Appendices

Prepared for:

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Appendix 2.A:
Summaries and Descriptions of 2023 MA SHMCAP Meetings

Kickoff Meeting

The project kickoff was held on May 23, 2022, and included between 45 and 55 participants from the RMAT and contract team to discuss the task of updating and developing the 2023 SHMCAP. During the project kickoff, the RMAT members provided a vision of project success, including the useful materials, the final product, end users, and desired outcomes. The contract team, led by Eastern Research Group, Inc., introduced the technical leads and their roles, provided an overview of the stakeholder engagement plan, and provided an overall project timeline, including an introduction to the Vulnerability Assessment and Risk Assessment and mitigation strategy development.

RMAT Meeting #1: Introduction of 2023 SHMCAP Update Process, State Capability and Adaptive Capacity Analysis, and State Vulnerability Assessment

The first RMAT meeting, attended by between 60 and 70 participants, was held on July 26, 2022. The project team provided an overview of the approach for the 2023 update to the SHMCAP, including data, information, and documents to be included, FEMA's 2023 SHMP guidance, the workplan, and the draft 2023 SHMCAP outline. Meeting participants were provided the opportunity to identify best available data, information, and science, as well as documents that should be incorporated in the update.

The meeting also included the initiation of the State Capability and Adaptive Capacity Analysis and the State Agency Vulnerability Assessment. The project team facilitated discussion and gathered feedback on the Capabilities and Capacities chapter outlines and reviewed and discussed the state agency survey. The survey was described as a tool to capture data needed for the vulnerability and capability assessment to determine the issues and areas where agencies felt they had the necessary capabilities and capacities to address risk and build resilience across the Commonwealth, as well as the issues and areas where their agencies or the Commonwealth as a whole were lacking, including data, funding, expertise, authority, and other resources. Written feedback was requested for the document review framework after the meeting. Group discussion of agency capabilities, the survey process, past experiences, and lessons learned concluded the meeting. The meeting participants were given the opportunity to provide feedback in the meeting and were also given a week to review and respond to material provided to them after the meeting.

RMAT Meeting #2: State Agency Survey and Discussion of 2023 SHMCAP Mission and Goals

The second RMAT meeting occurred on September 14, 2022, and was attended by between 90 and 110 participants and support staff. The project team led a discussion about the State Agency Vulnerability Assessment survey administration, duration, and response collation. The survey overview was followed by an open discussion to allow time for questions about the survey purpose, roles, and process timeline. The project team then walked through a list of definitions to provide information for completing the survey, discussed changes made to the survey based on participant feedback, and highlighted example survey questions. The latter half of the meeting involved a team-led overview of the 2023 SHMCAP mission and goal setting process followed by a group discussion of the mission and breakout groups to discuss goals. Participants reconvened for a brief report-out session from the breakout rooms. In addition to an invitation to provide feedback on the goals during the meeting, the RMAT received a copy of the goals and the opportunity to provide direct feedback within a week of the meeting.

RMAT Meeting #3: Introduction of Risk Assessment

The third RMAT meeting was held on November 8, 2022, and was attended by between 60 and 70 participants and support staff. The project team polled attendees to request feedback on the second draft of the Risk Assessment Problem Statements, capture general sentiment on the vulnerabilities and consequences including climate influences and projections associated with each hazard, and invited feedback to consider incorporating into the problem statements. The project team then introduced the process for the 2023 SHMCAP Risk Assessment, including:

- Role and purpose of the Risk Assessment.
- Data, information, and science informing the Risk Assessment.
- Proposed approach and methodology.
- Updates to 2018 Risk Assessment.
- Role of MA Climate Assessment.

Following a period for questions, participants entered breakout rooms by sector for small group discussions on the Risk Assessment early findings, approach, and methodology. A brief report-out session was held with all participants before the meeting wrap-up discussion and conclusion.

RMAT Meeting #4: Risk Assessment Update and Introduction to Action Development

The fourth RMAT meeting occurred on January 24, 2023, and was attended by between 60 and 70 participants and support staff. The project team provided an overview of the 2023 SHMCAP Risk Assessment development process and review timeline and presented an overview of hazards (results of the hazard snapshot analysis). This section highlighted the magnitude, scale, and consequence of high-consequence hazards (e.g., hurricanes, inland and coastal flooding, extreme temperature), which was followed by an overview of the framework and process for developing actions to address high-consequence vulnerabilities and priority impacts. The meeting ended with the initiation of the first round of action development, which was intended to be a brainstorming session. To begin Round 1 of action development, the project team facilitated a discussion around the following questions:

- Considering your agency’s roles and responsibilities, what new actions can your agency lead or support to address priority impacts and high-consequence vulnerabilities?

- Do any of your 2018–2020 SHMCAP actions address these impacts and vulnerabilities?
- What actions can your agency and others take to address these impacts and vulnerabilities?

After reconvening, participants were tasked with completing Round 1 of action development, in which they were responsible for:

1. Considering the agency's role, review the priority impacts and vulnerabilities to determine which agency should lead, support, partner, or not participate.
2. Providing a status update on 2018 SHMCAP actions and evaluating the need to refine or remove 2018 actions based on the agency's ability to address priority impacts and vulnerabilities. The participants were also asked to identify agency actions developed since 2020 and evaluate the need to refine or remove those actions based on the agency's ability to address priority impacts and vulnerabilities.
3. Develop new, high-level actions to respond to priority impacts and vulnerabilities.

RMAT Meeting #5: Review of Statewide Actions and Next Steps in Action Development

The fifth RMAT meeting occurred on March 15, 2023, and was attended by between 50 and 60 participants. The project team began with an update on the status of 107 total actions from 2018 and a synthesis of approximately 120 actions proposed for the 2023 SHMCAP by action type, geographic region, and consistency with 2023 SHMCAP goals. This was followed by a brief recap of qualitative findings on perceived gaps based on the Capability and Capacity Analysis, Risk Assessment, and Vulnerability Assessment, and an overview of next steps for Round 2 of action development, including addressing the following:

- Identify gaps between priority impacts/vulnerabilities and the current proposed actions, with a focus on identifying where there are no actions or a small number of actions related to urgent priority impacts and other high-consequence vulnerabilities.
- Assess the consistency of actions with 2023 SHMCAP goals, including disproportionate impacts, adaptability to increasing risks due to climate change, and reduction of risks to critical assets, lifelines, and underserved communities. Use performance metrics to evaluate progress in achieving goals.

The majority of the meeting was spent in a working session to help develop and refine the draft cross-government actions intended to reduce risk across state government and the Commonwealth. Participants used an interactive whiteboarding tool to respond to the following questions:

- How can these cross-government actions make it easier for your agency to advance climate resilience and hazard mitigation?
- What modifications should be made to these cross-government actions to make them more relevant to your agency's priorities and concerns?

- How can these cross-government actions help reduce risks for socially vulnerable communities?
- Who should be part of the partnership to implement these cross-government actions?
- How would Massachusetts work with local jurisdictions and interested parties to implement these cross-government actions?
- What additional types/topics of cross-government actions should be considered in the 2023 SHMCAP?

Participants reconvened for a brief overview of the project timeline, including the discussion of next steps for Round 3 of action development, which included the following:

1. Agencies were asked to refine actions and develop any additional actions as needed. During this step, agencies were to consider the input and comments received from the stakeholder meetings and revise actions as needed.
2. Agencies were asked to complete an Action Scorecard to assist with prioritizing actions and modifying actions as needed.
3. Agencies were asked to provide their final actions (including those signed off by agency leadership) by April 28.

RMAT Meeting #6: Action Development Report Out, Description of the Strategy and Ongoing Maintenance

The sixth and final RMAT meeting was held on May 31, 2023, and was attended by between 50 and 60 participants. The meeting served as a final report-out on the cross-government and state agency actions and themes in addition to the strategy, implementation, and plan maintenance. During the meeting, the project team presented on the following:

- Recap of the three rounds of action development
- Summary of cross-government actions by goal
- Strategy development
  - 2023 SHMCAP types of actions
  - State agency action topics and detailed examples of state agency actions, organized by priority impacts
- 2023 SHMCAP Implementation
  - Feedback from municipal, NGO, and community focus group meetings
  - Consideration for future opportunities during action implementation
- Maintenance process and schedule, including the action tracker, annual meetings, and meetings for plan implementation and maintenance.

Lastly, the project team asked the participants about where there are opportunities to engage with RMAT moving forward and ways that MEMA/EEA could best support RMAT. The project team concluded the meeting by highlighting next steps for submitting the plan to FEMA and the next RMAT meeting, tentatively scheduled for the summer of 2023.

One-on-One Agency Meetings with MEMA and EOEEA

Between Round 2 and Round 3 of action development, MEMA and EOEEA held thirteen one-on-one meetings with individual state agencies to support agency action development, with a focus on closing gaps on priority impacts, refining actions, coordinating actions among agencies, increasing the level of detail, and supporting agencies who had questions or needed additional assistance with the process. Meetings were held with the following agencies:

- Executive Office for Administration and Finance (EOA&F)
- Executive Office of Energy and Environmental Affairs
- Executive Office of Housing and Economic Development (EOHED)
- Executive Office of Labor and Workforce Development (EOLWD)
- Executive Office of Public Safety and Security (EOPSS)
- Executive Office of Technology Services and Security (EOTSS)
- Massachusetts Bay Transit Authority (MBTA)
- Massachusetts Department of Conservation and Recreation (DCR)
- Massachusetts Department of Environmental Protection (DEP)
- Massachusetts Department of Housing and Community Development (DHCD)
- Massachusetts Department of Public Health (DPH)
- Massachusetts Department of Transportation (MassDOT)
- Massachusetts Division of Capital Asset Management and Maintenance (DCAMM)
- Massachusetts Division of Fisheries and Wildlife (MassWildlife)
- Massachusetts Office of Coastal Zone Management (CZM)

Risk Assessment subject matter expert meetings

The Risk Assessment was informed by state agency input through RMAT meetings, several rounds of reviews, and one-on-one meetings with subject matter experts. The project team held one-on-one meetings with federal, state, and regional subject matter experts recommended by the PMT and state agency experts. The feedback provided during the meetings assisted with identifying the best available data, clarifying and refining the understanding of who and what was most vulnerable, and identifying the characteristics of that vulnerability. For example, through meetings with subject matter experts, the project team identified a recent update to soils data in the Commonwealth. The soils data were used in the second round of Hazus analysis for the earthquake assessment and refined the understanding of the vulnerability across the Commonwealth depending on soil type present. The following one-on-one meetings with subject matter experts were held in support of the Risk Assessment:

- Wildfire risk discussion with the State Fire Warden, Dave Celino, and other DCR representatives.
- Hazards resulting from changes in groundwater with the Metropolitan Area Planning Council and Dr. David Boutt with the University of Massachusetts Amherst.
- Earthquakes were discussed with Dr. Laurie Baise and Marshall Pontrelli with Tufts University and Dr. Stephen Mabee with University of Massachusetts Amherst, and Dr. John Ebel with Boston College.
- Hurricanes were discussed with Joe Famely at Woods Hole Group. This discussion informed the decision to use SLOSH data to evaluate storm surge inundation and Hazus for wind speed damage estimates.

In addition to Risk Assessment discussions during the third and fourth RMAT meetings, state agencies had the opportunity to review problem statements and hazard profiles and provide comments and recommendations for refinements. State agencies and subject matter experts had two opportunities to review the Risk Assessment. The first review cycle of a preliminary draft of the Risk Assessment began on December 15, 2022, and was reviewed by subject matter experts. The first draft of the Risk Assessment, which was provided to reviewers on January 31, 2023, incorporated input from the subject matter experts and added RMAT members and other key reviewers. A third draft, which incorporated the review and recommendations of the subject matter experts and the RMAT members, was shared with the Office of Climate Innovation and Resilience in late April 2023.

Office Hours

In addition to the meetings highlighted above, drop-in optional office hours were held to provide assistance to agencies and answer any questions regarding the survey and action development worksheet. Office hour date and topics included:

- October 6, 19, 26, 2022 – Capacity and Capabilities Assessment, State Agency Vulnerability Assessment
- February 9, 15, 2023 – Round #1 Action Development
- March 23, 2023 – Round #2 Action Development
- April 14, 25, 2023 – Round #3 Action Development

Coordination with Municipalities, Regional Planning Agencies, NGOs, Communities, and Others

In addition to engagement with state agencies, subject matter experts, and other key partners, the 2023 SHMCAP and MA Climate Assessment included engagement with municipalities, regional planning agencies, NGOs, community representatives, and others. For more detail on the engagement included as part of the MA Climate Assessment, refer to Section 2.2 of the MA Climate Assessment. A full list of entities engaged in the planning process is available in Appendix 2.B.

Municipalities, Regional Planning Agencies, and NGOs

As part of stakeholder engagement, EOEEA and MEMA led two statewide engagement meetings in April 2023 focused on municipal, regional, NGO, and other interested parties. The objectives of these meetings were to:

- Gather local, regional, and stakeholder input regarding cross-government actions to guide the Commonwealth's resiliency and hazard mitigation priorities.
- Vet draft cross-government actions developed by state agencies with key local government and NGO partners.
- Refine actions based on local, regional, and stakeholder input to ensure that they are effective strategies to address the most urgent adaptation and hazard mitigation gaps and are implementable by local partners, where applicable.

The same meeting material was presented at two different meetings, held on April 4 and April 6, 2023. The first meeting included 86 participants and the second meeting included 46 participants, representing municipalities, regional planning commissions, nonprofits, and private industries. The meetings were held for two hours. The first hour was used to provide background information on the 2023 SHMCAP and related planning efforts, including the MA Climate Assessment. The second hour was dedicated to small breakout group discussions on cross-government actions. The actions were grouped into four categories: funding and finance; strategy, planning, and codes; collaboration, engagement, and education, and assessment and research. The project team moderated the breakout groups and asked participants (1) whether the proposed actions address the types of risks that their community is concerned about, (2) for suggestions to improve the action to better assist their community, and (3) to generate ideas for additional actions that they would like to see the Commonwealth take to reduce risk and increase resilience. Meeting participants were largely in favor of the proposed actions and felt that the actions aligned with the hazards and issues their communities face. A summary of feedback collected through the meeting included the following:

- Suggest sharing all tools and data with municipalities to use for their own planning processes and tailor to address local needs.

- Suggest incorporating more public engagement with these actions, particularly in small communities.
- The actions should prioritize equity for vulnerable populations.
- Communities need additional sources of funding for resilience planning, including cost matches, because the cost of grant application and management processes can be prohibitive.
- Suggest increasing the total amount of funding to the MVP program to be able to fund more projects.
- Revise codes and regulations to increase flexibility to support resilience projects and strategies.
- Improve the regulatory review and permitting process for pilot climate adaptation and ecological restoration projects (e.g., cranberry bog or saltmarsh restoration).
- Use pilot projects to test some of the proposed actions (e.g., school curriculum, mobile solar energy systems).

The full list of comments and recommendations collected from participants regarding cross-government actions during the two meetings are presented in Appendix 2.C.

Community Focus Groups

Throughout the development of the 2023 SHMCAP, the Commonwealth contracted with local small businesses, LyRyv Consultants, and Marcos Luna (an independent contractor) to lead community focus group meetings to gain input from local and regional community groups and organizations, some of which were involved with the MA Climate Assessment, regarding the proposed actions. During April 2023, the project team met with nine community organizations and NGOs, totaling 21 individuals, including representatives from the following entities:

- A Better City
- Boston Climate Action Network
- Change is Simple
- Commonwealth Green Low-Income Housing Coalition (CGLIHC)
- Mothers Out Front
- Mystic River Watershed Association (MyRWA)
- Neighbor to Neighbor
- Public Health Institute of Western Massachusetts (PHI WM)
- Quincy Climate Action Network

Throughout the engagement process, the community groups provided the following high-level feedback:

- The Commonwealth needs to support more education on climate change and hazard preparedness, utilize more creative avenues for that education (e.g., schools, community liaisons, community-based organizations), and reframe communication in ways that are relevant and understandable to non-experts.
- Schools and education to schoolchildren are underutilized resources for effective community education on climate and other hazards.
- Language interpretation and translation is critical and needs to be integrated into all state outreach and communication.
- The Commonwealth should utilize NGOs or consultants with legitimate expertise in community outreach and education, and take expertise of outreach more seriously.
- The Commonwealth needs to improve equitable access to energy efficiency and renewable energy program incentives for residents with lower incomes, renters, and non-English-speaking residents, and to improve contracting and employment in clean energy transition for smaller businesses and contractors in historically underserved communities.
- The Commonwealth needs a regional planning entity that can complement municipal vulnerability planning and coordinate decision-making across multiple municipalities in a region with common concerns.
- The Commonwealth should prioritize climate solutions with multiple co-benefits, especially for vulnerable communities.

Notes from the NGO and Community Focus Group meetings are presented in Appendix 2.C.

Appendix 2.B:
List of Agencies Participating in the 2023 MA SHMCAP

- Commonwealth Corporation
- Executive Office for Administration and Finance (EOA&F)
- Executive Office of Education (EOE)
- Executive Office of Elder Affairs
- Executive Office of Energy and Environmental Affairs
- Executive Office of Health and Human Services (EOHHS)
- Executive Office of Housing and Economic Development (EOHED)
- Executive Office of Labor and Workforce Development (EOLWD)
- Executive Office of Public Safety and Security (EOPSS)
- Executive Office of Technology Services and Security (EOTSS)
- Executive Office of Veterans Services
- Massachusetts Appellate Tax Board (ATB)
- Massachusetts Bay Transit Authority (MBTA)
- Massachusetts Board of Registration in Medicine
- Massachusetts Bureau of Geographic Information (MassGIS)
- Massachusetts Bureau of the State House (BSH)
- Massachusetts Civil Service Commission (CSC)
- Massachusetts Commission for the Blind (MCB)
- Massachusetts Department of Agriculture (MDA)
- Massachusetts Department of Agriculture – State Reclamation Mosquito Control Board
- Massachusetts Department of Career Services (DCS)
- Massachusetts Department of Children and Families (DCF)
- Massachusetts Department of Correction (DOC)
- Massachusetts Department of Conservation and Recreation (DCR)
- Massachusetts Department of Conservation and Recreation Office of Dam Safety (DSO)
- Massachusetts Department of Conservation Services (DCS)
- Massachusetts Department of Criminal Justice Information Services (DCJIS)
- Massachusetts Department of Developmental Services (DDS)
- Massachusetts Department of Early Education and Care (EEC)
- Massachusetts Department of Elementary and Secondary Education (ESE)
- Massachusetts Department of Energy Resources (DOER)

- Massachusetts Department of Environmental Protection (MassDEP)[1]
- Massachusetts Department of Family and Medical Leave
- Massachusetts Department of Fire Services (DFS)
- Massachusetts Department of Housing and Community Development (DHCD)
- Massachusetts Department of Industrial Accidents (DIA)
- Massachusetts Department of Labor Relations (DLR)
- Massachusetts Department of Labor Standards (DLS)
- Massachusetts Department of Mental Health (DMH)
- Massachusetts Department of Public Health (DPH)
- Massachusetts Department of Public Utilities (DPU)
- Massachusetts Department of Revenue (DOR)
- Massachusetts Department of Telecommunications and Cable (DTC)
- Massachusetts Department of Transitional Assistance (DTA)
- Massachusetts Department of Transportation (MassDOT)
- Massachusetts Department of Transportation – Rail and Transit Division
- Massachusetts Department of Unemployment Assistance (DUA)
- Massachusetts Department of Veterans' Services (DVS)
- Massachusetts Department of Youth Services (DYS)
- Massachusetts Division of Administrative Law Appeals (DALA)
- Massachusetts Division of Apprentice Standards (DAS)
- Massachusetts Division of Capital Asset Management and Maintenance (DCAMM)
- Massachusetts Division of Ecological Restoration (DER)
- Massachusetts Division of Fisheries and Wildlife (MassWildlife)
- Massachusetts Division of Insurance (DOI)
- Massachusetts Division of Marine Fisheries (DMF)
- Massachusetts Division of Standards (DOS)
- Massachusetts Emergency Management Agency (MEMA)
- Massachusetts Environmental Police (MEP)
- Massachusetts Environmental Policy Act Office (MEPA)
- Massachusetts Group Insurance Commission (GIC)

[1] A meeting was held with the Chief Fire Warden relating to wildfire risk in the state and the Wildfire section of the Risk Assessment received review and comment.

- Massachusetts Historical Commission (MHC)
- Massachusetts Human Resources Division (HRD)
- Massachusetts Municipal Police Training Committee (MPTC)
- Massachusetts National Guard (MANG)
- Massachusetts Office of Business Development (MOBD)
- Massachusetts Office of Climate Innovation and Research (OCIR)
- Massachusetts Office of Coastal Zone Management (CZM)
- Massachusetts Office of Consumer Affairs and Business Regulation (OCABR)
- Massachusetts Office of Disability (MOD)
- Massachusetts Office of Fishing and Boating Access (OFBA)
- Massachusetts Office of International Trade and Investment (MOITI)
- Massachusetts Office of Public Safety & Inspections (OPSI)
- Massachusetts Office for Refugees and Immigrants (ORI)
- Massachusetts Office of the Chief Medical Examiner (OCME)
- Massachusetts Office of Travel and Tourism (MOTT)
- Massachusetts Operational Services Division (OSD)
- Massachusetts Parole Board
- Massachusetts Permit Regulatory Office (MPRO)
- Massachusetts Port Authority (Massport)
- Massachusetts Public Employee Retirement Administration Commission (PERAC)
- Massachusetts Rehabilitation Commission (MRC)
- Massachusetts Sex Offender Registry Board (SORB)
- Massachusetts State 911 Department
- Massachusetts State Police Crime Lab (MSPCL)
- MassHealth
- Soldiers' Home in Chelsea
- Soldiers' Home in Holyoke
- State Library of Massachusetts

Appendix 2.C:
2023 MA SHCMAP RMAT Meeting Materials

2023 MA SHMCAP
Kick off Call

Massachusetts SHMCAP Update

Kickoff Meeting
May 23, 2022

Agenda

- Welcome and Introductions (20 minutes)
- Vision of success for the Commonwealths' 2023 SHMCAP (20 minutes)
  Whiteboard activity:
    - What does success look like from a process perspective?
    - What does a successful final product look like?
    - How would a successful SHMCAP be used to advance your priorities? Who would use it?
- Workplan discussion (60 minutes)
  - Timeline (5 minutes)
  - Stakeholder engagement plan (10 minutes)
    - Workshop timeline and connection to tasks
  - Task A2- Develop Outline, Data Collection Tools and Frameworks (10 minutes)
  - Task A3 – Supplementary risk assessment (10 minutes)
  - Task A4 - State Agency Vulnerability Assessment (10 minutes)
  - Task A5 - Hazard Mitigation and Climate Adaptation Strategy (5 minutes)
  - Task A6 - Plan Maintenance, Review, Evaluation, and Implementation (5 minutes)
  - Task A7 – Compile and Finalize SHMCAP (5 minutes)
- Next steps (15 minutes)
  - Draft/final work plan
  - July RMAT meeting
  - Questions for RMAT

Defining project success

What does success look like from a process perspective?

