notice will include a shared document where everyone can collaborate to track progress, document hazard impacts, and identify future projects. The collaborative updates by the responsible parties will provide written documentation of progress, document new hazards and problem areas, and will help to capture institutional knowledge. The information collected throughout the year will be used to develop an annual progress report, which will be included as an addendum to the plan. In the second two quarters of each year, OEM will schedule group meetings with the responsible parties for

Fields Corner

coordination and planning purposes. The final two meetings will coincide with most department's annual budgetary efforts. Throughout the regular check-ins, priorities will also be updated or amended to meet the priorities of the current leadership and public input.

By continuously maintaining the 2021 NHMP, the City will have a competitive edge with their application when applying to FEMA for funding to update the plan. Once the resources have been secured to update the plan, the ESC will determine whether to undertake the update itself or hire a consultant. If the ESC decides to update the plan itself, the group will need to review the current FEMA hazard mitigation plan guidelines for any changes to the requirements since the last update. The updated draft of Boston's 2021 NHMP will be forwarded to MEMA for review and to FEMA for ultimate approval. The ESC will begin drafting the full update of the plan approximately four years from the date of this plan's approval. This will position the City to avoid a lapse in its approved plan status and grant eligibility when the current plan expires at the end of year five.

By continuously maintaining the 2021 NHMP, the City will have a competitive edge with their application when applying to FEMA for funding to update the plan.

8.4 Integration of the Plans with Other Planning Initiatives

The ESC will be responsible for ensuring that the NHMP is integrated into future plans and initiatives within their department, through their roles on various committees, and in coordination with other City departments and offices. Appropriate sections of the NHMP will be integrated into other City plans, policies, and documents as those are updated and renewed, including but not limited to the writing of, or updates to, Climate Ready Boston, the Urban Forest Plan, Heat Resiliency Study, the Open Space and Recreation Plan, the Comprehensive Emergency Management Plan, master planning efforts, and capital and operating budget planning. The integration of planning efforts will likely entail an alignment of goals and priorities.

8.3 Continuing Public Participation

The adopted plan, along with the annual progress reports, will be posted on OEM's website along with opportunities for the community to stay involved and an option to submit questions and comments. OEM will also work with the City's Department of Information Technology to discuss options for creating an online interactive tool that will track progress on plan implementation and will also function as a tool to crowd source data on natural hazard experiences as they occur throughout the City. The online tool could become a central place for City departments to centralize data collection, as well as a location for the community to remain involved. The City will also encourage local participation whenever possible during the next five-year planning and implementation cycle.

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