What does a successful final product look like?

How would a successful SHMCAP be used to advance your priorities? Who would use it?

Project team structure

Massachusetts Emergency Management Agency

Management Team

Charles Goodhue
Project Manager, Task 1 Lead

Lindy Lowe
Technical Lead, Task 5 and 6 Lead

Hannah Stroud
Deputy Project Manager

Cristina Ruiz
Deputy Technical Lead

Expert advisors

Jim Neumann (IEc)
MA Climate Assessment

Kirk Bosma (WHG)
Coastal Modeling

Arleen O'Donnell
Hazard Mitigation Policy

Elizabeth Cooper (CBI)
Expert Facilitator

Lydia Rivera (LydRiv)
DOT and Stakeholder Engagement

Paul Kirshen †
Climate Adaptation

Ellen Douglas †
Natural Hazards & Vulnerability

Marcos Luna †
Environmental Justice

Jennifer Lam
Task 2 Lead

Eliza Berry
Task 3 Lead

Diana Pietri
Task 4 Lead

Chris Lamie
Task 7 Lead

Shanika Amarakoon
Stakeholder Engagement Lead (Task 5)

Support Staff

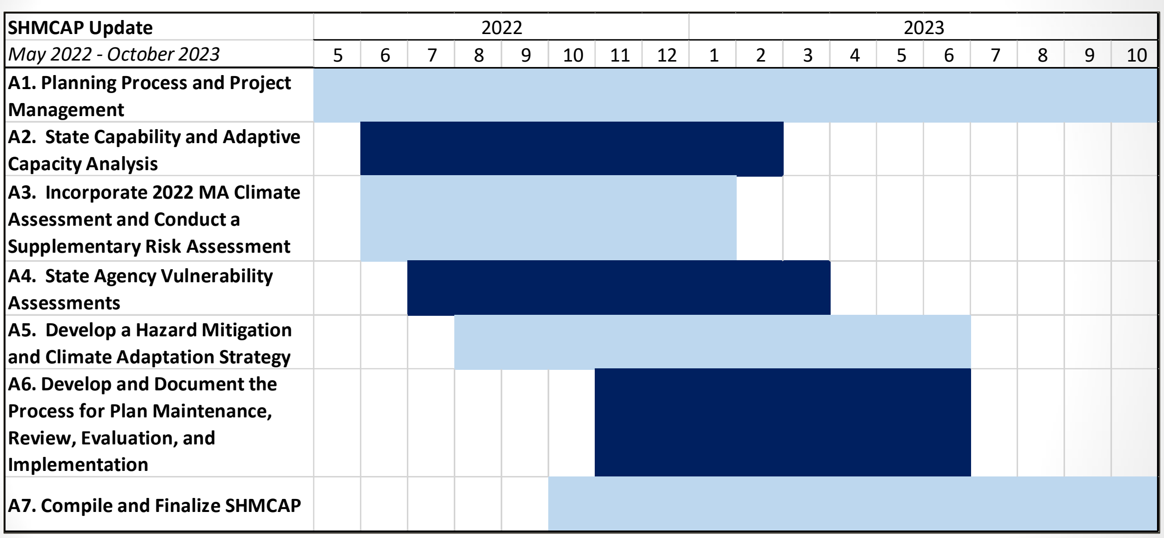
ERG: Alexa Sears, AnnaClaire Marley, Caitline Barber, Clara Berger, Diana Pietri, Eliza Berry, Evan Fago, Heather Perez, Jennifer Lam, Kellie DuBay, Matt Mitchell, Sylvia Chang, Sumayal Shrestha, Sean van der Heijden
IEc: Brent Boehlert, Charles Fant, Hayley Kunkle, Jacqueline Willwerth, Kenneth Strzepek, Karen Noiva, Lena Flannery
Woods Hole Group (WHG): Brittany Hoffnagle, Conor Ofsthun, Joe Famely, Leslie Fields, Matthew Schultz, Melissa Jaffe, Nasser Brahim
CBI: Ona Ferguson

Approach

<u>2023 SHMCAP</u>
<u>Proposed Enhancements</u>

- Expand assessment of assets beyond physical and municipal assets
- Include climate justice and sustainability in goals and objectives
- Promote meaningful internal and external stakeholder engagement
- Implement rigorous prioritization approach
- Develop implementation roadmaps and adaptation pathways

Timeline



Stakeholder Engagement

RMAT Workshops

1. (A2, A4) Review Capabilities Analysis outline and Vulnerability Assessment methodology
2. (A2, A4) Review draft assessment tools for Capabilities Analysis and second draft of Vulnerability Assessment methodology
3. (A4) Virtual training on survey
4. (A2) Present key findings of survey
5. (A2, A4) Feedback on first drafts of Capabilities Analysis and Vulnerability Assessment
6. (A2, A4) Feedback on first drafts of Capabilities Analysis and Vulnerability Assessment
7. (A6) Plan Maintenance development

Stakeholder Workshops
(under Task A5)

1. Stakeholder Kickoff
   - Build shared understanding across all levels.

2 – 5. Subgroup Workshops
   - Subgroups by hazard and/or agency purview
   - Fill knowledge gaps identified in first stages of project.

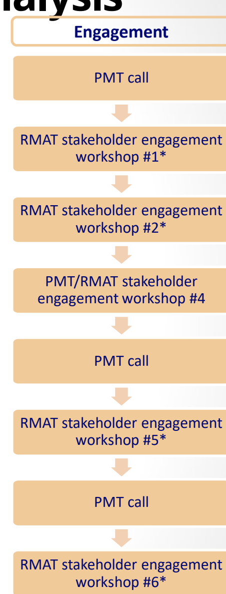
6. Closing Workshop on Draft SHMCAP
   - Solicit feedback on draft results

Stakeholders will represent agencies/organizations at local, state, regional, and federal levels.

A2 State Capability and Adaptive Capacity Analysis

Key Steps

- **Develop Outline, Data Collection Tools and Frameworks**
  - Report outline
  - Document review framework
  - Online survey *(administered jointly with A4 survey)*, interview tool, and invitee/interviewee lists
  - Funding framework
- **Collect and Analyze Data**
  - Gather input on key capabilities and adaptive capacity *(online survey, interviews, document review).*
    - E.g., planning, regulatory, administrative, technical, capital projects and asset management, financial, education, outreach, capacity building
  - Inventory existing federal, state, and local funding sources that could support climate adaptation and hazard mitigation *(funding database).*
- **Draft and Finalize Report**
  - Two rounds of review



**combined meeting with A4.*
Note Workshop #3 occurs in A4.

A2 State Capability and Adaptive Capacity Analysis (cont.)

Deliverables

- State Capability and Adaptive Capacity Analysis Report outline
- Document review database
- Online survey and interview tool and participant lists
- Funding research database
- Draft 1 report
- Draft 2 report
- Final report

A2 State Capability and Adaptive Capacity Analysis (cont.)

Specific questions for RMAT

- **Are there lessons learned/best practices from past Commonwealth and/or agency efforts** on engaging state and local agency and tribal representatives and promoting a high response rate for surveys and interviews?

- **Are there any documents that have been published or changed since 2017** that we should include in the document review?

- **Are there are any funding strategies** that existing agencies have developed that can inform the funding inventory effort?

A3 Supplementary Risk Assessment

Key Steps

- **Develop Hazard Analysis and Hazard Profile**
  - Use the climate projections developed for the Climate Risk Assessment.
- **Analyze Additional Hazards**
  - Determine additional hazards.
  - Conduct a literature review and targeted interviews.
- **Analyze Changes in Development and Requirements**
  - Review available land use projections.
  - Rely on the best available information on forecast population demographics.
  - Review resilient building codes focused on critical hazards..
- **Assess Hazard Impacts, Risk, and Vulnerability Analysis**
  - Use urgency scoring will help us to focus development of the action strategy.
  - Develop a Supplementary Risk Assessment and a one-page risk assessment synopsis.
  - Two rounds of review.

A3 Supplementary Risk Assessment (cont.)

Deliverables

- Supplemental Risk Assessment and Synopsis Draft 1
- Supplemental Risk Assessment and Synopsis Draft 2
- Final Supplemental Risk Assessment and Synopsis

A3 Supplementary Risk Assessment (cont.)

Specific questions for RMAT

- The RFP called out specific hazards that were not included in the Climate Assessment - **earthquake, ground failure, and tsunami hazards** – is there anything missing?
  - Have any of your organizations conducted analyses on any of these hazards
- **Are there any agency specific documents** regarding the hazards that we should review?

A4 State Agency Vulnerability Assessments

Key Steps

- **Develop Outline, Data Collection Tools and Frameworks**
  - Report outline
  - Document review framework
  - Online survey (*to be administered jointly with A2 survey*)
- **Collect and Analyze Data**
  - Work with the PMT and climate coordinators to engage and promote a high response rate for surveys
  - Train RMAT in survey purpose, structure, and content
  - Identify key state agency assets, functions, missions, and services that will be affected by natural hazards and climate change
  - Determine recommended actions for state agencies to reduce vulnerabilities
- **Draft and Finalize Vulnerability Assessment Summary Report**
  - Two rounds of review

Engagement

PMT call
↓
RMAT stakeholder engagement workshop #1*
↓
RMAT stakeholder engagement workshop #2*
↓
RMAT stakeholder engagement workshop #3
↓
PMT call
↓
RMAT stakeholder engagement workshop #5*
↓
PMT call
↓
RMAT stakeholder engagement workshop #6*

**combined meeting with A2*

A4 State Agency Vulnerability Assessments (cont.)

Deliverables

- State agency vulnerability assessment report outlines (for state agency-specific reports and for summary report)
- State vulnerability assessment methodology (including document review database and online survey tools)
- State agency vulnerability reports
- Draft 1 summary report
- Draft 2 summary report
- Final summary report

A4 State Agency Vulnerability Assessments(cont.)

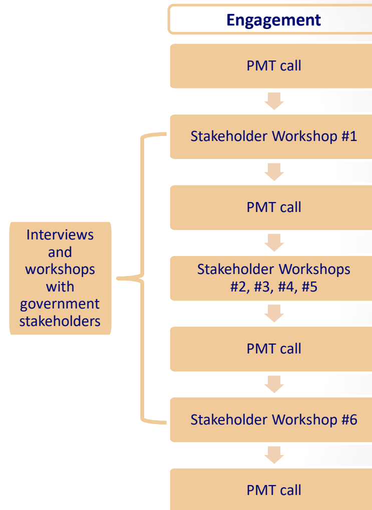
Specific questions for RMAT

- **Are there lessons learned/best practices** from the 2018 SHMPCAP state vulnerability assessment survey?
- **What additional documents**, beyond those listed in the RFP and ERG's proposal, should we review? **In addition to those listed below:**
  - 2018 SHMCAP State Vulnerability Assessments
  - Statewide Resilience Master Plan
  - Climate Resilience Design Standard Tools
  - DPH 2014 Report: Capacity to Address the Health Impacts of Climate Change in Massachusetts
  - MassDOT-FHWA Pilot Project Report: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery
  - 2017 Great Marsh Coastal Adaptation Plan
  - Massachusetts 2015 State Wildlife Action Plan
  - Chapter 5: Climate Change and Massachusetts; Species of Greatest Conservation Need
- **Have any agencies conducted** a vulnerability assessment since 2018?

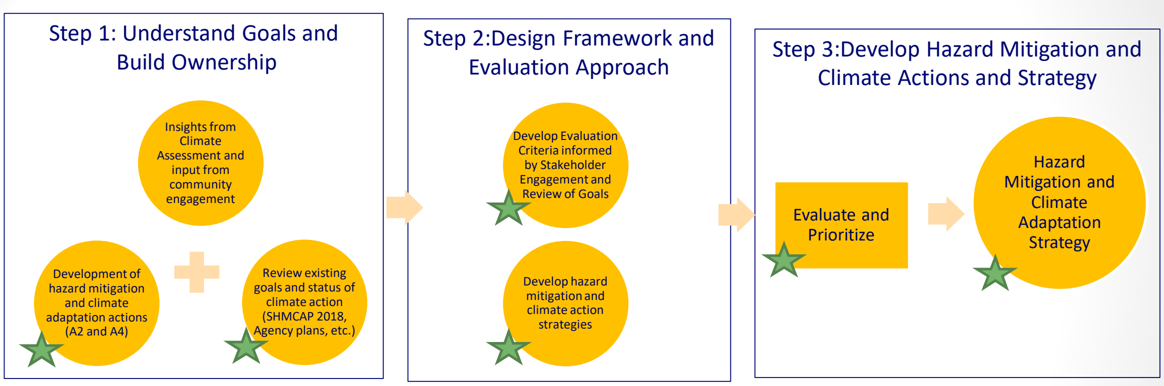
A5 Hazard Mitigation and Climate Adaptation Strategy

Key Steps

- **Develop and Refine Goals**
  - Workshop #1: Kick-off meeting with key agency representatives
- **Draft Hazard Mitigation and Climate Adaptation Actions and Evaluation Criteria**
  - Three focused workshops for subgroups focused on focus areas
- **Framework for Hazard Mitigation and Climate Adaptation Strategy**
- **Evaluate and Prioritize Actions**
- **Draft strategy and list of actions**
  - Closing workshop to solicit input from key agency and government representatives
- **Finalize strategy and list of actions**



A5 Hazard Mitigation and Climate Adaptation Strategy (cont.)



Deliverables

- Documented understanding of goals and priorities across stakeholders
- Engagement design and implementation documents (agendas, worksheets, summary notes)
- Evaluation criteria (draft and final)
- Revised and final Strategy

Stakeholder Engagement

A5 Hazard Mitigation and Climate Adaptation Strategy

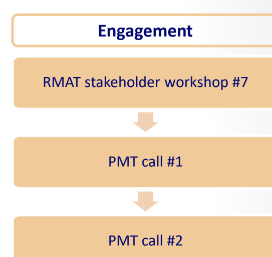
Specific questions for RMAT

- **Who are the key agencies, departments, and leaders** who are or will be engaging in hazard mitigation and/or climate adaptation actions in the next ten years?
- Are there **agency or regional level climate mitigation** and adaptation strategies or lists of adaptation actions that have been developed since 2018?
- **What documents or offices** reflect state, agency, regional level priorities and goals when it comes to climate adaptation?

A6 Plan Maintenance, Review, Evaluation, and Implementation

Key Steps

- **Review 2018 SHMCAP Maintenance Process**
  - Review of proposed maintenance plan and process in 2018 SHMCAP
- **Hold Engagement Workshop**
  - Discuss successes, challenges, and lessons learned from 2018 SHMCAP with RMAT
  - Identify timeline, milestones, roles, and responsibilities for implementation, review, and evaluation of the Plan
  - Specify metrics, outcomes, and expected monitoring, evaluation, and learning process
  - Share a straw proposal for the components of the new maintenance plan with RMAT and receive feedback
- **Develop and Revise Maintenance Plan Document**
  - Two rounds of review



A6 Plan Maintenance, Review, Evaluation, and Implementation (cont.)

Deliverables

- Draft 1 maintenance plan document
- Draft 2 maintenance plan document
- Final maintenance plan

A6 Plan Maintenance, Review, Evaluation, and Implementation (cont.)

Specific questions for RMAT

- **Are there lessons learned/best practices** from developing the 2018 SHMCAP maintenance plan or from implementing the maintenance plan?
- **How can this maintenance plan be designed** to be an effective tool for your agency?

A7 Compile and Finalize SHMCAP

Key Steps

- **Advanced preparation**
  - Identify audiences
  - Develop product samples for feedback and preferences
  - Early design work to improve ease of use, and identify opportunities for an interactive, and dynamic approach
  - Develop content outline with FEMA's Enhanced State Plan requirements in mind
  - Gather design input, including feedback on 2018 SHMCAP
  - Determine editorial preferences and design standards
- **Compile and Review**
  - FEMA Review tool
  - Two rounds of review with PMT
- **Finalize all formats and 508 PDFs**

Deliverables

- Completed FEMA State Hazard Mitigation Review Tool
- Draft 1 of SHMCAP
- PMT Call
- Draft 2 of SHMCAP
- PMT and FEMA Region 1 Call
- Final plan for promulgation
- Final plan in all formats

Next Steps

Draft and Final Work Plan

- Draft work plan submitted by June 3, 2022
- Comments provided to contract team by June 10, 2022
- Final work plan June 15, 2022

RMAT July Meeting – RMAT Workshop 1

- July 26, 2022 from 2:00pm-3:30pm ET

Next Steps

Questions for RMAT

A2 - State Capability and Adaptive Capacity Analysis

- Are there lessons learned/best practices from past Commonwealth and/or agency efforts on engaging state and local agency and tribal representatives and promoting a high response rate for surveys and interviews?
- Are there any documents that have been published or changed since 2017 that we should include in the document review?
- Are there are any funding strategies that existing agencies have developed that can inform the funding inventory effort?

A3 - Supplementary Risk Assessment

- The RFP called out specific hazards that were not included in the Climate Assessment - earthquake, ground failure, and tsunami hazards – is there anything missing?
- Have any of your organizations conducted analyses on any of these hazards
- Are there any agency specific documents regarding the hazards that we should review?

A4 -State Agency Vulnerability Assessments

- Are there lessons learned/best practices from the 2018 SHMPCAP state vulnerability assessment survey?
- What additional documents, beyond those listed in the RFP and ERG's proposal, should we review? In addition to those listed below:
  - 2018 SHMCAP State Vulnerability Assessments
  - Statewide Resilience Master Plan
  - Climate Resilience Design Standard Tools
  - DPH 2014 Report: Capacity to Address the Health Impacts of Climate Change in Massachusetts
  - MassDOT-FHWA Pilot Project Report: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery
  - 2017 Great Marsh Coastal Adaptation Plan
  - Massachusetts 2015 State Wildlife Action Plan
  - Chapter 5: Climate Change and Massachusetts; Species of Greatest Conservation Need

Next Steps

Questions for RMAT

A5 - Hazard Mitigation and Climate Adaptation Strategy

- Are there lessons learned/best practices from developing the 2018 SHMCAP maintenance plan or from implementing the maintenance plan?
- How can this maintenance plan be designed to be an effective tool for your agency?

A6 - Plan Maintenance, Review, Evaluation, and Implementation

- **Are there lessons learned/best practices** from developing the 2018 SHMCAP maintenance plan or from implementing the maintenance plan?
- **How can this maintenance plan be designed** to be an effective tool for your agency?

SHMCAP Update Kick-off Call Notes

May 23, 2022 11am ET

[Click here to join the meeting](#)

+1 413-459-9173,,205815640#

Phone Conference ID: 205 815 640#

Find a local number | Reset PIN

Attendees

RMAT: Marybeth Goff (MEMA), Margot Mansfield (EEA), Angela Davis (EPS), Mark Talbot (MEMA), Nicholas Bulens (EOHED), Pat Carnevale (CDA), Caitlin Connors (A&F), Marie Johnson (FEMA Region 1), Brigitte Ndikum-Nyada (FEMA Region 1), Alexis Meehan (FEMA Region 1), Lauren Stara (BLC), Brenda Enos (MassDOT), Lisa Hennessy (CDA), Carolyn Meklenburg (EEA), Jenn Doherty (MHC), Julia Knisel (EEA), Courtney Rocha (EEA), Kaitlyn Connors (A&F), Meg Blanchet (DPH), Michelle O'Toole (CDA), Michael Enko (MEMA), Kara Runsten (EEA), Katherine Kemen (MassDOT), Katherine Fichter (MassDOT), David Woodbury (CDA), Robert Jones (EHS), Erica Heidelberg (CDA), Sharon Lee (DEP), Sean Loughlin (FEMA Region 1), Michelle Rowden (EEA), Michael Flanagan (DLS), Joy Duperault (DCR), Alejandra Moutenot (MA Archives / COSTEP MA), Hillary King (EEA), Rebecca Quinones (FEW), Angela Davis (EPS), Kate Adams (DPH), Cristina Kennedy (FWE), Paul Holloway (ENE), Elizabeth Isenstein (DCP), Miklos Lavicska (EOTSS)

Contract Team

ERG: Charles Goodhue, Lindy Lowe, Andrea Cristina Ruiz, Hannah Stroud, Arleen O'Donnell, Shanika Amarakoon, Eliza Berry; **IEc**: Jim Neumann, Jackie Willwerth; **Woods Hole Group**: Joe Famely, Kirk Bosma; **CBI**: Elizabeth Cooper; Paul Kirshen, Marcos Luna, Lydia Rivera

I. Welcome and Introductions (20 minutes) (11:00 – 11:20)

Marybeth Goff and Charles Goodhue welcomed everyone to the call. Ms. Goff facilitated introductions from the RMAT members present, who introduced themselves and stated which organization they were from. Mr. Goodhue facilitated introductions of the contract team, who introduced themselves and their role in the project.

II. Vision of success for the Commonwealths' 2023 SHMCAP (20 minutes) (11:20 – 11:40)

Mr. Goodhue led the team through a Google Jamboard exercise to discuss what a successful project would look like from process and final product perspectives, using the following questions.

1. What does success look like from a process perspective?
   Common themes on this question included:
   - Broad and inclusive stakeholder engagement, across state agencies and the public
   - Transparency and clear communication
   - Support throughout the process and after to help agencies take action.
   - Flexibility
   - Keep the goals and final product of the SHMCAP in mind from the start, so the final plan is accessible and useful.
2. What does a successful final product look like?

Accessibility was brought up by many RMAT members. Common features mentioned included:

- Easy to navigate plan, that is digestible for all stakeholders
- Clear, practical and measurable action
- Dynamic plan with actions that integrate flexibility
- A plan that has broad support across all levels of government
- Includes useful visuals and maps, with underlying data made available for other planning efforts.

3. How would a successful SHMCAP be used to advance your priorities? Who would use it?
   Potential uses varied by agency. Some common uses mentioned include:
   - Data from SHMCAP will be used to justify priorities of grant programs.
   - Data will be used in other planning efforts.
   - Educating community organizations to help gain support for taking action.
   - Identify collaboration opportunities across agencies.
   - Reference it as a model for other states and municipalities to follow at a local scale.
   - Provide direction for agencies that don't have climate or hazard expertise.

III. Workplan discussion (11:40 – 12:20)

Mr. Goodhue presented a high level overview of the contract team's approach to the SHMCAP update.

- Team structure: Lindy Lowe is the technical lead, supported by Andrea Cristina Ruiz as the deputy technical lead. Charles Goodhue is the project manager and will be supported by Hannah Stroud.
  - Several expert advisors to provide reviews and insight: Arleen, Marcos, Lydia, Paul and Ellen
  - CBI helping with facilitation
  - Modeling from Woods Hole Group
- Timeline: Many tasks will occur concurrently, with tasks A2, A3 and A4 starting within the next month. The bulk of the work will be completed by May 31, 2023 so the draft can be submitted to FEMA for review on June 1, 2023. The project will continue through the fall to address final edits and provide the plan in all its final formats.
- Stakeholder engagement plan: Stakeholder engagement will occur throughout tasks A2, A4, A5 and A6. There are two stakeholder series. One with the RMAT, which have a total of 7 workshops, and one series with a broader set of stakeholders that will have 6 workshops.

Ms. Lindy Lowe then walked through the remaining 6 tasks. For each task, she presented the key steps, list of deliverables and posed questions for RMAT.

Task A2- Develop Outline, Data Collection Tools and Frameworks

- Overlap with Task A4, with four workshops

Questions for RMAT

- Lessons learned from past efforts for surveys and interviews with state, local and tribal represetnatives?
    - Joy Duperault: Interviews with key staff work far better for state agencies than do surveys - especially if those individuals are contacted by their superiors or someone they already work with
    - Lauren Stara: Incentives are the way to get good response, if that's possible for this process. A chance to win something in a random drawing of respondents.
    - Hillary King: Is there some way to use MassAchieve to promote surveys / encourage responses?
- Are there any documents that have been published or changed since 2017 that we should include in the document review?
    - Joy Duperault: We need new data for rising groundwater due to SLR, and also increasing groundwater impacts in interior areas due to increased rainfall. e.g. just had a discussion about all of the basement flooding in Woburn this morning, which is not from overland flow
    - Paul Kirshen: US National Climate Assessment, IPCC reports, UMass Boston Greater Boston Research Advisory Group Consensus Climate Change Projections - to be released June 1 2022
- Are there are any funding strategies that existing agencies have developed that can inform the funding inventory effort?
    - Joy Duperault: All the big state funding comes through EEA, the big federal funding comes through MEMA

Task A3 – Supplementary risk assessment

- The information from A3 will be presented in the A2/A4 workshops.

Questions for RMAT:

- The RFP called out specific hazards that were not included in the Climate Assessment - earthquake, ground failure, and tsunami hazards – is there anything missing?
    - Joy Duperault: groundwater flooding of basements, and impacts of rising groundwater on coastal roads
        - Jim Neumann - groundwater flooding/subsurface risks are technically in-scope for the Climate Assessment, but as a result of the Project Working Group process that impact was not included in the "short-list" of impacts for urgency scoring. We do have some information on this topic, however, including some data from the work of Dr. David Boutt of UMass-Amherst,
- Any agency specific documents regarding the hazards we should review?
    - 2021 Massachusetts Ocean Management Plan - https://www.mass.gov/service-details/2021-massachusetts-ocean-management-plan
    - NOAA SLR Report and updated SLR data https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html

        - Joy Duperault shared the following contact information for NFIP data: Brian Kennedy, Emergency Management Specialist, Floodplain Management & Insurance Branch, FEMA Region I, Mobile: 617-794-6907, Brian.M.Kennedy@fema.dhs.gov

Task A4 - State Agency Vulnerability Assessment

- Run along side A2
- Online survey will be administered along side the A2 survey
- Will want to integrate and pull in information from RMAT

Questions for RMAT

- Are there lessons learned/best practices from the 2018 SHMPCAP state vulnerability assessment survey?
    - Ensure that the survey is shared with the appropriate level staff person. High level so they know what is going on but important to get to the staff who are conducting the work
- What additional documents should we review?
    - Paul Kirshen: the UMass Boston report on feasibility of a Boston Harbor Surge Barrier - 2018.
    - Cristina Kennedy: https://thetrustees.org/content/state-of-the-coast-report/
    - Julia Knisel: 2021 update to the shoreline change project: 2018 shorelines and rates have been published and added to the USGS Coastal Change Hazards Portal https://marine.usgs.gov/coastalchangehazardsportal/ui/item/EuTvXS6c
- Have agencies conducted any other vulnerability assessments or hazard work since 2018?
    - Rebecca Quinones: updates to BioMap2 in the works. BioMap3 proposes resiliency strategies

Task A5 - Hazard Mitigation and Climate Adaptation Strategy

- Much of the work in Task A5 will be pulled into the RMAT workshops of A2 and A4, which will allow RMAT to stay updated and provide feedback.
- 4 subgroup workshops that will be determined by the RMAT and Commonwealth's key concerns and issues.

Questions for RMAT:

- Who are the key agencies, departments, and leaders who are or will be engaging in hazard mitigation and/or climate adaptation actions in the next ten years?
    - Marybeth: Are there any agencies that were not included in the 2018 planning process who should be included in this update?
    - Nicholas Bulens: Stakeholder agencies in EOHED: Office of Consumer Affairs and Business Regulation (OCABR) - Office of Public Safety and Inspections (Building Inspectors); Department of Housing and Community Development (DHCD) - Division of Public Housing, CHARM Study: https://www.mass.gov/service-details/resiliency-initiatives; Community Programs and Resources Office (CPRO) - MassWorks Infrastructure Program
- Are there agency or regional level climate mitigation and adaptation strategies or lists of adaptation actions that have been developed since 2018

- What documents or offices reflect state, agency, regional level priorities and goals when it comes to climate adaptation?
    - Rebecca Quinones: Action tracker from EEA
    - Elizabeth Isenstein: DCAMM resilience check list
    - Jane Doherty: MHC has been making use of the Park Service's guidelines on flood adaptation when reviewing projects: Guidelines on Flood Adaptation for Rehabilitating Historic Buildings (U.S. National Park Service) (nps.gov)
    - Meg Blanchet : CDC Framework for incorporating public health into climate planning (including evaluation): https://www.cdc.gov/climateandhealth/BRACE.htm

Task A6 - Plan Maintenance, Review, Evaluation, and Implementation

- The engagement workshop for the maintenance plan will be used in part to think about how the maintenance can be used to catalyze action.

Questions for RMAT:

- Are there lessons learned/best practices from developing the 2018 SHMCAP maintenance plan or from implementing the maintenance plan?
    - Marybeth added that hearing how the Action Tracker has been used, how it could be improved, how it's been helpful would also be valuable
- How can this maintenance plan be designed to be an effective tool for your agency?

Task A7 – Compile and Finalize SHMCAP

- Hillary King shared scope, but thought this report had a good layout with these "1-pager" pull out actions: Blackstone River Watershed Needs Assessment Report

Discussion and questions on Tasks and Approach (12:20-12:30)

- Marybeth – FEMA has released new guidance and policies, this plan will follow those. In terms of task A2, we want to keep in mind it's not just a list of capabilities, but actually assessing them, and thinking about how we can improve these capabilities.
- Crisitina Kennedy – for those who are newer to this process, it would be helpful to get an overview of what is in the SHMCAP, and summary slides of the goals from the 2018
    - Marybeth: We have done that in the past and can share those with you.
    - Lindy: We can start the first session with that overview to make sure everyone is on the same page.
    - Lindy will share a few documents that are good introductions to the process with Marybeth to share with RMAT
    - Sharon Lee: EPA and NOAA have tools that are geared towards water utilities that help with assessing flood risks for infrastructure: https://www.epa.gov/crwu/climate-resilience-evaluation-and-awareness-tool-creat-risk-assessment-application-water and https://coast.noaa.gov/stormwater-floods
    - Joy Duperault shared https://www.mass.gov/service-details/massachusetts-integrated-state-hazard-mitigation-and-climate-adaptation-plan

- Rebecca Quinones: Has there been evaluation of the actions of the 2018 document that have been implemented? Any kind of summary of how well the 2018 plan has been used and moved forward across the state?
  - Marybeth: We haven't don't an assessment, but that will be part of this process with the 2023 update.
  - Lindy: We'll make sure to look at areas where agencies where people have gotten stuck in implementing the plan and think about how to move those forward.
- Hillary King shared: Several municipalities in the state are also compiling Climate Action Plans. And their "Blueprints" are often well laid out. Example:

  Beverly Salem Climate Action Plan Blueprints https://kladashboard-clientsourcefiles.s3.amazonaws.com/Beverly-Salem/Resilient+Together+Blueprints.pdf

  Cool community page, that allows the municipal climate initiative to track their goals on a more individual level: https://community.massenergize.org/HarvardMA/

Next steps and closing comments (12:30- 12:35)

Mr. Goodhue presented the next steps:

  - Workplan
    - Submit work plan within ten days (June 3)
    - Comments by June 10
    - Final work plan by June 15
  - July 26 RMAT Meeting will be our first workshop
- Marie Johnson shared FEMA is looking at this plan as an example to reflect the new FEMA policies, FEMA is here to support Massachusetts, in the end the focus needs to be on getting things done and that risk reduction happening.
- Lindy reiterated that the RMAT's most important role is help us understand their main concerns and priorities, and help identify actions.

What does success look like from a process perspective?

Not only incorporating the best scientific data, but understanding the best way to utilize and implement the data

This process and plan acknowledges the Tribal planning and plans and presents opportunities to share and collaborate as natural hazards know no boundaries.

appreciates what this plan and so has their staff fully engaged and knowledgeable and contributing to the process and implementation. The process is institutionalized into the State agencies responsibilities daily and year after year in

provides some flexibility on changing agency priorities (priority actions related)

make a meaningful strategy that is implementable

Plan with broad public support

Broaden participation to state agencies that do not typically participate. This will likely need to be done through education

The Governor is engaging with this work and being an advocate for the implementation by all the State agencies collaboratively and collectively.

A state plan that includes all stakeholder concerns regarding climate change impacts and hazard mitigation opportunities

A process that benefits from input of a full range of stakeholder groups and where stakeholders learn from each other and build a stronger plan based on that learning

Agencies and Secretariats are provided assistance on determining gaps and needs. This is not the expertise of many of us. Asking us to do a gap analysis is ineffective since ew don't even know all the questions to ask.

total work (with its communities) on continued long term risk reduction of its vulnerabilities to its hazards including with the impacts of climate change. Success is not starting over again with each 5 year update. Success is in the actions and

Be able to clearly and simply communicate internally and to external partners what the SHMCAP is and what the goals are.

Plan that explicitly considers the uncertainty of the future climate - eg, looks at range of future climates

collection of "stories" as data... making this process / the challenges accessible across the state.

transparent and directed while still allowing flexibility to incorporate all perspectives

Communities are feeling supported and have a strong model set by the STate to do their work

Including key stakeholders

Broad collaboration

Findings presented in succinct, easily digestible format/language to support broad understanding and use; detail/technical info provided as support.

Identifying what didn't go well that past few years and how to improve

Encouraging / enabling more actions from a broader cross-section of agencies.

Start with the finished product in mind. Do we need a more interactive plan than we have in the 2018 plan? if so, what would be helpful to state agencies and/or local communities?

Maybe look at metrics on the funding of actions? For which hazards, etc?

It's not overgeneralized. Good specifics.

Responsiveness to the ongoing Climate Assessment.

Ensuring the correct level of folks are involved.

consider upstream and downstream impacts of actions, particularly for environmental justice communities

Takes an social equity-minded approach

Develop strong long-term goals while addressing current vulnerabilities.

Solicitation and incorporation of feedback from people who are most at risk from climate hazards (e.g. environmental justice communities)

a transparent and inclusive process

Engagement from both agency leaders and staff responsible for implementation

total work (with its communities) on continued long term risk reduction of its vulnerabilities to its hazards including with the impacts of climate change. Success is not starting over again with each 5 year update. Success is in the actions and

incorporates natural resources on equal footing with hard infrastructure

An education program that reaches all levels - from residents to the very top - so people understand why we need to do this & increase buy-in

work results in meaningful and actionable long term risk reduction for MA - with equity and time urgency

What does a successful final product look like?

A plan that is easy to navigate and contains comprehensive data for understanding climate impacts and mitigation opportunities

Plan is supported by expert guidance and not just agency/secretary best estimate.

interactive checklist that can show the status (whats been completed) for specific actions. Detailed items can be collapsed into larger headings. Actions targeted to different stakeholder groups

Easy to measure success

Contains an honest review of the past SHMCAP goals and what was achieved, describe lessons learned that were incorporated into new report

Transferrable to multiple formats (slide decks, trackers, web content).

this is not one agency doing risk reduction but it is being done by all. All these state agencies/staff including the Governor/Governor's office uses this document for all State planning and reviews for budgets, capital improvements.

A dynamic plan that is usable by state and local officials

Make components of it interactive on a web site perhaps by placing on web in a summarized format

A plan that is useable by policy makers and communities

Compelling graphics of vulnerability and actions with practical implementation steps.

supported by all upper level staff - decision makers need education on plan's relevance

Easy to read with near term actions to demonstrate early success and build momentum

Clear advice, broadly supported, actionable across levels of government

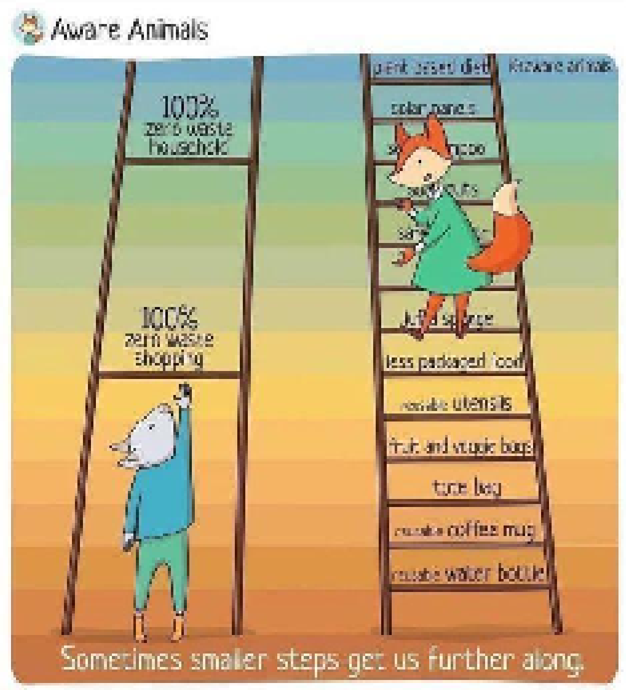
User friendly and digestible for all stakeholders

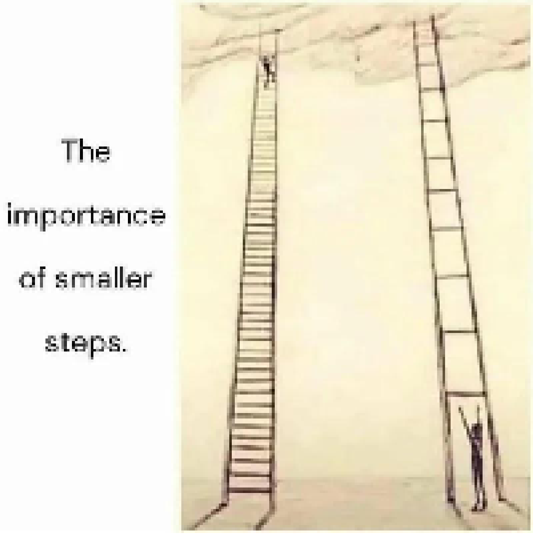
Easy to navigate and understand risks. Maps/data that can be used in other planning efforts.

better links (information, models etc) between climate adaptation and mitigation

Accessible to a broad audience, including limited-English speakers

been in place. Reflects how each of the State agencies have and are playing a role in making these successes happen (with specifics) and helping to meet the State's goals. Maybe this is quantified such as the $1 of mitigation saves $6 of disaster





total work (with its communities) on continued long term risk reduction of its vulnerabilities to its hazards including with the impacts of climate change. Success is not starting over again with each 5 year update. Success is in the actions and

Pathways, strategies, and actions that integrate flexibility

Practical action items - not a report that gets put on a shelf and is never looked at again

A successful final product is appreciated by everybody and is recognized and referenced nationwide like the 2018 SHMCP..

a plan that is consistent with other direction from other relevant authorities (e.g., AFWA guidance on SWAPs, National Climate Adaptation Strategy)

built in evaluation measures

Clear and measurable action items

+1!

Easily navigable, well laid out products should include most useful information presented in plain language with useful visuals (!!)

Roadmap for accomplishing both short and long term goals.

explicit consideration of the uncertainty of the future climate on adaptation recommendations -

Fewer, more focused, possibly phased action items with measurable outcomes or outputs

Makes underlying data available for other researchers

possible interactive online link to this document

Easily digestible for all levels of climate knowledge that continues to be updated over time as data and information evolves

How would a successful SHMCAP be used to advance your priorities? Who would use it?

It will be used to advance mitigation project applications and demonstrate the application's consistency with the SHMCAP priorities. (State Hazard Mitigation Team)

Provide direction and level of understanding to our communities about how our projects/funding/work will be beneficial to them long term (State Hazard Mitigation Team)

To share with the neighboring States as climate change and impacts from the natural hazards do not recognize borders. Share for ideas and best practices as well.

We also use the plan to educate our communities by sharing portions of the plan when appropriate (state floodplain manager)

To communicate and educate those that live in the New England region about risk and mitigation/climate adaptation.

Note who "you" are in the sticky note

own facilities and assets. The plan demonstrates that this is not one agency doing risk reduction but it is being done by all. All these state agencies/staff including the Governor/Governor's office uses this document for all State

The plan needs to clearly list priorities so that when we write grants we can show statewide support for those actions (state floodplain manager)

Reference it as "model" for other how other states in the country should develop their plans. BE THE BEST

Would be great to also have as a "model" for municipalities to follow at the local scale. What does climate adaptation look like at the state-scale, can it be replicated in local government? (MVP)

Clear benchmarks for agency leadership(s) and availability of resources to implement adaptations

have interactive data that can be pulled into other planning efforts.

The plan is used by anyone who wants to understand and act upon mitigation and adaptation actions to solve climate and hazard problems in their community (state floodplain manager)

schools, universities, transportation, health care, and other systems (required to be used for SOW and budget requests). This would be to analyze the changes in risk by these decisions and to ensure resiliency and

resources: understanding risk/urgency of crisis/how to better prepare and mitigate risk towards a goal of resiliency and also towards a goal of strengthening relationships with emergency

It would be used to demonstrate how hazard mitigation project applications are consistent with the SHMCAP. (State Hazard Mitigation Team)

Identifying especially vulnerable communities for risk assessment, planning, and accountability assessments

I'd hope that collaborations among state agencies is once again highlighted. As in those sharing similar goals and potential overlapping projects

Plans would provide quantified data to justify prioritization of resilient capital projects by grant programs ~ Grant Manager

The plan should include priorities that are easily integrated into capital building projects.

Share the plan with community organizations educating them on processes with our goal of them becoming additional mouthpieces.

Public libraries are a great place to push ideas and education to communities. The BLC can incentivize these goals in our construction grants, but also disseminate info. - Lauren, Bd of Library Comm.

focused on natural resources with a concerted state effort, continue to partner with other offices/agencies and learn from each other, stay abreast of latest climate change data, be able to point to plan for grants and proposals, fund DER

This is not the area of expertise for anyone at LWD. We need help in learning what we need. The priorities would then be clear action items we could work on. The COO should be the primary stakeholder. She would then use it to direct staff.

the State identifies it's vulnerabilities and risk and how it will take action to reduce or eliminate these vulnerabilities/risk for the long term. Then, that would help us to understand needs and where the support and building capability

Identify collaboration opportunities/cross cutting actions across agencies to increase transparency and avoid duplicated efforts.

(1) Continued funding for local action - EEA/Gov's office (2) Stronger policies/regs on high-risk development - Legislature/various agencies (CZM)

2023 MA SCHMCAP
RMAT Meeting 1

SHMCAP Working Group #1 Meeting

Tuesday, July 26th, 2022
2:00 – 4:00 pm EDT

Meeting Objectives

- Update on SHMCAP progress to date, related meetings and efforts, and relationship between the Climate Assessment and the SHMCAP
- Provide an overview of the SHMCAP engagement approach for State Capability and Adaptive Capacity Analysis (Task A2) and State Agency Vulnerability Assessments (Task A4)
- Discuss and gather feedback on draft data collection tools and State Capability and Adaptive Capacity Analysis report outline

Time (EDT)	Agenda Item	Lead
2:00 – 2:10 pm	**Welcome and Introductions** • Framing, purpose, and meeting goals	MEMA/ERG
2:10 – 2:25 pm	**Save-the-Date: Climate Change 101 MA Training** **SHMCAP Implementation Funding**	Hillary King/ Courtney Rocha
2:25 – 2:40 pm	**Overview on SHMCAP progress to date** • Document identification and review • Integration with Climate Assessment • Alignment with updated FEMA guidance for 2023 plans • Identification of best available data, science, and information • Updated workplan **Engagement Approach: State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessments** • Involvement of the SHMCAP Working Group • Survey/Document review • Upcoming SHMCAP Working Group meetings • Additional smaller sector/issue-based meetings as needed	MEMA /ERG
2:40 – 3:00 pm	**Review Draft Report Outline and Document Review Framework** • Review State Capability and Adaptive Capacity Analysis report outline • Review State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessments document review framework • Questions and discussion	ERG
3:00 – 3:55 pm	**Review and Discuss Draft Survey** • Survey objectives for the State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessments • Proposed survey format and distribution process • Survey questions • Questions and discussion	ERG
3:55 – 4:00 pm	**Wrap Up and Next Steps** • Provide written feedback on outline, document review framework, and survey by EOD Tuesday, August 2nd • Upcoming August 10 agency workshop on MA Climate Assessment • Climate 101 Training feedback by EOD Tuesday, August 2nd	ERG

2023 SHMCAP Update

RMAT Meeting
July 26, 2022

ERG IEc WOODS HOLE GROUP CBI CATALYZING COLLABORATION

1

1

Agenda

Welcome and Introductions
RMAT Updates: Climate Change 101 MA Training FY23 SHMCAP Implementation Funding
2023 SHMCAP Progress and Overview of Engagement Approach
Chapter Outline and Document Review Process *(State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment)* • Questions and discussion
Draft Agency Survey *(State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment)* • Questions and discussion
Wrap Up and Next Steps

2

Welcome and Introductions

Please put your affiliation in the webinar participant list or chat

3

Meeting Goals

1. Update RMAT on **2023 SHMCAP progress**
2. Provide brief overview of **relationship between MA Climate Assessment and SHMCAP**
3. Describe the **engagement plan** for State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessments
4. Discuss and gather **feedback on draft data collection tools** and State Capability and Adaptive Capacity Analysis chapter outline
   - Document Review Process
   - State Capability and Capacity Analysis Chapter Outline
   - Capacity and Vulnerability Survey Questions

4

RMAT Climate Change 101 Training

RMAT Climate Change 101 Training

Presented by Courtney Rocha, Municipal Vulnerability Preparedness Coordinator, SE Region

- **Progress to date**
  - Completed and recorded script
  - Compiled content for the training
  - Worked with Steve Korzen, EEA – audio, graphics, avatar, content
- **Snippets to full training**
- **Video Clip**
- **Feedback – Tools & Training WG to review each 1 to 4 minute video (email forthcoming)**
  - **Provide feedback via email by 8/5.** Courtney.rocha@mass.gov & Hillary.King@mass.gov with feedback. (Ex. Climate Resilience Lectora Part 3: ….)

RMAT Climate Change 101 Training

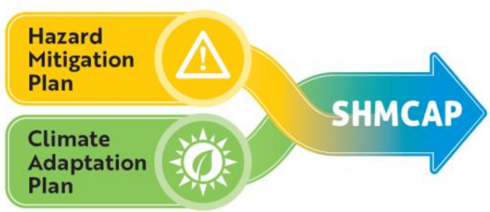
Presented by Courtney Rocha, Municipal Vulnerability Preparedness Coordinator, SE Region

FY23 SHMCAP Implementation Funding Awarded

RMAT awarded over $5.7M to 22 agency projects through a combination of bond cap and ARPA 1.0 funds

Awarded Projects - to be completed by June 30, 2023

1. EOHED – Building Code Study and Action Guide
2. DHCD – Gloucester Housing Authority (Riverdale Park)
3. LWD – Climate Risk Analysis and Mitigation Planning
4. DPH – Educational Content on Social Determinants of Disease and Climate and Health Outcomes
5. MBTA – Systemwide Tunnel Flood Mitigation Program: Blue Line Airport Portal Tunnel Flood Protection Design
6. MEMA – SHMCAP 2023 Update
7. MEMA – Local Hazard Mitigation Plan Pilot Program
8. MEMA – FEMA Hazard Mitigation Technical Support
9. EEA – Establishing Flooding Vulnerability from Rising Groundwater Under Climate Change
10. EEA – Guidance for Public Water Suppliers for Developing Local Drought Plans
11. EEA – MVP Planning 2.0
12. EEA – Resilient MA Enhancements
13. EEA/CZM - Boston Harbor Resiliency Study
14. EEA/CZM - MC-FRM Stakeholder Training
15. MassDEP – Statewide Hydraulic Model Phase 2A
16. DCR – Parkways Vulnerability Assessment
17. DCR – Cultural Resource Inventory
18. DER – Municipal and Other Dam Removals
19. DER – Stream Crossings in Transition Phase II
20. MassWildlife – Launching BioMap
21. MassWildlife – Great Marsh Ecosystem Restoration Project Phase III
22. MassWildlife – Integration of water temperature and streamflow models to guide climate adaptive actions in coldwater climate refugia

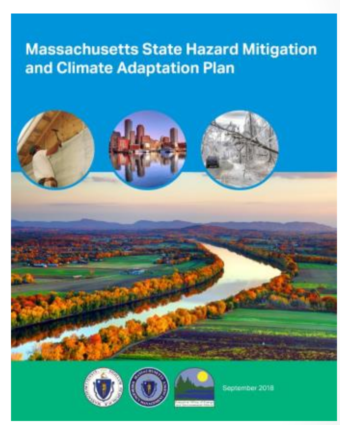


SHMCAP Update Purpose, Update Progress, and Relationship to MA Climate Assessment

Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) 2023 Update

2023 SHMCAP Update overview:

1. Update to the 2018 SHMCAP.
2. Includes hazard mitigation and climate adaptation.
3. Informed by the Climate Assessment technical and engagement work.
4. FEMA requires that hazard mitigation plans be updated every five years to maintain eligibility for funding.
5. Massachusetts receives many millions of dollars from FEMA to reduce risks, improve public health and safety, and respond to disasters.
6. FEMA released a new State Mitigation Planning Policy Guide that will take effect for 2023 SHMCAPs, which includes:
   a) New FEMA grant programs.
   b) New priorities related to climate adaptation, equity, resilience, and building codes.

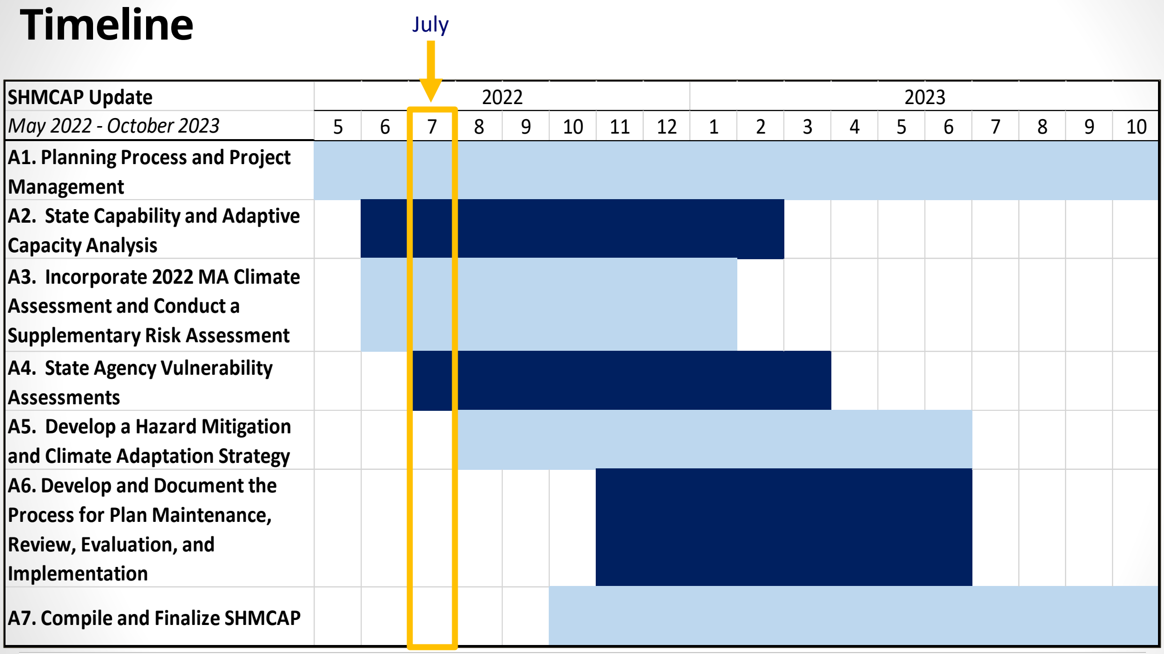


SHMCAP Progress to Date

Summary of SHMCAP progress:

1. Document identification and review, draft document review process
2. Climate Assessment progress
3. Continued integration with Climate Assessment
4. Continued identification of best available data, information, and science
5. Revised SHMCAP workplan and FEMA 2023 guidance crosswalk
6. Draft State Capacity and Adaptive Capability Report Chapter Outline (*to be discussed today*)
7. Draft State Agency Survey (*to be discussed today*)

Timeline



Climate Assessment Update

Climate Assessment Objectives

1. **Provides most of the risk assessment information** for the 2023 SHMCAP
2. **Assesses impacts** from climate stressors and hazards across five sectors
3. **Includes findings and recommendations** to inform the prioritization of actions in the 2023 SHMCAP

Current Status of the Climate Assessment

1. Upcoming Project Working Group session on **August 10** to review draft urgency rankings (make up on Aug. 15)
2. Draft Report: August 2022
3. Peer and Public Review: September 2022
4. Final Draft: Late October 2022
5. All data from assessment integrated with ResilientMA.org: December 2022

Climate Assessment and SHMCAP Relationship

How does the Climate Assessment inform the SHMCAP?

1. Will **provide most of the data and information needed** for the 2023 SHMCAP's **risk assessment,** excepting non-climate hazards such as earthquakes and other hazards such as groundwater.
2. 2023 SHMCAP will incorporate as much of the Climate Assessment framework as possible, including **use of the five sectors, the data and information used to assess the impacts, and the findings regarding magnitude and disproportionality of risks.**
3. Will include findings and recommendations to **inform the evaluation and prioritization of 2023 SHMCAP actions.**
4. 2023 SHMCAP **will use the robust engagement included in the Climate Assessment to inform stakeholder priorities** for 2023 SHMCAP.

Overview on SHMCAP and Engagement Approach

State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment

Key Organizations

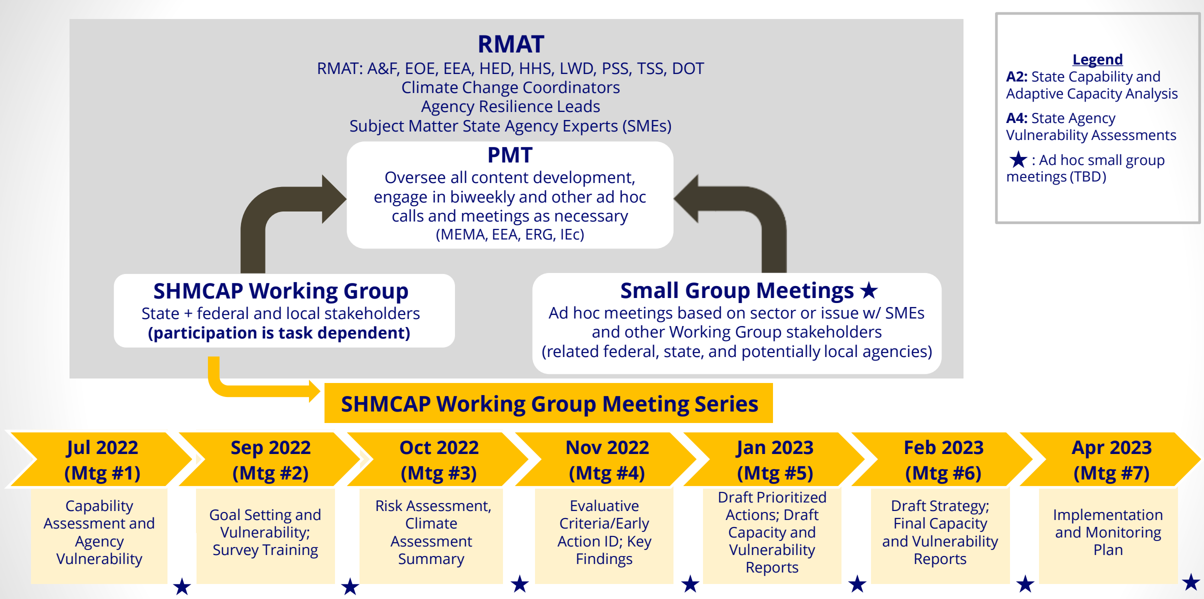
Definition, Roles, and Responsibilities

Organization	Roles and Responsibilities
RMAT	**Led by EEA and MEMA**, includes Climate Change Coordinators, Agency Resilience Leads and Subject Matter Experts: **a. Climate Change Coordinators:** Provide guidance and review of most key deliverables and drafts of all final deliverables. **b. Agency Resilience Leads**: Participate in plan update through meeting participation and review of most key deliverables and drafts of all final deliverables. **c. Subject Matter State Agency Experts:** May be consulted on sector or issue basis as needed
PMT	**Made up of MEMA, EEA, + consultant team** oversees all content development, engages in biweekly and other ad hoc calls and meetings as necessary.
SHMCAP Working Group	**Federal, state and local stakeholders**. Participation will be task dependent. Some stakeholders will be included in all tasks and some in fewer. May include review of key deliverables and drafts of final deliverables.

RMAT Role in SHMCAP

Engagement Approach for 2023 SHMCAP

1. RMAT representatives are considered critical partners in the 2023 update process, including:
   - Review and comment **on all key deliverables.**
   - Identify **opportunities, vulnerabilities, and challenges related to their agencies.**
   - **Identify agency stakeholders at the local and community level** that should be engaged.
   - Participate directly in development of **evaluation and prioritization of 2023 SHMCAP actions.**
   - **Participate in a series of seven meetings**, the first is today.
2. SHMCAP Working Group will be made up of **federal, state, and local stakeholders.** Some members may participate in all seven RMAT SHMCAP meetings, while others may only participate in discrete tasks and in ad hoc meetings.

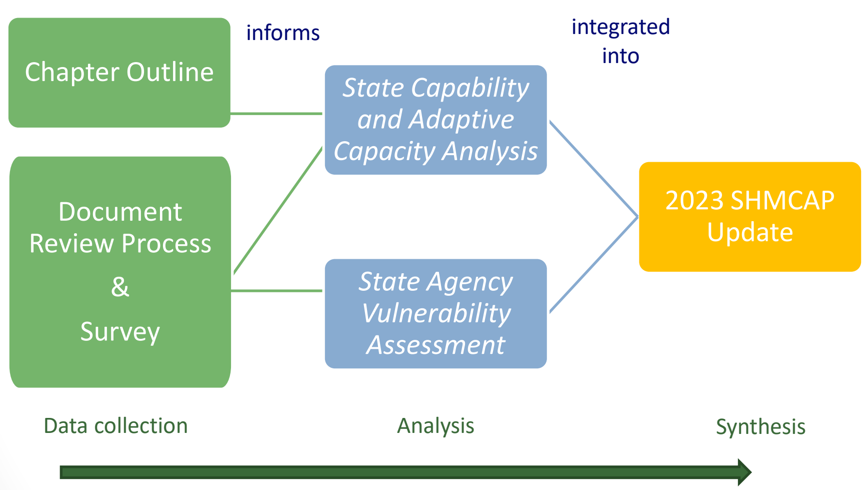


Chapter Outline and Document Review Process

State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment

Chapter Outline and Document Review Process

State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment



Chapter Outline

State Capability and Adaptive Capacity Analysis

Draft Chapter Outline

Introduction and Purpose

State Capabilities and Adaptive Capacity

- Comprehensive Statewide Hazard Mitigation and Climate Adaptation Program
- Existing State Capabilities
- Adaptive Capacity of State Agencies
- Administration of FEMA Mitigation Programs
- Hazard Mitigation Assistance

Local Capabilities and Coordination

- Existing Local Capabilities (including challenges, gaps, barriers, and how state agencies can support and increase collaboration with local governments)

Conclusions

****Written feedback on draft outline also requested after meeting****

Document Review Process

State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment

Purpose

- Provides for **effective and efficient review** of relevant documents and efforts and organizes information to directly inform 2023 SHMCAP report sections.

Overarching	State Capability & Adaptive Capacity	Vulnerability Assessment
• Document Title • Access Link • Author/ Organization • Year • Geographic Scope • Document Topical Focus • Agency Mission and Goals	**Capabilities** • Planning and Regulatory • Administrative and Technical • Capital Projects and Asset Management • Financial • Education, Outreach, and Capacity-building • Other Notes **Capacity** • Challenges/Needs • Opportunities • Other Notes	• Assets Managed • Potential Hazards Impacting Assets • Scale Of Hazards • Scenarios • Primary Asset Consequences • Secondary Asset Consequences • Functional Consequences • Governance Authority • Vulnerability Concerns • Hazard Mitigation and Adaptation Actions

****Written feedback on draft document review process also requested after meeting****

Questions and Discussion

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Discussion: Chapter Outline

State Capability and Adaptive Capacity

Does the outline include information that will be hard to obtain or provide? Are there issues or concerns missing from the outline?

- Incorporate MVP plans
- Look at what happens between agencies

Introduction and Purpose

State Capabilities and Adaptive Capacity

- Comprehensive Statewide Hazard Mitigation and Climate Adaptation Program
- Existing State Capabilities
- Adaptive Capacity of State Agencies
- Administration of FEMA Mitigation Programs
- Hazard Mitigation Assistance

Local Capabilities and Coordination

- Existing Local Capabilities (including challenges, gaps, barriers, and how state agencies can support and increase collaboration with local governments)

Conclusions

****Written feedback on draft chapter outline and document review process also requested after meeting****

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Discussion: Chapter Outline

State Capability and Adaptive Capacity

Are the state and local agency capabilities categories still the most appropriate?

- Think about how to illustrate interagency engagement and actions; encourage respondents to highlight these examples in the survey
- Will add a section in the chapter outline about interagency capacity and capabilities

Capability Categories

- Planning and Regulatory
- Administrative and Technical
- Capital Projects and Asset Management
- Financial
- Education, Outreach, and Capacity-building

****Written feedback on draft chapter outline and document review process also requested after meeting****

25

25

Discussion: Document Review Process

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Are there categories for which data and information may be difficult to obtain from available reports? Is there anything missing from the categories?

- x

Overarching	State Capability & Adaptive Capacity	Vulnerability Assessment
• Document Title • Access Link • Author/ Organization • Year • Geographic Scope • Document Topical Focus • Agency Mission and Goals	**Capabilities** • Planning and Regulatory • Administrative and Technical • Capital Projects and Asset Management • Financial • Education, Outreach, and Capacity-building • Other Notes **Capacity** • Challenges/Needs • Opportunities • Other Notes	• Assets Managed • Potential Hazards Impacting Assets • Scale Of Hazards • Scenarios • Primary Asset Consequences • Secondary Asset Consequences • Functional Consequences • Governance Authority • Vulnerability Concerns • Hazard Mitigation and Adaptation Actions

Survey

State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment

Survey

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Purpose

- Gather information on **existing state capabilities and capacity**
- Identify **key asset classes within each sector** that will be affected by hazards and climate change
- Address the **degree of vulnerability** of key asset classes
- Help determine **high priority vulnerabilities and consequences** for each agency

Hazard Mitigation and Climate Adaptation Actions

- State Capabilities
- Vulnerability of State Agency Assets (Physical & Non-Physical)
- State Adaptive Capacity

****Written feedback on draft survey also requested after meeting****

Survey
State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

State Agency Capabilities
- Agency's role in and capacity for climate adaptation and mitigation and role in local jurisdiction capacity.
- Current capabilities, resources, and populations served.
- Challenges, disproportionate impacts, sensitivities.

Adaptive Capacity
- Plans and programs for adaptation and mitigation.
- Identify policies, projects, and programs that would reduce risks and increase ability to respond to changes in climate and associated risks and consequences.

Vulnerability Assessment
- Asset classes managed/owned and vulnerability.
- Hazards and concerns from impacts, including to services and populations served. Disproportionate impacts and highly sensitive and consequential assets.

****Written feedback on draft survey also requested after meeting****

Survey
State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Example Questions: State Capability and Adaptive Capacity

1. What is your **agency's role** in state and local hazard mitigation and climate adaptation?
2. How is your agency **incorporating hazard mitigation and climate adaptation** in its existing:
   a) Plans?
   b) Programs?
   c) Policies and procedures?
   d) Decision-making processes?
   e) Capital planning and finance?
3. How many **staff (full-time equivalent [FTE])** are dedicated to hazard mitigation and climate adaptation efforts?

****Written feedback on draft survey also requested after meeting****

Survey
State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Example Questions: State Agency Vulnerabilities

Asset Class	Services Provided	Population Served
Critical response services		
Community support		
Etc.		

Hazard Category	Hazard Impact	Not at all	Infrequently	Frequently	Very Frequently
Changes in precipitation	Inland flooding	○	○	○	○
	Drought	○	○	○	○
	Landslide	○	○	○	○
	Soil erosion	○	○	○	○
	Freshwater ecosystem degradation	○	○	○	○
	Dam overtopping	○	○	○	○

****Written feedback on draft survey also requested after meeting****

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Survey
State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Survey Administration Process

Climate Coordinators
- Review and provide feedback on survey *(Aug).*
- Identify lead agency representatives *(Aug*).

Agency Representatives
- Participate in survey training (*mid-Sept*).
- Identify appropriate people to coordinate with in agencies *(mid Sept – Oct*).

Agency Representatives and Staff
- Review and fill out survey (*mid-Sept. – Oct*).
- Reach out to ERG **via ERG helpline** with questions at any time during survey process.

****Written feedback on draft survey also requested after meeting****

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Questions and Discussion

Discussion: Survey Process

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Does the process outlined seem reasonable and efficient? Do you have any suggested improvements or anyone else who should be involved in this process?

- Build on existing VAs, pre-populate information
- Consider for large Agencies like MassDOT, there should be multiple surveys, at least one for Highway, one for Mass. Aeronautics, and one for the MBTA
  - Like DCR: forestry, parkways, state parks, beaches, cultural sites, flooding

For Climate Coordinators, will you want to review and approve survey responses from the agencies?

- X

****Written feedback on draft survey also requested after meeting****

Discussion: Past Survey Experience

If your agency completed a survey in 2018, how did that go? What was valuable about the process, and what was missing? If your agency did not complete a survey, why not?

- Challenge to get answers from relevant folks who are busy (limited capacity). How to better facilitate this within agencies?
- Challenge getting leadership approval and review for online survey platform (paper approval->upload online platform; review/approval online survey link before submission)
- Challenge with getting $ numbers; sensitive info around vulnerable populations
  - Include heat risk
- Be able to save survey mid-stream
- Use better collaboration tools to gather information across different staff
- Want to see results statewide
- Pulling info from existing vulnerability assessments
- Be able to "print/save as pdf" a draft survey
- Make sure Qs are specific, no jargon
- Consider streamlined survey for existing VAs that are already specific and approved

****Written feedback on draft survey also requested after meeting****

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Discussion: Survey Content

Based on your review thus far, are these the right questions to be asking? Is there anything missing?

- Identify inter-agency collaboration efforts that impact state capability & vulnerability
- Q47: Maybe instead of or in addition to the word 'depend,' add the word 'partner'?
  - Related to Q14 - how might any vulnerabilities of the asset classes impact ability of your agency to do its work
- For dams, most are private. If capturing private infrastructure vulnerability that affects public resources (river flow and fisheries), need to assess whether the dams are run-of-river or actively managed, this will assist us in drought management.
- Efforts on incentivizing development near MBTA stations and routes, when some of these routes and MBTA maintenance facilities are quite vulnerable
- First bullet means hazard mitigation, not climate mitigation
  - define "climate mitigation" ,"tide gates" , etc. for people working through this process.
  - clear definitions/examples on what to include for agencies that don't own land/physical structures
- Does it make sense to split "natural resources" from purely recreational (playgrounds, etc.?)
- Ensure language around non-physical assets

****Written feedback on draft survey also requested after meeting****

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Discussion: Survey Complexity

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Will the questions be something your agency is able to answer within the allotted timeframe? Is anything confusing or unclear?

- x

****Written feedback on draft survey also requested after meeting****

POLL

Go to the website "Sli.Do" and enter #123 3 117

- **Do you have any last-minute thoughts or questions?** If you would like us to follow up to answer questions you have, please include your email address in the response.

https://app.sli.do/event/fxAsEJk1zEWwBLXZc9PyNB

Wrap Up and Next Steps

- Provide written feedback on chapter outline, document review process, and survey by EOD **Tuesday, August 2nd**.
- SHMCAP Working Group meeting in **mid-September; date TBD**.
  - Topics: SHMCAP Goal Setting, Vulnerability Assessment Progress, and Survey Training.
- Climate 101 Training feedback by EOD **Tuesday, August 2nd**.
- Upcoming **August 10th** agency workshop on MA Climate Assessment.
  - Make-up session on **August 15th**

RMAT Meeting 1 – Summary Notes

July 26, 2022

Agenda

- Welcome and introductions
- RMAT Update
- 2023 SHMCAP Progress and Overview of Engagement Approach
- Chapter Outline and Document Review Process
- Draft Agency Survey
- Wrap up and Next Steps

Introduction, motivation, and meeting goals

- Introductions included appreciation for participant attendance. There was recognition that participants had busy schedules and RMAT activities would be capitalized as possible.

RMAT Climate Change 101 Training

- Climate Change 101 Training will be available on Mass Achieves and available voluntarily. Feedback on the training script requested by August 5th to Courtney.rocha@mass.gov and Hillary.King@mass.gov.

FY 2023 SHMCAP Implementation Funding

- The MVP program awarded over $5.7M to 22 agency projects through a combination of bond cap and ARPA funds. A list of awarder projects was shared.
- Each year funding to support the State Hazard Mitigation and Climate Action Plan (SHMCAP) implementation grows. Participation is encouraged as a source of finance to implement and advance SHMCAP.

SHMCAP Update Overview

- Motivation and purpose:
  - A key component of the 2023 SHMCAP is to update actions in the plan. This is an opportunity to incorporate lessons learned and to plan for the future.
  - Hazard mitigation program implemented actions change vulnerabilities. Climate change impacts will likely also change vulnerabilities and thus, will inform and change mitigation actions as climate change impacts and consequences are realized.
  - State Hazard Mitigation Plans are required to access FEMA funding but also a good opportunity to update plans.
- The SHMCAP is the state's plan and participation from state agencies is important to develop actions that benefit the Commonwealth and reduce risks to populations and assets.
- A summary of the SHCMAP Update process and timelines (slides 11 and 12).

  - Chapter outline was shared prior to the meetings and a request for feedback remains for meeting participants.
- Question- How have the "Climate Change Projections" (page 5 of 2018 SHMCAP Exec Summary) through end of century changed for the 2023 plan? Do they now include hydrodynamic (e.g., MC-FRM) model outputs? This summary page is highly referenced, so any news on updates to it will be valuable.
  - The updated climate projections (from Cornell University) will be summarized in the Climate Assessment. MC-FRM outputs were also used in the Climate Assessment.
  - Yes, they do include hydrodynamic model outputs. We can provide a list of the changes from what informed 2018.
- Question- will a list of documents reviewed be available
  - Yes, we will provide a list of the documents reviewed.

Relationship between Climate Assessment and SHCMAP

- Provides most of the risk assessment information for the 2023 SHMCAP, focused on assessing impacts for stressors across the five sectors presented in the MA Climate Assessment.
- An overview of the relationship between SHMCAP and the Climate Assessment was discussed, with main points covered in slides 13 and 14.

SHMCAP Process and engagement summary

- Summary of meeting goals, outcomes, and roles of various groups including: PMT, RMAT, SHMCAP Working Group, Climate Coordinators. The summary is available on slide 16.
- RMAT agency representatives will serve as SHMCAP State Agency Working Group, participate in a series of meetings, and will be asked to participate in small group meetings and developing actions for the 2023 SHMCAP. More details are available on slide 17-18.
  - SHMCAP Working Group/RMAT Meetings are an important avenue to provide input and develop the mitigation plan and strategy. It is important for participants to read the provided materials and be ready to discuss questions during these meetings.

Chapter Outline and Document Review, *details available on slides 20-23*

- The document review provides an effective and efficient assessment of relevant documents and efforts to inform the 2023 SHMCAP.
- Capabilities considers laws, authorities granted to state for adaptation and hazard mitigation, staff and funding to support climate adaptation, adaptive capacity- or ability for agencies to adjust or modify their operations and policies to adapt to changing hazard and climate change impact in the short and long term.
- Capability report will also consider local capabilities, challenges, gaps, barriers, and opportunities for the state to support local efforts and collaborate with local institutions.
- Written feedback on draft outline requested after meeting.

Discussion

- In general, there are gaps in planning and training for hazard mitigation, need additional training and resources for the process to be accessible to all agencies.
- It would be helpful to provide an example of each of the items defined, e.g. climate adaptation.

- Historic districts should be considered when developing and implementing actions and strategies.
- There is room for improvement in how we prioritize/ support disadvantaged communities/ vulnerable populations. The state uses some scoring criteria and other funding priorities that exist within federal and state grant programs when administered. Will be interesting to see how this evolves.
- Question- Is there a compilation/analysis of the MVP planning documents that would be useful in developing the Local capabilities section?
  - Yes, we are incorporating the MVP plans and our analysis of them and coordinating with that team. Great point!
- Question- EEA went through extensive vulnerability assessment. How is SHMCAP different? How is this effort bringing forth information from the last effort? Alternatively, is this something new? What are state agencies providing input on.
- Consideration of inter-agency and intra agency work and collaborations. Discussion concluded that these considerations would be included explicitly in the outline. Will add a section in the chapter outline about interagency capacity and capabilities.
  - We need to include a look at what happens BETWEEN agencies as well as what happens within each agency.
  - SHMCAP update will look for ways to illustrate interagency engagement and actions.
  - Working Group encouraged to share examples in survey.
- Question- will mitigation assets be considered? We manage forest, depend on how you want to consider forests.
  - We want to consider all assets.
  - From a resilience point of view can capture in both directions, capture adaptation and mitigation.

State Capability and Capacity Analysis Chapter Outline, *details available on slides 27-38*

- Reminder to think about adaptation and resilience not as individual agencies but as a collaborative effort where agencies work together to improve resilience and adapt the state as a whole.

Discussion

- A copy of the past capability analysis can be sent. Questions agencies to consider when thinking about the assessment, what am I doing that is relevant? Share examples to climate action team.
- Question- I am reviewing private property developments, is this relevant? Anything that considers or changes the risk profile should be included. Consider how agencies serve constituents whether through programs or assets.

Capacity and Vulnerability Survey, *details available on slides*

- The survey is a tool to capture data needed for the vulnerability and capability assessment. Please bring your institutional knowledge.

- The survey will draw from 2018 information, include pre-populating. The state capabilities and capacity within the 2023 SHMCAP will also be built upon responses to the survey.

- The process for the 2023 SHMCAP development will be different from 2018. This round will focus on people, asset classes and divisions, with the goal to make the process less burdensome.

The update will also focus on establishing a degree of vulnerability for asset class for both physical and non-physical assets.

- The survey will help the team identify hazard mitigation and climate adaptation focus areas, vulnerabilities, and eventually inform actions included in the 2023 SHMCAP.
- Helpline will be available, can reach out to anyone at any time during process while survey is open.
- Discussion questions: Does the process outlined seem reasonable and efficient?
    - Do you have any suggested improvements or anyone else who should be involved in this process?
    - For Climate Coordinators, will you want to review and approve survey responses from the agencies?
    - If your agency completed a survey in 2018, how did that go? What was valuable about the process, and what was missing?
    - If your agency did not complete a survey, why not? Based on your review thus far, are these the right questions to be asking? Is there anything missing?

2023 MA SHMCAP
RMAT Meeting 2

2023 SHMCAP Update Working Group #2 Meeting

Wednesday, September 14, 2022

2:00 – 4:00 pm EDT

Note, part of this meeting will be recorded

Agenda

Meeting Objectives

- Provide survey training and discuss State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment survey process and roles for obtaining responses within agencies.
- Discuss and gather feedback on draft mission and goals for 2023 SHMCAP update.

Pre-Meeting Materials *(see following pages)*

- Survey definitions list
- Agency leads for survey process
- Draft 2023 Mission and Goal

Time (EDT)	Agenda Item
2:00 – 2:10 pm	**Welcome and Introductions** • Updates since 7/26 RMAT meeting (including document review inventory)

2:10 – 2:55 pm	**Survey Training**
	This training will be recorded
	• Survey purpose, roles, and process
	  o Q&A
	• Survey definitions and key questions and examples
	  o Overview on comments received and survey revisions
	  o Q&A
	• Technical assistance and "office hours"

2:55 – 3:55 pm	**Mission and Goal Setting** • Overview on mission and goal setting process and update • Review and discuss SHMCAP 2023 Mission • Review and discuss SHMCAP 2023 Goals o Goal discussion breakout groups • Report back
3:55 – 4:00 pm	**Wrap Up and Next Steps** • Launch survey on 9/26 • Review draft Climate Assessment Report (forthcoming) • Share feedback on Goals Document Draft 1 by 10/3 • Next meeting to be held on 10/25

2023 SHMCAP Update

RMAT Meeting
September 14, 2022

ERG IEc WOODS HOLE GROUP CBI CATALYZING COLLABORATION

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Agenda

Welcome and Introductions
- Updates since 7/26 RMAT meeting

Survey Training *(*This training will be recorded*)*
- Survey purpose, roles, and process
  - Q&A
- Survey definitions and key questions and examples
  - Overview on comments received and survey revisions
  - Q&A
- Technical assistance/office hours available

2023 SHMCAP Mission and Goal Setting
- Overview on mission and goal setting process and update
- Review and discuss SHMCAP 2023 Mission
- Review and discuss SHMCAP 2023 Goals
  - Goals discussion breakout groups
- Report back

Wrap Up and Next Steps

2

Welcome and Introductions

Please put your affiliation in the webinar participant list (next to your name) or chat

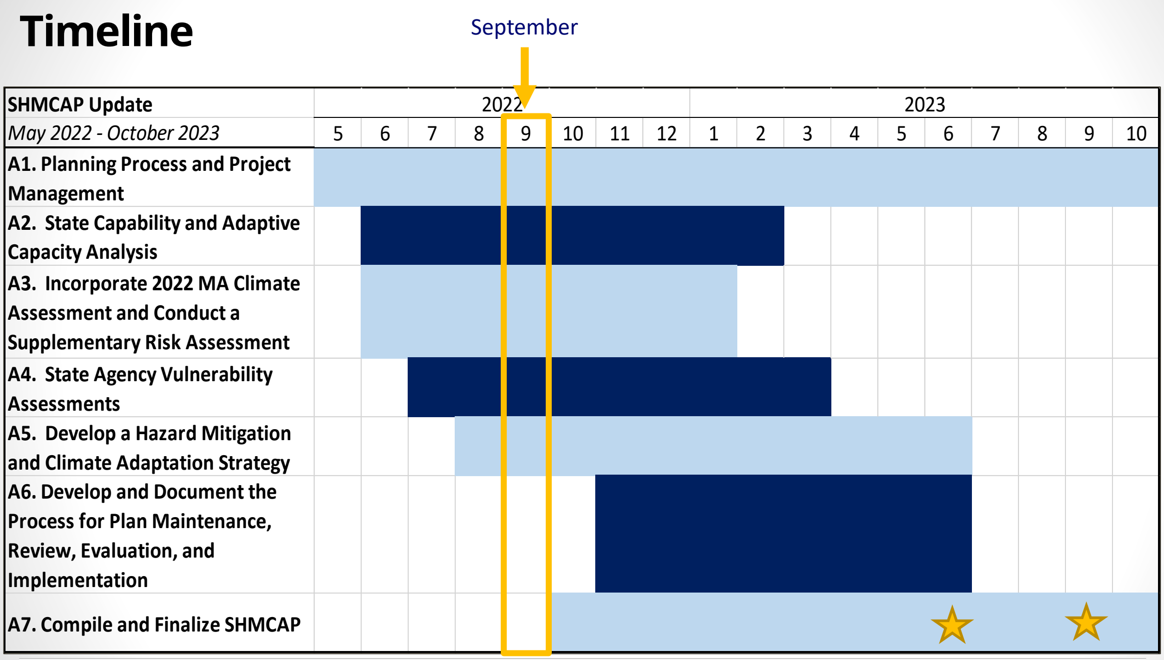
Meeting Goals

1. Provide **survey training** and discuss State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessments survey process and roles for obtaining responses within agencies
2. Discuss and gather feedback on **draft mission and goals** for 2023 SHMCAP update

Updates since 7/26 RMAT Meeting

1. Conducted document review (*ongoing, ~70 docs reviewed to date*)
2. Continued integration with Climate Assessment
3. Continued identification of best available data, information, and science
4. Revised and finalized State Agency Survey ***(process to be discussed today)***
5. Drafted 2023 SHMCAP Update Goals and Mission ***(to be discussed today)***
6. Draft Risk Assessment approach and methodology

Timeline



Survey Training

State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment

This training is recorded

To download recording:

https://drive.google.com/file/d/1FC1nIcoqmq0aadSYLpl3QOA_1-Iq8aAF/view?usp=sharing

Survey Purpose

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

- Gather information on **existing state capabilities and capacity**
- Identify **physical assets, non-physical assets, and functions within each sector** that will be affected by hazards and climate change impacts on those hazards
- Determine the **degree of vulnerability** of physical assets, non-physical assets, and functions
- Highlight or begin to identify **high priority vulnerabilities and consequences** for each agency

Hazard Mitigation and Climate Adaptation Actions

- State Capabilities
- Vulnerability of State Agency Assets (Physical & Non-Physical) and Functions
- State Adaptive Capacity

Survey Logistics

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Survey Format
- ERG will administer the survey in Qualtrics.

Respondents
- All agencies identified by the Climate Change Coordinators will receive a survey.

Agency Leads
- Climate Change Coordinators selected "Agency Leads" who will coordinate with agency respondents on the survey and serve as liaison with SHMCAP team.

Agency Participants
- Agency Leads should work with others in their agency who have knowledge on the agency's physical and non-physical assets, functions, and capabilities.

Timeframe
- Agencies will have from **September 26 to October 28** to respond to the survey.

Role of Agency Leads

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Survey

Agency Lead

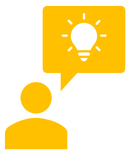
*Coordinates and gathers survey input from Agency Participants, acquires Agency Leadership approval on survey input (if required), and submits survey. Serves as liaison between 2023 SHMCAP team and agency staff. **see link in agenda packet***

Agency Participants

Provides survey input based on technical and policy expertise and agency knowledge to Agency Lead.

Role of Agency Leads

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment



Agency Leads

Identified by Climate Change Coordinators. See handout for full list.

Agency Lead Responsibilities:

- **Access** the survey via a unique agency Qualtrics link.
- **Coordinate** with others in their agency to share survey content and Qualtrics log in and address questions.
- **Ensure** all responses from others within their agency are uploaded into Qualtrics.
- **Reach out** to ERG with questions and clarifications.
- **Facilitate review** of the survey by agency or Executive Office leadership, if needed.
- **Submit** Qualtrics survey responses.

Survey Process

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Long Survey

- For agencies with no existing vulnerability assessments.
- For agencies where existing assessments do not contain sufficient information.

Short Survey

- For select agencies who have adequate existing vulnerability assessments.
- Includes all capacity and capability questions.
- Includes some selected state agency vulnerability assessment questions.

Survey Process Steps and Timeline

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

- **September 26:** ERG sends survey invitation to Agency Leads.
- **Week of September 26 and October 3**: Agency Leads identify staff to respond to the survey and share link.
- **Week of October 10 and 17**: Agency Leads and staff fill out survey. Agency leads can work with staff to facilitate collating responses (e.g., through a Google Doc or SharePoint doc that leads transfer to Qualtrics).
- **Week of October 17 and 24**: Agency Leads fill any needed gaps in survey, start obtaining approvals from leadership.
- **Week of October 24:** Agency Leads obtain needed approvals on survey from leadership and Climate Change Coordinators.
- **October 28**: Agency Leads submit survey responses.
- **November onward:** ERG reviews data and develops draft reports.

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Questions and Discussion

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Discussion: Survey Purpose, Roles, and Process

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Do you have any concerns you would like to discuss regarding the survey purpose, roles, process, or timeline?

- Timeline can be flexible based on Agency Leads' coordination– only set deadline is 10/28 submission.
- Outreach to Agency Leads and Leadership – work with Secretariats on how best to approach
- Can move through Qualtrics without submitting responses. Survey will be provided as DOC and PDF with survey link as well for each agency lead.
- We will send out meeting notes, slides, and recording of training
- Survey builds on the 2018 SHMCAP VAs

What can our ERG team do to help you while your agency is taking the survey?

- x

Do you have any other questions for us regarding the survey process?

- x

Survey Definitions

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

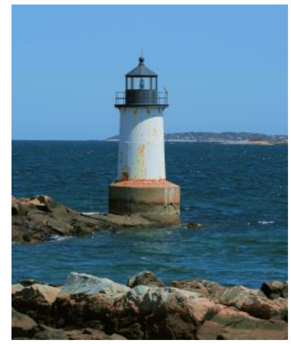
ERG developed a survey definitions list, drawing on definitions used by FEMA, the 2018 SHMCAP, and the 2022 MA Climate Assessment. Terms identified in the list include:

- Adaptive capacity
- Climate adaptation
- Exposure
- Functions
- Hazard mitigation
- Non-physical assets
- Physical assets
- Resilience
- Sensitivity
- State capability
- Underserved communities
- Vulnerability

Draft Survey Comments Received and Revisions

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

- **Streamlined process** to help gather information in collaborative and efficient manner.
- **Builds on existing** vulnerability assessments.
- **Added more examples** for clarity.
- **Refined definitions**, including asset categories, physical and non-physical assets, and functions.
- **Added questions** on interagency collaboration efforts.
- **Ensured that non-physical and functional assets, services and programs** were included.



Survey Key Concepts

State Capability and Adaptive Capacity

Survey Question

How is your agency addressing ***hazard mitigation and climate*** *adaptation in its existing plans, programs, policies and procedures (e.g., regulations, laws), decision-making (e.g., governance) processes, and capital planning and finance?*

Hazard Mitigation and Climate Adaptation Examples:

- Assessing risks from hazards and climate change for new construction
- Revising policies
- Developing a climate health and communication plan with clear interventions
- Adding new regulations regarding new construction and retrofits
- Revising maintenance and operation schedules and approaches

Survey Key Concepts
State Capability and Adaptive Capacity

Survey Question

Outline and briefly describe your agency's ***available resources*** *to reduce risks to its physical and non-physical assets and functions from damage, disruption, and loss due to current and future hazards that will be affected by climate change. Please describe the resource, as well as populations served, and any other relevant details.*

Agency Resources Examples

- Physical and non-physical asset inventories
- Inventory of vulnerabilities
- Methodologies and prioritization documents
- Vulnerability assessments
- Remote operation capability
- Capital improvement
- Climate change adaptation plans
- Adaptive management plans

Survey Key Concepts
State Capability and Adaptive Capacity

Survey Question

Building on the 2018 State Capability and Adaptive Capacity Analysis, does your agency have any ***updated*** *or* ***new capabilities*** *not included in your 2018 SHMCAP response?*

Capabilities Examples

- Updating the State Forest Action Plan to enhance climate change mitigation and adaptation strategies
- Prioritizing clean energy resiliency infrastructure projects
- Assessing climate change effects on travel and tourism
- Reviewing building codes
- Facilitating programs for sharing resources between municipalities

Survey Key Concepts
State Capability and Adaptive Capacity

Survey Question

Building on the 2018 State Capability and Adaptive Capacity Analysis, has your agency ***updated*** *or developed* ***new approaches to improve the resilience of your agency, and continuity of operations*** *that were not included in the 2018 SHMCAP survey response?*

Approaches to Improve Resilience and Continuity of Operations

- Plans or programs that address current and future hazards affected by climate change (e.g., sea level rise, extreme heat, nuclear power, etc.).
- Studies can include hazard specific information, vulnerability assessments, data gathering to support risk assessments, and more.

Survey Key Concepts
State Agency Vulnerability Assessment

Survey Question

Please indicate which of the following ***categories of physical assets, non-physical assets, and functions*** *your agency is directly responsible for implementing, administering, owning, managing, providing routine guidance related to, or leasing as part of its regular operations.*

(Note that it is not necessary for your agency to own these assets, if management or influence over the assets is part of the agency's functions. Influence over the assets could include a role in permitting, regulating, providing guidance, designing and managing codes, providing service to or receiving service from, or a planning and policy role.)

Survey Key Concepts

Physical and Non-Physical Assets and Functions Examples

- **Critical physical and non-physical assets and functions:** Hospitals and medical facilities, prisons, animal care facilities, medical services, police stations, fire stations, safety and education services, public schools, emergency response services, critical infrastructure support, workplace safety services

- **Community physical and non-physical assets and functions:** day cares, food banks, grocery stores, senior centers, education and research institutions, youth and elder care, housing, courthouses, research, waste transfer stations, landfills, recycling and reclamation facilities, incinerators, waste collection and transfer, household hazardous waste collection sites, social or transitional services such as unemployment assistance, job placement, job centers, workers compensation and paid family/medical leave support

Survey Key Concepts

Physical and Non-Physical Assets and Functions Examples

- **Utilities and infrastructure physical and non-physical assets and functions:** reservoirs, dams, industrial and sanitary sewer systems, flood control infrastructure, stormwater systems, power utilities, fuel and natural gas pipelines, oil refineries, power provision, flood control, drinking water provision

- **Transportation and mobility physical and non-physical assets and functions:** local streets and roads, state highways, bus shelters, bus and train stations, bridges and tunnels, railroads and freight lines, transit services [bus, light rail], ferry and boating services, movement of goods, bike/pedestrian routes, airports

- **Ports and maritime physical and non-physical assets and functions**: seaports and marine terminals, shipping and commerce services, seawalls and riprap, docks, nature-based flood and stormwater systems

Survey Key Concepts

Physical and Non-Physical Assets and Functions Examples

- **Communication physical and non-physical assets and functions:** land line telephone systems, cable systems, cellular telephone antennae, underground communication conduits, Internet and telecommunications provision
- **Recreation, open space, natural areas, and working lands physical and non-physical assets and functions:** park and recreation facilities, designated open space, cultural and historic resources, bike/pedestrian trails, natural areas, agricultural and working lands, natural and working lands resource management, natural and working lands regulations and programs, recreational opportunities, wildlife habitat, wildland-urban interface buffer provision
- **Hazardous materials sites and contaminated lands physical and non-physical assets and functions:** hazardous materials, landfills, cleanup sites, hazardous waste disposal and transfer, toxic and contaminant reduction

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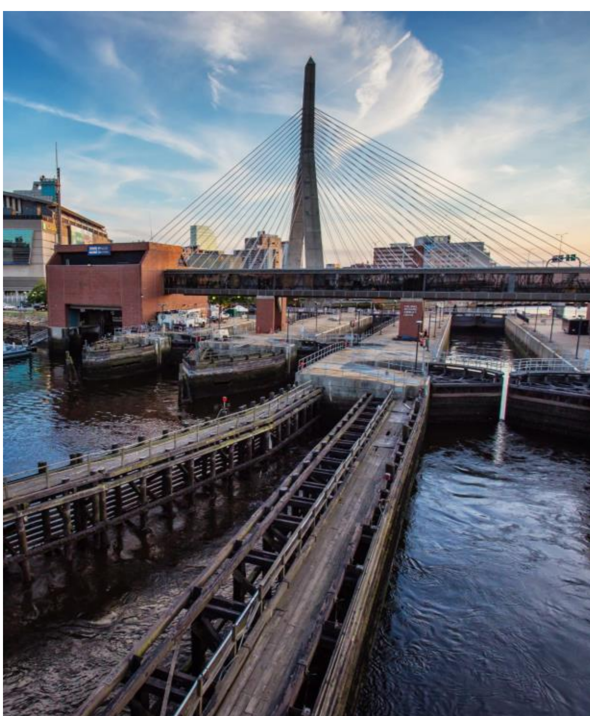

Questions and Discussion

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Discussion: Definitions and Concepts

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

Do the definitions shared align with the way your agency is using these terms?

- Agencies could start thinking about categorizing their assets and functions prior to survey based on definitions.
- Some Qs will relate to asset/function categories, while other Qs will be more specific

Are there any concepts that you have questions about or would like clarification on?

- Survey Qs on interagency connections, ways to respond to physical and non-physical assets and functions
- Survey Qs for regulators: Qs also focus on functions

Do you have any other questions for us regarding survey content?

- Think about confidential information and how that is handled/shared

Survey Technical Assistance

State Capability and Adaptive Capacity / State Agency Vulnerability Assessment

- **Reach out to ERG via ERG helpline with questions at any time during survey process.**

Topic	Name	Email
State Capabilities and Adaptive Capacity	Jennifer Lam	Jennifer.lam@erg.com
Vulnerability Assessment	Diana Pietri	Diana.pietri@erg.com
Technical Survey Assistance	Brielle Kissel Meade	Brielle.kissel@erg.com

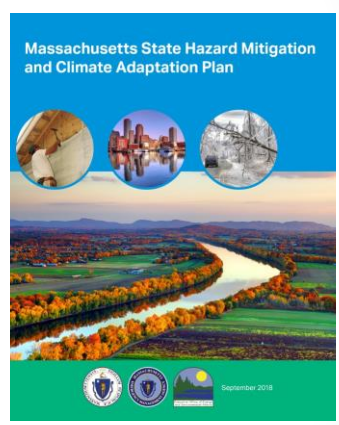
- **ERG will hold two Zoom "office hour" sessions to answer questions that you may have while taking the survey.**
  - Thursday, October 6 at 2:00—3:00 PM ET
  - Wednesday, October 19 at 2:00—3:00 PM ET
  - Join ZoomGov Meeting: https://www.zoomgov.com/j/1605850150

Mission and Goals
2023 SHMCAP Update

Motivation, Mission and Goals

Why does it matter and how does this play into the 2023 SHMCAP update?

- **Collaboratively establish** a shared vision, ambition, and motivation
- **Ensure that strategies and actions** outlined in the plan are:
  - **Aligned with your mission and goals**
  - **Measurable**
  - **Reflect Massachusetts priorities**
- **Draft goals** are informed by a review of:
  - MA Climate Assessment
  - State agency mission and goals
  - 2013 SHMP and 2018 SHMCAP
  - Local hazard mitigation plans
  - FEMA goals for hazard mitigation and climate adaptation



Process Overview and Timeline

High-level overview of the process

- **September 14:** SHMCAP Working Group Review of Draft 1
- **September – October:** Incorporating feedback from 9/14
- **October 25:** SHMCAP Working Group to Review Goal Document
- **January – March:** SHMCAP Goal Document Final Draft will be open for revisions as we receive input from other stakeholders
- **March 2023:** Mission and Goals document finalized

Setting the Stage- Mission

Significant changes in understanding of and experience with climate change impacts, as well as policy around hazard mitigation, climate adaptation, and climate change

2020- IPCC AR6
- Latest climate science, urgency reduce emissions, and invest in adaptation

FEMA updated guidance
- Effective April 2023
- Long-term planning and land use, hazard mitigation AND adaptation
- Considers systems and services
- Requires consideration of equity and climate change impacts

BIL and IRA legislation
- Billions of dollars in funding to GHG reduction, adaptation, and hazard mitigation
- FEMA funding $700 million to $1.16 billion in 2021, $3 billion in 2022

Hazards and climate impacts
- Increase frequency and severity of weather/climate disasters
- 9 Events with losses exceeding $1 billion in 2022 in the U.S.
- 17.8 (avg/year 2017-2021)

MA Climate Impact Assessment
- Launched, September 2021 is identifying high urgency climate risks statewide
- Extensive public engagement

MA legislation and funding
- Announcement $32.8 million in grants to cities and towns through the Municipal Vulnerability Preparedness program
- $100 million to 341 cities and towns through the MVP program

Setting the Stage: Mission

Mission and goals have not changed significantly since 2013 SHMP update

2013 SHMP: Reduce the statewide loss of life, natural resources, property, infrastructure, and economy from natural hazards and climate change through the development of a comprehensive and integrated hazard mitigation and climate adaptation program.

2018 SHMCAP: Reduce the statewide loss of life, and protect natural resources, property, infrastructure, public health and the economy from natural hazards and climate change impacts through the development of a comprehensive and integrated hazard mitigation and climate adaptation program.

2023 Mission Statement

DRAFT - For discussion purposes only

Increase the capacity of the Commonwealth to **prepare for, adapt to, and reduce the risk** of natural and other hazards and climate impacts through the development of a **comprehensive and integrated** hazard mitigation and climate adaptation program. This program will ensure an **equitable and just approach to reduce loss of life; protect social, environmental, and economic wellbeing; and protect health and safety** of Massachusetts, including the built and natural environment that sustains it.

Avenues for feedback available today:

Raise hand to speak | Comment in the chat | Add to Menti (code **7223 2399**) - open for 24 hours
Email feedback to AndreaCristina.Ruiz@erg.com by **October 3**

2023 SHMCAP Goals Categories

Goals will aim to cover the following areas

1. Strengthened Collaboration and Partnership
2. Science-based and Informed Decision-Making
3. Enhanced Protection of Assets and Services
4. Long-Term Hazard and Climate Impact Reduction
5. Equitable Climate Adaptation and Hazard Mitigation
6. Ongoing Communication and Engagement
7. Climate Mitigation
8. Resilient Infrastructure and Communities

Discussion questions

- Are we covering all the critical issues?
- Are the goals adequate to guide the design and prioritization of actions?
- How can we use the goals to measure progress as the plan is implemented?

Discussion Groups to Review 2023 Update Goals

Breakout session discussion questions

- Do you have any feedback to the goals as written to improve their purpose as an active guide to inform hazard mitigation action and climate adaptation strategies?
  - Are we covering all the critical issues?
  - Will the goals provide enough guidance when prioritizing and designing actions?
  - How can the goals be used to measure progress during the implementation and maintenance of the 2023 SHMCAP?

2023 SHMCAP Goals

Please reference the goals shared last week (available here for reference)

1. ***Strengthened Collaboration and Partnership***: Increase the state's institutional capacity to integrate hazard mitigation and climate adaptation actions in programs, policies and services through enhanced coordination and collaboration among state agencies and with local jurisdictions, regional agencies, Tribal governments, and community organizations.

2. ***Science-based and Informed Decision-Making***: Enhance and advance the state's understanding of current and future vulnerability and risks from natural and other hazards and climate impacts. Integrate and build on the 2022 Massachusetts Climate Change Assessment and incorporate the latest scientific and local knowledge to develop coordinated and collaboratively identified actions that address short, medium, and long-term vulnerabilities and implementable, comprehensive, and equitable.

2023 SHMCAP Goals (cont.)

Please reference the goals shared last week (available here for reference)

3. ***Enhanced Protection of Assets and Services***: Continue and enhance the Commonwealth's ability to protect state assets and services to maintain continuity of service, community lifelines, state functions, and infrastructure. Use strategies and actions that advance community resilience, reduce community stressors, and promote sustainable development.

4. ***Long-Term Hazard and Climate Impact Reduction***: Work collaboratively at the State and local level to reduce natural and other hazard and climate impacts. Increase community safety through equitable, risk-informed plans, policies, regulations, codes, and land use planning, as part of short- and long-term hazard mitigation and adaptation strategies.

2023 SHMCAP Goals (cont.)

Please reference the goals shared last week (available here for reference)

5. ***Equitable Climate Adaptation and Hazard Mitigation:*** Safeguard the right of all people, especially environmental justice populations, to enjoy equal protection, equitable distribution of benefits, and meaningful involvement in the 2023 SHMCAP's development and implementation. Ensure the plan provides meaningful and measurable approaches to build community resilience and reduce community stressors.

6. ***Ongoing Communication and Engagement:*** Support implementation and evolution of this plan through increased education, awareness, and partnership among state agencies, local governments, private industry, non-profits, and the public.

2023 SHMCAP Goals (cont.)

Please reference the goals shared last week (available here for reference)

7. ***Climate Mitigation:*** Recognize and support climate mitigation actions and strategies that could reduce long-term climate risks.

8. ***Resilient Infrastructure and Communities:*** Ensure the 2023 SHMCAP is designed to result in actions and strategies to reduce the most significant consequences to communities, infrastructure, environment, and economy and that can result in measurable increases in community and infrastructure resilience.

2023 SHMCAP Goals Breakout Group Sharing

Breakout room facilitators share take-aways from their breakout sessions

After today, feedback can be shared by:

- Commenting in the chat
- Menti will remain open for 24 hours **(7223 2399)**
- Emailing AndreaCristina.Ruiz@erg.com by **October 3**

Wrap Up and Next Steps

- Launch survey on **September 26**
- Review draft Climate Assessment report **(forthcoming)**
  - Week of 9/26 it will be sent to the Climate Assessment Project Working Group and then release for public review at end of Oct
- Share feedback on Goals Document Draft 1 by **October 3**
- Next SHMCAP meeting to be held on **October 25**

Thank you

Definitions List

The definitions listed below are used throughout the survey.

Adaptive Capacity: The ability of state agencies (including their assets, functions, missions, and services/programs) to adjust or modify their operations, policies, or other functions to adapt to changing hazards and climate change impacts, both in the short and long term. For example, an agency which can operate remotely likely has greater adaptive capacity than an agency which must operate from a damaged building. Similarly, a community or facility that can continue to operate during extended periods of drought due to a resilient, redundant water supply system has greater adaptive capacity than one that may encounter water restrictions.

Assets:
For the purposes of this survey, there are two main types of assets: physical and non-physical.
These are defined below:

> **Physical assets**: These include any tangible facilities, equipment, landholdings, natural resources, etc. that meet the definition of criticality below by playing a significant role in the operation and mission of your agency.
>
> **Non-physical assets**: This category captures non-tangible resources, such as power, internet connectivity, transit services, recreation services and programs, public K-12 education, emergency preparedness and response, public health and safety functions and services, waste management, youth programs and foster care services, animal shelter and safety services, cloud-based data, and more that make up many of your agency's functions (functions are defined below).

Climate adaptation: Measures taken in response to actual or projected climate change to eliminate, minimize, or manage related impacts on people, infrastructure, and the environment.

Criticality: This definition is provided to aid agencies with the identification of critical assets or functions for the purpose of this survey. Criticality is based on three parameters: scope, time, and severity.

> **Scope** describes the geographic area and population that would be affected by the loss or inoperability of an asset or function. An asset or function is considered critical if it serves a region or the entire state or would affect greater than 10,000 people.
>
> **Time** describes the length of time that an asset or function can be inoperable without consequences. An asset or function is considered critical if it is inoperable immediately after a hazard event or one to two days after an event.
>
> **Severity** describes the consequences of the loss and inoperability of an asset or function. There are a multitude of consequences, including public health and safety, economic losses, environmental effects, interdependencies, political effects, and psychological effects. An asset or function is considered critical if the consequences include loss of life or severe injuries, significant economic loss, extensive environmental contamination, significant impact on other agencies, significant impact to service delivery, or significant loss of confidence in the agency.

These parameters and examples should be taken into consideration when identifying your critical assets and functions for the purpose of this survey.

Exposure: The extent to which physical and non-physical assets, functions, and population groups are in direct contact with natural hazards or their related climate change impacts. Exposure is often determined by examining the number of people or assets that lie within a geographic area affected by a natural hazard or by determining the magnitude of the climate change impact. For example, measurement of flood depth outside a building or number of heat waves experienced by a county are measurements of exposure.

Functions: The programs and services an agency provides to its customers in order to fulfill its mission. These programs and services depend on the mission of your agency and could include activities such as planning, policy development, regulatory enforcement, research, permitting, grant-making, outreach/education, or stewardship of critical resources.

Hazard mitigation: Hazard mitigation is any sustained action taken to reduce or eliminate the long-term risk to human life and property from natural and non-natural hazards. An example of hazard mitigation is elevating or strengthening a bridge to reduce damage, disruption, or loss from a flood or an earthquake. It also includes the development of regulations to require new construction to include methods and procedures to reduce risks from current hazards and increasing risks from climate change.

Resilience: Ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies.

Sensitivity: Sensitivity refers to the impact on a system, service, or asset when exposed to natural hazards. For example, if a facility is exposed to storm surge, how will its ability to function be affected? When a critical threshold has been identified, the level of sensitivity of your agency, a specific asset, function, or population group served to a hazard indicates how much or to what extent the occurrence of a hazard exceeds the critical threshold for that asset or function such that it would disrupt the ability of the agency/asset/function to continue normal operation. If the critical threshold is not exceeded, then the sensitivity to a certain hazard is low, even if it is exposed.

State Capability: Includes the authorities, laws, policies, programs, staff, funding, and other resources available to the Commonwealth to support and advance hazard mitigation and climate adaptation efforts at state and local levels. Examples of a state capability for hazard mitigation and climate adaptation is having dedicated staff who work primarily on hazard mitigation and climate adaptation or including hazard mitigation in existing plans/planning processes to assess risk and implement actions to reduce that risk.

Underserved communities: Refers to populations sharing a particular characteristic, as well as geographic communities and environmental justice populations, that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life. The barriers to opportunity and participation these communities face have occurred throughout history and continue today.

Vulnerability: The overall vulnerability of your agency to a hazard is determined by combining your exposure, sensitivity, and adaptive capacity. Agencies or assets that are highly vulnerable may be highly sensitive to a certain natural hazard or climate change impact, highly exposed, and/or have low adaptive capacity. On the other hand, agencies or assets that have low sensitivity or high adaptive capacity may not be impacted by a natural hazard or climate change impact at all.

Agency Leads for Survey

For each Executive Office, Climate Change Coordinators selected "Agency Leads." The role of Agency Leads will be described in more detail during the September 14 meeting, and the appointed Agency Leads are listed below. In generally, Agency Leads will:

1. Be responsible for coordinating with others within their agency to respond to the survey.
2. Serve as a liaison with the SHMCAP team.
3. Work with others in their agency who have knowledge on the agency's physical and non-physical assets, functions, and capabilities.
4. Acquire Agency Leadership approval on survey responses, if needed.
5. Submit survey.

To view the most current agency leads list, see: Survey POC List

Draft 2023 Goals and Mission

For SHMCAP Working Group
Review 2023 SHMCAP Goals Document (Draft 1)

Dear SHMCAP WG,

Establishing a shared mission and goals for the 2023 State Hazard Mitigation and Climate Adaptation Plan update is a critical step in ensuring we have a shared vision and level of ambition. The mission and goals will be informed by stakeholder engagement with multiple avenues for feedback including:

1. Participation during the September 14 SHMCAP WG meeting through verbal feedback, chat participation, virtual engagement tools (mentimeter).
2. Submitting input through the mentimeter, available until 3pm on September 15.
3. Submitting an email to AndreaCristina.Ruiz@erg.com by October 3, 2022.
4. Participating in the October 25 SHMCAP Working Group meeting.

The mission statement will be developed with stakeholder input. We will invite stakeholders to provide feedback on drafts of the vision (mission and goals) for adapting to climate change and mitigating risk from natural and other hazards across the Commonwealth.

We invite you to share your feedback on Draft 1 of the Goal Document at this time. You will have an opportunity to share feedback prior to the meeting, during the meeting via discussion, chat, breakout rooms, and mentimeter, and after the event via email and mentimeter. The October 25th SHMCAP WG meeting will offer a second opportunity for feedback.

As you read through the document, please consider the following questions:

- Are we covering all the critical issue?
- Are the goals measurable and meaningful to your agency?

Thank you in advance for your participation.

SHMCAP Project Management Team and Eastern Research Group, Inc.

Introduction:
Due to climate change, natural hazards are increasing in intensity, frequency, and duration—in addition to affecting larger geographic areas. The 2023 SHMCAP's mission statement and goals represent the vision of the Commonwealth of Massachusetts for a future in which communities and the environment have enhanced resilience and reduced vulnerabilities from natural hazards and climate change impacts. The Commonwealth will reduce the consequences of hazards and climate change to communities and the environment equitably and collaboratively through specific hazard mitigation and climate adaptation actions and partnerships.

The mission statement and goals reflect the needs identified in the risk and vulnerability assessments including the Massachusetts Climate Change Assessment, and the ongoing state agency vulnerability assessment and state capability and adaptive capacity analysis.

Mission statement: The **mission** for the 2023 State Hazard Mitigation Climate Adaptation Plan (SHMCAP) is as follows:

> *Increase the capacity of the Commonwealth to prepare for, adapt to, and reduce the risk of natural and other hazards and climate impacts through the development of a comprehensive and integrated hazard mitigation and climate adaptation program. This program will ensure an equitable and just approach to reduce loss of life; protect social, environmental, and economic wellbeing; and ensure health and safety of Massachusetts, including the built and natural environment that sustains it.*

Goals: These goals provide a framework to implement the Commonwealth's (state's) vision for mitigating risk and increasing social, environmental, and economic resilience from natural and other hazards and the effects of climate change on these hazards. Reviewers, please read the footnote.[1]

1. ***Strengthened Collaboration and Partnership****:* Increase the state's institutional capacity to integrate hazard mitigation and climate adaptation actions in programs, policies and services through enhanced coordination and collaboration among state agencies and with local jurisdictions, regional agencies, Tribal governments, and community organizations.
2. ***Science-based and Informed Decision-Making****:* Enhance and advance the state's understanding of current and future vulnerability and risks from natural and other hazards and climate impacts. Integrate and build on the 2022 Massachusetts Climate Change Assessment and incorporate the latest scientific and local knowledge to develop coordinated and collaboratively identified actions that address short, medium, and long-term vulnerabilities and implementable, comprehensive, and equitable.
3. ***Enhanced Protection of Assets and Services:*** Continue and enhance the Commonwealth's ability to protect state assets and services to maintain continuity of service, community lifelines, state functions, and infrastructure. Use strategies and actions that advance community resilience, reduce community stressors, and promote sustainable development.
4. ***Long-Term Hazard and Climate Impact Reduction:*** Work collaboratively at the State and local level to reduce natural and other hazard and climate impacts. Increase community safety through

[1] Note to reviewer: The focus of the section below is to develop robust, complete goals and allow for the language to provide context as to the intent of the goal. As was done in 2018, we will use formatting (bold and italics) and consider developing an abridged executive version of the goals. We are also piloting the use of titles to the goals to make them easier to skim and more accessible to web/print.

equitable, risk-informed plans, policies, regulations, codes, and land use planning, as part of short- and long-term hazard mitigation and adaptation strategies.

5. ***Equitable climate adaptation and hazard mitigation:*** Safeguard the right of all people, especially environmental justice populations, to enjoy equal protection, equitable distribution of benefits, and meaningful involvement in the 2023 SHMCAP's development and implementation. Ensure the plan provides meaningful and measurable approaches to build community resilience and reduce community stressors.
6. ***Ongoing Communication and Engagement:*** Support implementation and evolution of this plan through increased education, awareness, and partnership among state agencies, local governments, private industry, non-profits, and the public.
7. ***Climate mitigation***: Recognize and support climate mitigation actions and strategies that could reduce long-term climate risks.
8. ***Resilient infrastructure and communities***: Ensure the 2023 SHMCAP is designed to result in actions and strategies to reduce the most significant consequences to communities, infrastructure, environment, and economy and that can result in measurable increases in community and infrastructure resilience.

Although not specifically referenced in the goal statements, the need to build resilient infrastructure and communities, hazard mitigation post-fire, and high hazard potential dams, as identified by the Federal Emergency Management Agency (FEMA), is recognized by the Commonwealth in our specific actions and in our funding prioritization criteria for Hazard Mitigation Assistance (HMA) grants.

Anticipated timeline for 2023 SHMCAP Goal Document:

- **September 14** - Through a one-hour interactive session, SHMCAP WG members provide feedback that will be incorporated into the first working draft into the final draft of SHMCAP Goal Document (draft 2).
- **October 3**- Deadline to submit written feedback to AndreaCristina.Ruiz@erg.com
- **October 25** - The SHMCAP WG will have an opportunity to review the SHMCAP Goal Document (draft 2) in October before it is finalized.
- **October 31** – Final goals document. The SHMCAP Goal document (final draft) will be shared with municipal, Tribal, and regional government entities for feedback through engagement process in January-March of 2023.
- **November**-**March Stakeholder Engagement-** The Goal Document (final draft) will be included in stakeholder engagement. During the stakeholder engagement meeting series, stakeholders beyond the SHMCAP Working Group will have the opportunity to share reactions, feedback, and suggestions to the Goal Document. We will need to be open to update and amend the goals based on stakeholder feedback. Stakeholders that will be engaged as part of the stakeholder engagement plan.

RMAT Meeting and 2023 SHMCAP Update – Summary Notes

September 14, 2022

Survey training recording available here: *https://drive.google.com/file/d/1FC1nIcoqmq0aadSYLpl3QOA_1-Iq8aAF/view*

Welcome, Introductions, and Meeting Goals

The meeting goals included:

- Provide survey training and discuss State Capability and Adaptive Capacity Analysis / State Agency Vulnerability Assessment survey process and roles for obtaining responses within agencies.
- Discuss and gather feedback on draft mission and goals for 2023 SHMCAP update.

Announcements and next steps:

- Draft report of the Climate Assessment will be coming your way week of 9/26, there will be a public comment period in late October so if you don't get to first review can add in late October.
- The Resilience Mass working group developed a climate change 101 training that we will share soon. The training is housed on MassAchieves and all state staff can use that training. We're going to be following up with all climate change coordinators and relevant staff who will need to take that training. We'll follow up w/email but if you have a chance to go into MassAchieves there are some experts who will take you through that training.
- In addition to feedback shared through the Mentimeter, chat, discussion, and breakout rooms, you can provide feedback on goals by emailing AndreaCristina.Ruiz@erg.com by October 3rd, 2022.
- Survey action items:
  - Survey will be shared on 9/26. Please submit responses by 10/28 (See section on process for suggested timeline)
  - Office hours will be available on:
    - Thursday, October 6 at 2:00—3:00 PM ET
    - Wednesday, October 19 at 2:00—3:00 PM ET
    - Join ZoomGov Meeting: https://www.zoomgov.com/j/1605850150
  - Questions can be directed to:
    - Jennifer Lam Jennifer.lam@erg.com
    - Diana Pietri Diana.pietri@erg.com

Survey Purpose, Logistics and Process

Purpose

- Gather information on existing state capabilities and capacity
- Identify physical assets, non-physical assets, and functions within each sector that will be affected by hazards and climate change impacts on those hazards

- Determine the degree of vulnerability of physical assets, non-physical assets, and functions
- Highlight or begin to identify high priority vulnerabilities and consequences for each agency

Logistics

- ERG will administer the survey through Qualtrics.
- All agencies identified by the Climate Change Coordinators (CCCs) will receive the survey. Coordinators selected "agency leads" who will manage coordinating with agency respondents on the survey and serve as a liaison with the SHMCAP team.
- Agency leads should work with others in their agency who have knowledge on the agency's physical and non-physical assets, functions, and capabilities.
- Agencies have about a month to complete the survey (September 26 to October 28).
- Agency leads will work closely with others in their agency to get the information needed and approval on survey. Agency leads will reach out to SHMCAP team if their agency has any questions through email or office hours.
- Agency leads will be able to access the survey via their unique Qualtrics link. Agency leads will need to coordinate with others in their agency to ensure all responses are added to Qualtrics and that the response is submitted.
- There are two slightly different versions of the survey:
    - The long version is for agencies without existing vulnerability assessments since the 2018 SHMCAP survey where agencies filled out survey and did brief assessment as part of that. If there has been anything since 2018, ERG will review that work or assessment and if its insufficient for our purposes, the agency will receive a long survey. Long survey has questions related to adaptive capacity and state capability questions and full vulnerability assessment questions.
    - ERG has received some vulnerability assessments from some agencies, they will receive the short survey, which does not contain many of the detailed vulnerability assessment questions.
- Based on the information we have; ERG will determine which survey questions agencies will need to respond to.
- ERG is still assessing which agencies fall to which bucket (long or short survey) based on info we've received to-date

Process

- On **9/26**, ERG will send the survey to agency leads with the unique link to go to survey and that's when it will be open.
- Weeks of **10/10 and 10/17**, agency leads, and staff fill out survey and collate responses.
- During the week of **10/24**, agency leads will obtain any needed approvals on the survey from agency leadership. On **10/28** agency leads submit survey responses.
- From November and onward, ERG will review the data and develop draft reports. ERG will reach out to agency leads directly if they need any additional information from the agency.

Survey Purpose, Process, and Timeline Discussion:

- Question: Our agency lead would input info to Qualtrics and then have 1 week for internal approval, info would be in the survey but not submitted is that correct?
    - Yes, that's correct
- To clarify about the timeline, since the survey is open until the deadline, each agency can spend the time how you want, some might move more quickly and others a bit more slowly but as long as all responses are in by 10/28 we're all good. In terms of having responses in the survey but not submitted, each agency will have unique log in and everyone can insert their responses as needed and that info will be saved whenever someone exits survey so when the lead person goes through they can see everything inserted into the survey to-date. When agency lead gets approval from the director or whoever, they can press submit and survey will be complete.
- I also wanted to add into the schedule, everyone will coordinate within your own secretariat, once agencies have gone through chain of command, some secretariats will want to review the surveys, so you might have to establish a timeframe within your own secretariat/agency.
- Question: How exactly is this request getting transmitted to various points of contacts? I ask because it might be helpful to ensure that agency heads or chiefs of staff are being notified that this is coming and is a requirement. A lot of folks here are at various levels, some in the middle, some more at the staff level, oftentimes its helpful for the secretariat or leadership to provide a top-down ask or notification saying that this needs to be done.
    - We're working on outreach materials to accompany this info for the agency leads. In terms of how to communicate to leadership I defer to Marybeth and others
    - Kind of plays into what I just said, maybe between now and 26th, we'll work with secretariats to see how they want to handle it.
- You can move through Qualtrics survey without submitting responses so you can see all the questions, ERG will also provide the survey in Word and PDF formats so you can flip through the survey and get an idea of the questions before answering.
- ERG will also be providing slides, notes, and the recording from today's training.
- The survey builds on vulnerability assessments from the 2018 SHMCAP, this 2023 effort is an update, so we're building and expanding upon the 2018 version.

Survey Key Concepts and Definitions

- **Definitions:** ERG has developed a definitions list that draws on terms used in 2018 SHMCAP and the 2022 climate assessment, as well as in the FEMA state hazard mitigation planning guidance in 2022. These terms were included in agenda packet so you can refer to them. These are words that are critical to understanding and completing the survey, such as how we're defining adaptive capacity, etc. Some of the terms are a bit of an amalgamation of other words being used in other areas (e.g., underserved communities)
- **Content:** Many of you reviewed and commented on the draft survey after the July meeting and we've since made some changes such as:
    - **Streamlined process** to gather info effectively, collaboratively, and efficiently
    - **Builds on existing** vulnerability assessments
    - **Added more examples** for clarity
    - **Refined definitions,** including asset categories, physical and non-physical assets and functions
    - **Added questions on interagency collaboration efforts**

    - **Ensured that non-physical and functional assets,** services, and programs were included

Concepts:

- Below, we highlight a few questions and examples (Again, these are listed in the survey)
- *How is your agency addressing hazard mitigation and climate adaptation in its existing plans, programs, policies and procedures (e.g., regulations, laws), decision-making (e.g., governance) processes, and capital planning and finance?*
    - Assessing risks from hazards and climate change for new construction
    - Revising policies to include new projections
    - Climate health and communications plan with clear interventions with a focus on environmental equity
    - New regulations to make sure buildings are built to standards to withstand hazards
    - Revising maintenance and operation schedules and approaches to address increasing frequency or intensity of storms or providing new personal protection equipment for workers during high heat days
    - *Outline and briefly describe your agency's available resources to reduce risks to its physical and non-physical assets and functions from damage, disruption, and loss due to current and future hazards that will be affected by climate change. Please describe the resource, the population served, as well as populations served, and any other relevant details.* Physical and non-physical asset inventories
    - Inventory of vulnerabilities
    - Methodologies and prioritization documents
    - Vulnerability assessments
    - Remote operation capability
    - Capital improvement
    - Climate change adaptation plans
    - Adaptative management plans
- *Building on 2018 state capability and adaptive capacity analysis, does your agency have updated or new capabilities that are not included in 2018 response? (Note that ERG will provide you with your 2018 answers to refresh your memory as a hyperlink in the survey).*
    - State forest action plan to enhance climate change mitigation
    - Clean energy resiliency infrastructure projects
    - Assessing climate change effects on travel and tourism
    - Reviewing building codes
    - Facilitating programs for sharing resources between municipalities
- *Building on 2018 analysis, has your agency updated or developed new approaches to improve the resilience of your agency and continuity of operations that were not included in 2018 response?*
    - Plans or programs that address current and future hazards affected by climate change
    - Studies can include hazard specific info, vulnerability assessments, data gathering to support risk assessments, and more
- *Please indicate which of the following categories of physical assets, non-physical assets, and functions your agency is directly responsible for implementing, administering, owning, managing, providing routine guidance related to, or leasing as part of its regular operations.*

- *(Note that it is not necessary for your agency to own these assets if management or influence over the assets is part of the agency's functions. Influence over the assets could include a role in permitting, regulating, providing guidance, designing, and managing codes, providing service to or receiving service from, or a planning and policy role.)* <u>Critical physical and non-physical assets and functions</u>
- <u>Community physical and non-physical assets and functions</u>
- Utilities and infrastructure physical and nonphysical assets and functions
- Transportation and mobility physical and nonphysical assets and functions
- Ports and maritime physical and nonphysical assets and functions
- Communication physical and nonphysical assets and functions
- Recreation, open space, natural areas, and working lands physical and non-physical assets and functions
- Hazardous materials sites and contaminated lands physical and non-physical assets and functions

Concept Discussion

- Question: For smaller, noncapital agencies, how do you deal with overlap in terms of answering those physical asset questions. How would we manage that process at A&F?
    - There are questions that ask about what other agencies you're dependent on or could interrupt your flow of functions so those questions would likely get at that.
    - For example, your office may be in another state agency's building, for you in your agency, think about it from the perspective of "if we were not to have this building, could we relocate?" Thinking about it from your agency's perspective and what does a building provide your agency? Consider that type of thing.
- Question: Some of our locations and vulnerabilities might be confidential, need help thinking about how we can provide relevant info that helps inform the survey and what level of detail does that need to be at? How can we share (or not share) this confidential info while also providing the proper info but keep things confidential
    - There are things that are at the asset category level which are not super specific so that might be a way to share that sensitive information, you can also work with the PMT and other agencies to think about the most appropriate way to handle and share confidential information.

SHMCAP Mission and Goal Setting

- We're presenting a shared vision, ambition, and motivation, want to communicate to stakeholders and community groups what matters and what will be prioritized in terms of strategies and actions, funding, things that are of utmost importance and how will projects be designed, aiming to design projects in consideration of issues that are important to stakeholders.
- Collaboratively establishing that shared motivation and vision, helping the Commonwealth develop the overall direction that MA is going in, and those actions add up to this overall vision.
- Strategies and actions outlined in plan align with agency's missions and goals, these goals need to be measurable (not necessarily quantitative, but measurable) and reflect the State's priorities

- Goals presented here were informed by reviewing the mission and goals from the Climate Assessment, the 2013 and 2018 Hazard Mitigation Plan and SHMCAP and FEMA goals of climate mitigation and adaptation.
- *Lindy Lowe provided overview of the process.*
- There have been several changes since 2013 and while there hasn't been a significant change in the mission and goals from 2013 to now, we do have a stronger understanding of the science. For example, FEMA has updated their guidance, there is a new focus on updating codes and how land use affects risk. New federal legislation (e.g., Infrastructure Bill, Inflation Reduction Act) is changing (increasing) the amount of money available for this work. Hazards and climate impacts on the ground have also changed people's perspectives. The Climate Assessment is an important piece of work, and we want to identify the priorities in that.
- The 2018 SHMCAP was catalyst for action, identifying what those actions have been a smart move.
- *Overview of meeting next steps:* Talk about the mission as a group and then breakout to discuss goals. Sharing 2013 and 2018 goals. 2013 was not a climate adaptation plan, the degree of change and updates between 2013 and 2018 was significant
- In the 2023 Mission Statement, there will be multiple opportunities to share feedback, the goal is to align the mission with hopes for your agency and what you think is important

Mission Discussion

- Suggestion that terms and concepts in the mission document be clearly, for example, a "just approach"
    - In addition to defining concepts on the SHMCAP, there will be a glossary in the SHMCAP to clarify those definitions
- Comment by agencies working in/with the natural environment, we're trying to transition from just protection to active management of these assets, want to make sure there's some nuance to the mission rather than still doing the hands-off protection/ that we used to think about, just inviting other folks to add their thoughts.
    - In support of the comment, someone opines that there is often too much thinking about forests in solely their mitigative capacity, need to make sure we focus on resiliency and adaptive capacity of those lands and the assets, trees, etc.
    - Also thinking about environmental justice communities, they're so often excluded from decision-making because they don't have the infrastructure, ability, resources that more wealthy communities have which would allow them to be more active participants in things like this.
- Food and security, this year's drought had really brought some of those issues to light, this relates to environmental justice communities and environmental justice broadly as well.
- Think about how we're presenting geographic boundaries and how to include tribes in that (Say Massachusetts and its visitors, rather than just focusing on residents).
- Work in the idea of enhancing these natural and working lands as well as preserving them.

Goals Discussion

- Have more goals than in the past. 2018 goals were focused on institutional framing of climate and hazard mitigation, relationship to natural hazard, goal about identifying information to inform what climate mitigation or adaptation was, mitigation of hazards and adaptation and identifying who would be involved in the process. 2013 focused a lot on mitigation.

- Collaboration and partnership. Time horizon for decision-making, what does protection mean, timeframe and long-term impact of climate adaptation, goal 5 focuses on equity and environmental justice, goal 6 speaks to communication and engagement, goal 7 speaks to importance of connecting mitigation, 8 focuses on resilient infrastructure and communities
- Just sharing my gut reaction, having equitable climate adaptation and hazard mitigation as a separate thing makes me feel like its not baked into all of the other goals, it should be much more of an umbrella effort, should be really baked into everything as it relates to this effort
    - Yes, that’s a good point and that relates to one of our guiding questions for the goals, we want to bake it in but also call it out explicitly, definitely a lens that we’ll revisit in the draft too to make sure its incorporated throughout

Report Back of Goals Breakout Group Discussions

Goal 1 and 2:

- Connecting SHMCAP goals to other goals, clarity of connections
- Measuring goals and progress towards these goals, focusing on outcomes rather than process, making sure goals are focused on outcomes
- Making sure that those who will be most impacted by climate change will have a seat at the table in this process and in the future.

Goal 3 and 4:

- Enhanced protection of services, environment we’re in now. Thinking out the pandemic, importance of physical buildings has a different importance than pre-pandemic. Thinking about people working at home and the implications for remote working
- Overarching discussion talking about defining success of these goals, can we put quantifiable metrics and progress and achievements on these goals
- How will we assess and analyze progress
- Adding natural resources as something to protect, maintain and manage
- Goal 4: similar topics about measuring progress towards the goal, some raised the point that this sounds a bit too emergency planning focused, increase community safety and resilience should maybe wordsmith that more, think about what we’re being more specific on, reducing impacts to, linkage back to goal #3, service, lifelines, infrastructure, thinking about climate change assessment and the tie in of this goal in sectors of the climate change assessment

Goal 5 and 6:

- Thinking about reflecting equity in SHMCAP as a whole, talked about how as phrased currently, its focused on equitable distribution and context of development and implementation, development and implementation feels restrictive and thinking about broadening this to make sure these are themes that are incorporated. There were some comments about the recent climate bill from the Governor and if that language should be included/related to the SHMCAP

- Do we want to be thinking only about equitable distribution or also JUST distribution and if there are areas that were underserved in the past and should be getting more investment in the future
- 6th goal related to themes Jen and Lindy mentioned in terms of measuring and tracking these goals and implementation and how to frame these goals and can track progress, how to refine this goal and others so that they are measurable and time-bound goals that are SMART for providing clarity on this moving forward

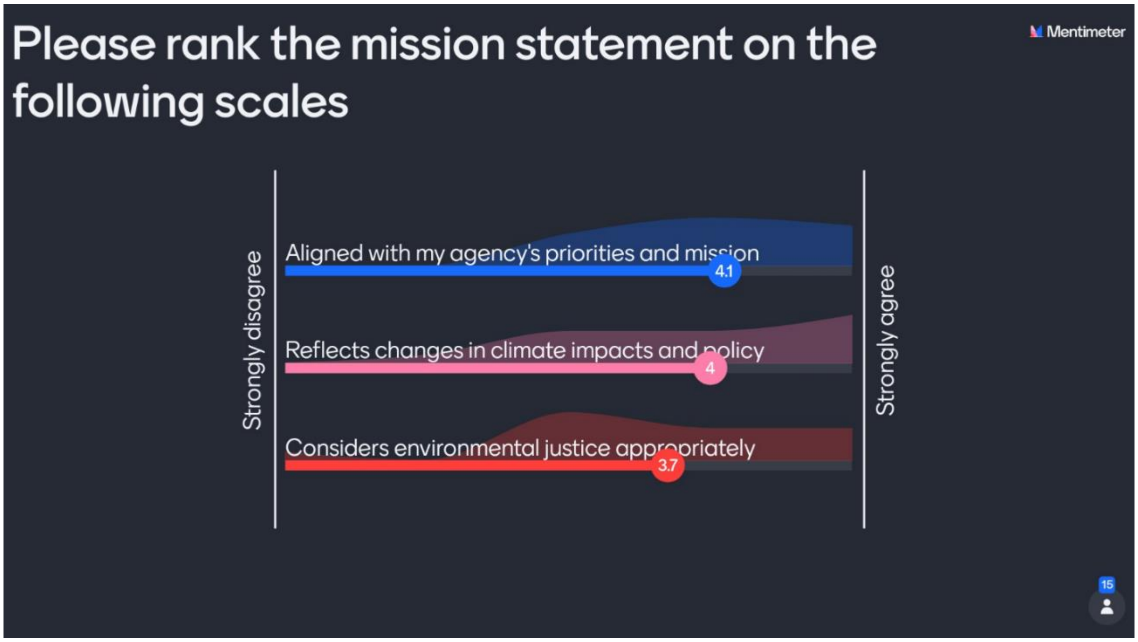
Goal 7 and 8:

- Conversation of time horizon as well, keeping in mind the hazard mitigation plan in terms of FEMA perspective, also GHG mitigation and alignment and creating more specific and clarification of how that goal is communicated and GHG mitigation being connected to long-term resilience planning in terms of lose/lose and win/win or win/lose strategies. Reducing tailpipe emissions and the impact that might have on health
- Goal 8: Community relationships and cohesion and how that may play into resilience and goal development
- Inclusivity of underserved communities throughout goals more intentionally, speaking through some level of bold action in regard to addressing long term plans

Wrap up:

- Survey launch Sept 26, heard some dates from Marybeth on climate assessment and draft report (Week of 26th for project working group) those involved in that report will be able to review that report, public review that starts at end of Oct and goes through Nov
- Would like feedback on goals document draft by Oct 3rd, we'll provide with that memo to house the goals directly in what we're drawing from in order to develop them as well as what they will be informing and why the SHMCAP has goals and what purpose they serve
- Next meeting will be on Oct 25

Copy of Mentimeter inviting feedback on SHMCAP 2023 Mission statement. Feedback submitted through open responses will be incorporated to develop Draft 2 Mission and Goals Document. The second draft will be shared in the upcoming October 25 meeting.



Appendix. Participant List (110 unique attendees)

Name	Affiliation
Adam Elliott	Massachusetts Human Resources Division
Adrienne Pappal	Massachusetts Office of Coastal Zone Management
Alex Giannantonio	Massachusetts Department of Agricultural Resource
Alisha Bouchard	Massachusetts Department of Agricultural Resource
Andrea Cristina Ruiz	Eastern Research Group, Inc.
Andrea Furtado	Massachusetts Department of Revenue
Angela Davis	Massachusetts Executive Office of Public Safety and Security
Ann Lowery	Massachusetts Department of Environmental Protection
AnnaClaire Marley	Eastern Research Group, Inc.
Betsy Isenstein	Massachusetts Division of Capital Asset Management and Maintenance
Bill Hinkley	Massachusetts Executive Office of Energy and Environmental Affairs
Bill VanDoren	Massachusetts Department of Conservation and Recreation – Division of State Parks and Recreation
Brenda L. Enos	TRC Companies, Inc.
Brian Ritzinger	Massachusetts Department of Public Utilities
Brigitte Q Ndikum-Nyada	U.S. Federal Emergency Management Agency
Carole Malone	Massachusetts Executive Office of Elder Affairs
Casey Cunningham	Massachusetts Executive Office of Education
Chris Bowman	Massachusetts Civil Service Commission
Chris Buzzell	Massachusetts Division of Banks
Courtney Rocha	Massachusetts Executive Office of Energy and Environmental Affairs - Municipal Vulnerability Preparedness Program
Cristina Kennedy	Massachusetts Division of Ecological Restoration
Dana Muldoon	Massachusetts Department of Environmental Protection - Office of General Counsel
Danah Tench	Massachusetts Department of Environmental Protection
Dave Manning	Massachusetts Department of Career Services
David Buckman	Massachusetts Department of Public Health
David Hilgeman	Massachusetts Department of Environmental Protection
David Raines	Massachusetts Sex Offender Registry
David Robinson	Massachusetts Board of Underwater Archaeological Resources
Diana Pietri	Eastern Research Group, Inc.
Doug Cameron	Massachusetts Department of Fish and Game - Office of Fishing & Boating Access
Elizabeth Weathers	Eastern Research Group, Inc.
Elyse Butterworth	U.S. Federal Emergency Management Agency
Emily Williams	Massachusetts Group Insurance Commission
Eric Friedman	Massachusetts Department of Energy Resources
Evan Knight	Massachusetts Board of Library Commissioners
Falah Hashem	Massachusetts Office for Refugees and Immigrants
Greg Abbe	Massachusetts Department of Housing and Community Development
Hannah Lyons-Galante	Massachusetts Bay Transportation Authority

Name	Affiliation
Hannah Stroud	Eastern Research Group, Inc.
Hayes Morrison	Massachusetts Department of Transportation
Hillary B. King	Massachusetts Executive Office of Energy and Environmental Affairs - Municipal Vulnerability Preparedness Program
Jaci Hamel	Massachusetts Emergency Management Agency
Jeff Zukowski	Massachusetts Emergency Management Agency
Jeffrey Quick	Massachusetts Department of Correction
Jen Adames	Massachusetts Operational Services Division
Jen DeWitt	Massachusetts Division of Banks
Jennifer Lam	Eastern Research Group, Inc.
Joanna Troy	Massachusetts Department of Energy Resources
John Mulloy	Massachusetts Department of Fire Services
Joy Duperault	Massachusetts Department of Conservation and Recreation
Kaitlyn Connors	Massachusetts Executive Office for Administration & Finance
Kajal Chattopadhyay	Massachusetts Department of Transitional Assistance
Kara Runsten	Massachusetts Executive Office of Energy and Environmental Affairs - Municipal Vulnerability Preparedness Program
Kate Adams	Massachusetts Department of Public Health
Kathleen Ledoux	Massachusetts Port Authority
Katie Kemen	Massachusetts Department of Transportation
Kristen Sullivan	Massachusetts State Police Crime Laboratory
Laurie Myers	Massachusetts Sex Offender Registry
Liam Seward	Massachusetts Department of Mental Health
Lindy Lowe	Eastern Research Group, Inc.
Margot Mansfield	Massachusetts Executive Office of Energy and Environmental Affairs - Office of Coastal Zone Management
Marjorie Wittner	Massachusetts Department of Labor Relations
Mark Rousseau	Massachusetts Division of Marine Fisheries
Mark Talbot	Massachusetts Emergency Management Agency
Mary Kamb	Massachusetts Office of the Chief Medical Examiner
Marybeth Groff	Massachusetts Emergency Management Agency
Maureen Quinn	Massachusetts Group Insurance Commission
Meg Blanchet	Massachusetts Department of Public Health
Mia Mansfield	Massachusetts Executive Office of Energy and Environmental Affairs
Michael DiBara	Massachusetts Department of Environmental Protection
Michael Flanagan	Massachusetts Department of Labor Standards
Michelle Rowden	Massachusetts Executive Office of Energy and Environmental Affairs
Mike Dumont	Massachusetts Office on Disability
Mike Enko	Massachusetts Emergency Management Agency
Nan Johnson	U.S. Federal Emergency Management Agency
Natalie Rodman	Eastern Research Group, Inc.

Name	Affiliation
Nathan Skrocki	Massachusetts Commission for the Blind
Nicholas Bulens	Massachusetts Executive Office of Housing and Economic Development
Norm Fournier	Massachusetts State 911 Department
Paul Holloway	Massachusetts Department of Energy Resources
Peter DeBruin	Massachusetts Port Authority
Rebecca Mulrean	Massachusetts Executive Office of Energy and Environmental Affairs
Rebecca Quinones	Massachusetts Division of Fisheries and Wildlife
Rory O'Hanlon	Massachusetts Executive Office of Housing and Economic Development
Ruth Rovezzi	Massachusetts Department of Youth Services
Ryan Chamberland	Massachusetts Executive Office of Public Safety and Security
Ryan FitzGerald	Massachusetts Department of Children and Families
Sarah White	Massachusetts Department of Conservation and Recreation
Sarah Wilkinson	Massachusetts Office of Public Safety and Inspections
Sean Carroll	Massachusetts Department of Telecommunications and Cable
Sean Loughlin	U.S. Federal Emergency Management Agency
Sharon Lee	Massachusetts Department of Environmental Protection
Sharon Lee	Massachusetts Department of Environmental Protection
Sheila Gallagher	Massachusetts Executive Office of Public Safety and Security - Municipal Police Training Committee
Stephanie Miller	Massachusetts Department of Revenue
Steven Couto	Massachusetts Department of Revenue
Sungjun Park	Massachusetts Human Resources Division
Tanya Shallop	Massachusetts Operational Services Division
Taylor Frizzell	Massachusetts Bureau of the State House
Thomas Maguire	Massachusetts Department of Environmental Protection
Tiffany	Massachusetts Human Resources Division
Tim Rooney	Massachusetts Department of Revenue
Tim Spencer	Massachusetts Division of Capital Asset Management and Maintenance
Tori Kim	Massachusetts Environmental Policy Act Office
William (Bill) VanDoren	Massachusetts Department of Conservation and Recreation
William Hinkley	Massachusetts Executive Office of Energy and Environmental Affairs

2023 MA SHMCAP
RMAT Meeting 3

2023 SHMCAP Update Working Group #3 Meeting

Tuesday, November 8, 2022

2:30 – 4:30 pm EST

Note, this meeting will be recorded

Agenda

Meeting Objectives

- Provide update on SHMCAP survey
- Review and discuss key climate change and hazard issues facing the Commonwealth through Risk Assessment preliminary findings
- *Note: Review of Draft 2 Mission and Goals document will be virtual please see page 2 to learn about next steps and new avenues for sharing your input.*

Pre-Meeting Materials *(see following pages)*

- Introduction, timeline, and instructions for submitting input on Draft 2
    - 2023 Mission and Goal Document Draft 2.
- Risk Assessment Memo

Time (EDT)	Agenda Item
2:30 – 2:40 pm	**Welcome and Introductions** • Updates since 9/14 RMAT meeting • Climate Assessment public review period • Climate Change 101 training
2:40 – 2:55 pm	**Survey Update** • Summary of survey participation • Survey analysis next steps and use in SHMCAP • How state agencies can use survey results
2:55 – 4:20 pm	**Risk Assessment Draft Findings** • What is a risk assessment, and how will it be used in the SHMCAP? • Findings from the 2022 Climate Assessment • Updates since 2018 • Approach and findings per hazard o Exposure o Vulnerability o Consequence o Draft problem statement • Next steps • Questions and discussion
4:20 – 4:30 pm	**Wrap Up and Next Steps** • Public review period for draft Climate Change Assessment Report (anticipated 11/2-11/16 5:00pm) • Share feedback on Goals Document Draft 2 by 11/23 • Next meeting to be held on 12/14

Kate Adams

2023 SHMCAP Risk Assessment Part 1

RMAT Meeting
November 8, 2022

MASSACHUSETTS EMERGENCY MANAGEMENT AGENCY

Executive Office of Energy and Environmental Affairs

SIGILLUM REIPUBLICÆ MASSACHUSETTENSIS

ERG IEc WOODS HOLE GROUP A CLS COMPANY CBI CATALYZING COLLABORATION

Agenda

Welcome and Introductions

SHMCAP Survey Update

Risk Assessment Part 1: Draft Findings

- What is a risk assessment?
- Sources for 2023 Risk Assessment
- Updates since 2018 SHMCAP
- Findings from the 2022 Climate Assessment
- Example findings and approach by hazard
- Next steps for the Risk Assessment
- Questions and discussion

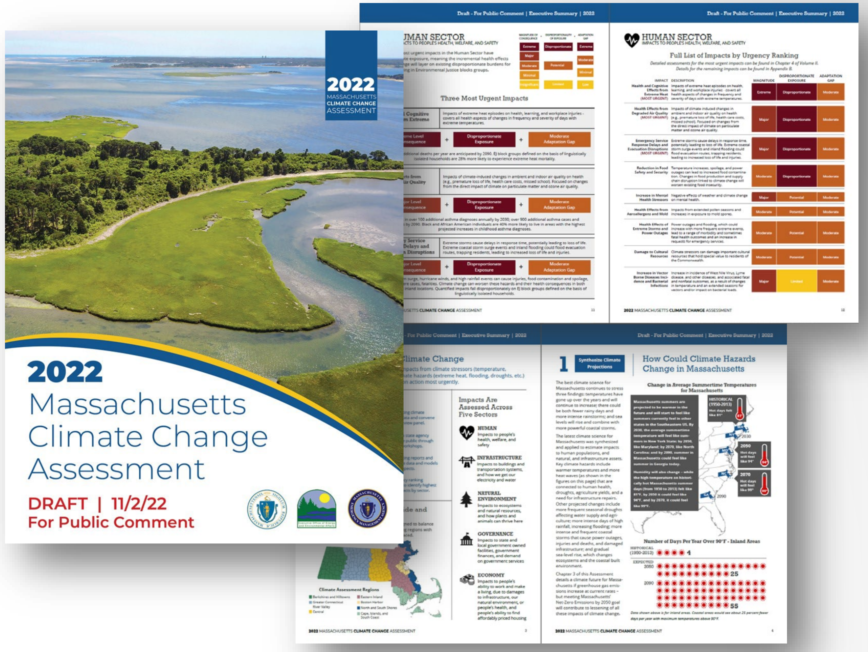
Wrap Up and Next Steps

Welcome and Introductions

Please put your affiliation in the participant list or chat

Climate Assessment Next Steps

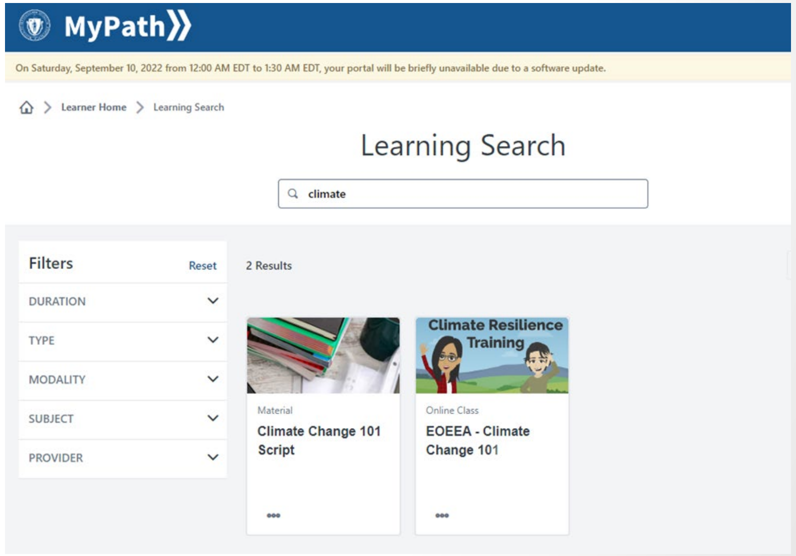
- November 2-16: Public Review Period https://www.mass.gov/info-details/ma-climate-change-assessment#public-comment-
- Mid December: Final Report Released
- January 2023: Public Release of Supporting Climate Science and Impact Data on resilientma.mass.gov



Climate Change 101 Training

SHMCAP Funding Eligibility Requirement

- **SHMCAP Project Working Group – due 12/14**
- Participation by relevant agency staff – details to come



Meeting Goals

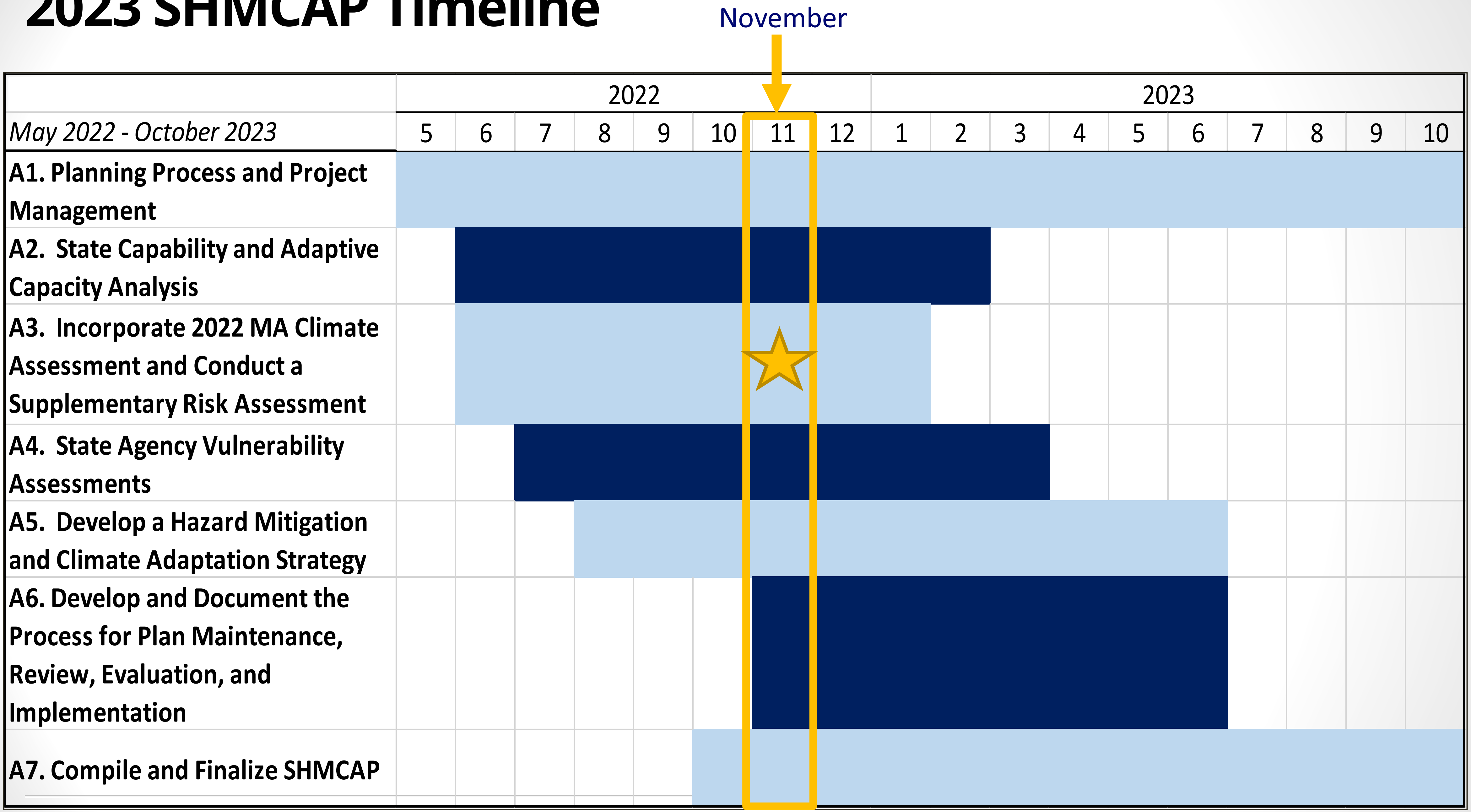
1. Provide update on SHMCAP survey process and function.

2. Review and discuss key climate change and hazard issues facing the Commonwealth through Risk Assessment preliminary findings.

Updates since 9/14 RMAT Meeting

1. Continued integration with Climate Assessment.
2. Continued identification of best available data, information, and science.
3. Sent out State Agency Survey (***closed October 28***).
    - *Held survey office hours on 10/6, 10/19, 10/25.*
    - *Responded to ongoing inquires and helped users troubleshoot issues.*
4. Incorporated 9/14 feedback into 2023 SHMCAP Goals and Mission *(Draft 2*).
5. Advanced Risk Assessment exposure, vulnerabilities, and consequences analysis *(to be discussed today).*

2023 SHMCAP Timeline



Survey Update

- **80 agency** responses representing 83 agencies submitted as of 11/7/2022.
- **12 agencies** did not respond
  - *Agencies may still complete the survey as an internal planning exercise; ERG will incorporate into SHMCAP where possible.*

Next steps

- Analyzing **state capability and capacity** questions.
- Analyzing and integrating **vulnerability assessment and capacity responses** with risk assessment findings.
- Developing a **results summary** (as a PDF or Excel) for each agency and **guidance** on how to use results. (*To be completed in advance of 12/14 meeting*.)
- Summarizing key vulnerability assessment findings to **inform SHMCAP action** development. (*To be discussed in January 2023 meeting*.)

Survey Outcomes

Integration of survey results into the 2023 SHMCAP will include:

- **Refinement of initial vulnerability results** from other sources.
- **Integration and updating risk assessment** vulnerability findings with agency specific-data on expected vulnerability and consequences.
- **Assessment of capacity** to address vulnerability and consequences.

State Agency Use of Survey Results

- **Understand strengths and gaps** in capabilities and capacity.
- **Improve or change** capabilities and capacity.
- **Strengthen coordination** with other agencies.
- **Identify and determine solutions** to address vulnerabilities.
- **Understand climate and hazard impacts** to functions, missions, services, and programs.
- **Determine strategies** to address high priority vulnerabilities for the agency.
- **Provide a template** for updated or new agency vulnerability assessments.


Irena Draksic

Risk Assessment Process and Draft Findings

2023 SHMCAP Risk Assessment

Risk Assessment Process and RMAT/Working Group Engagement:

- Provide **best available information and data** on hazards, assets, functions, and capacity via 2023 agency surveys, document review recommendations, and participation in meetings.
- Participate in SHMCAP November 8th Risk Assessment Part 1 meeting and provide agency perspectives and **input on hazards, data, subject matter expertise, problem statements and priority impacts.**
- Provide agency **perspectives and input** between November and December meetings.
- Participate in **SHMCAP December 14th Risk Assessment Part 2 meeting** and engage on draft risk assessment findings on vulnerability and consequences within each hazard and final problem statements.
- Provide any **additional comments and input** by December 20th.

What is a Risk Assessment?

- The purpose is to **identify risks** to the Commonwealth based on current and future projections of hazards, including effects of climate change.
- The risk assessment will serve as the **foundation** of the SHMCAP by integrating exposed assets, identified risks and hazards, and potential impacts and vulnerabilities.
- The risk assessment will be basis for beginning to **design and prioritize hazard mitigation actions.**

Steps of a Risk Assessment

Exposure analysis

- Identifies **nature and degree** (i.e., intensity, frequency, duration, location, timing) by which a hazard will affect the Commonwealth.

Vulnerability assessment

- Determines **populations, assets, and services** susceptible to hazards and at what scale.
- Indicates how hazards will **affect populations, assets, and geographies**, as well as potential **disproportionate impacts.**

Risks and consequences analysis

- Prioritizes **risks and consequences** resulting from exposure and vulnerabilities.
- Assess risks that **could be addressed to limit or eliminate** highest consequences to assets and populations.
- Facilitates development of **problem statements** that summarize risk and consequences.

Integrating Existing Information into the Risk Assessment

Climate Assessment

- Incorporate **latest climate data and projections** available for MA for coastal flooding, precipitation, and temperature.
- Draw on details from the Climate Assessment's **risk assessment for specific hazards**.
- Integrate **vulnerability and consequence** findings related to the five sectors.
- Identify which **priority impacts** for the five sectors are applicable to each of the hazards.

2018 SHMCAP

- 2023 SHMCAP as a **strategic update** to 2018.
- Will reflect new **State Hazard Mitigation Plan FEMA requirements**, as well as best available science and information since 2018.

Integrating Existing Information into the Risk Assessment *cont.*

Other sources

- Incorporate **updated data, projects, and information** from a variety of relevant sources, listed below.
- 2023 SHMCAP survey
- Agency-specific data and reports
- Hazard information from other sources, such as:
  - Cornell University Stochastic Weather Generator and Scaled Intensity-Frequency Duration Curves
  - Metropolitan Area Planning Council Land Surface Temperature Index
  - Massachusetts Coast Flood Risk Model (MC-FRM)
  - Alternative population forecast data from UMass Amherst's Donahue Center
  - Northeast-Midwest State Foresters Alliance Wildlife Risk Area
  - Northeast Wildfire Risk Assessment Geospatial Work Group
  - First Street Foundation
  - Digital Flood Insurance Rate Map
  - EOEEA invasive species distribution
  - MA Invasive Plant Advisory Group

Developing Problem Statements

- **Summarize how a hazard has or could impact** populations, assets, functions, and regions in the Commonwealth.
- **Serve as the basis** for developing mitigation actions.

A problem statement asks:

- Does the hazard have a defined location?
- What locations and populations will be exposed to the hazard?
- Where will the hazard have the greatest impacts (including potential disproportionate impacts)?
- What specific concerns or consequences could be solved through actions?
- What is the likelihood and timing of impacts and consequences, particularly for those hazards that may be affected by climate change?

Integrating Climate Assessment Priority Impacts

High Priority
Medium Priority
Lower Priority

- Climate Assessment also **includes prioritization of vulnerabilities** called priority impacts.
- Risk assessment will **connect priority impacts to their related hazards**.
- Risk assessment will **integrate priority impacts into problem statements.**

Climate Assessment Priority Impacts:

- Are organized by five sectors—human, infrastructure, natural environment, governance, and economy.
- Include 37 impacts, with 15 identified as the most urgent (i.e., three per sector).
- Prioritize impacts based on climate effect, disproportionate impacts, and adaptation action gaps.
- Will be used to inform vulnerability, consequences, and problem statements in the risk assessment, and actions in the 2023 SHMCAP strategy.

Exposure: List of Relevant Hazards

SHMCAP Hazards	
• Inland flooding • Dam overtopping • Flooding from precipitation (including urban drainage) • Drought (including impacts to groundwater) • Landslides and mudflows • Coastal flooding and storm surge • Groundwater rise • Coastal erosion • Tsunami • Average and extreme temperatures • Wildfires	• Invasive species • Hurricanes/tropical storms • Winter storms/Nor'easter • Tornados • Other Severe Weather • Earthquake • Ground failure Blue utilizes Climate Assessment data and information. Green new analysis outside of Climate Assessment

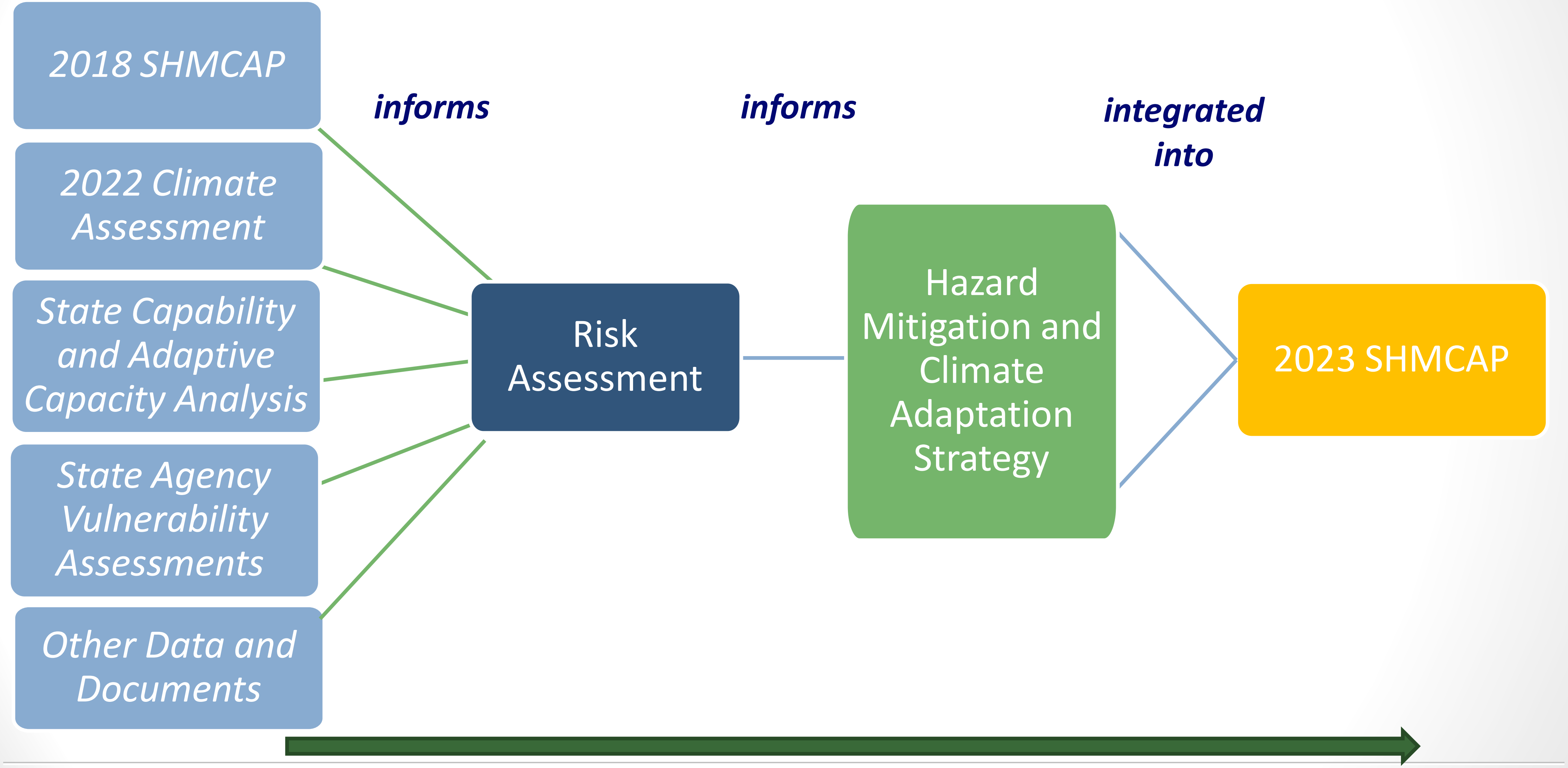
Physical and Non-Physical Assets and Functions with Potential Vulnerabilities to Hazards

SHMCAP Physical and Non-Physical Assets and Functions Categories

- **Critical** physical and non-physical assets and functions
- **Community** physical and non-physical assets and functions
- **Utilities and infrastructure** physical and non-physical assets and functions
- **Transportation and mobility** physical and non-physical assets and functions
- **Ports and maritime** physical and non-physical assets and functions
- **Communication** physical and non-physical assets and functions
- **Recreation, open space, natural areas, and working lands** physical and non-physical assets and functions
- **Hazardous sites and contaminated lands** physical and non-physical assets and functions
- **Other** physical and non-physical assets and functions that are not captured above

Sources for the Risk Assessment

2023 SHMCAP



2023 SHMCAP Risk Assessment Content Outline

I. General Background on Hazard

II. Hazard Profile
   a) Location
   b) Frequency of occurrence
   c) Severity/Extent
   d) Warning Time

III. Relationships Among Hazards

IV. Exposure and Vulnerability by Sector
   a) Human
   b) Governance
   c) Infrastructure
   d) Natural Environment
   e) Economy

Updates from 2018 SHMCAP

Key Updates Since 2018

Improved Climate Data and Projections

- Updated climate science used by Climate Assessment and 2023 SHMCAP.
- The Climate Assessment team worked with an external peer review panel of climate scientists in MA to provide critical input on the proposed use of climate projection data.

Climate Stressor	Climate Variable	Dataset	Recent Investment	Used in 2018 SHMCAP
Temperature	Average Daily and Extreme Temperature	Cornell University Stochastic Weather Generator	Yes	
	Potential for Heat Island Impacts	Metropolitan Area Planning Council Land Surface Temperature Index	Yes	
Precipitation	Seasonal to Annual Scale Precipitation	Downscaled Global Climate Models (GCMs)		Yes
	Extreme Precipitation and Inland Flooding	Cornell University Scaled Intensity-Frequency-Duration (IDF) Curves	Yes	
Sea Level Rise	Sea Level Rise and Coastal Flooding	Massachusetts Coast Flood Risk Model (MC-FRM)	Yes	

Key Updates Since 2018

Improved Climate Data and Projections

Cornell University's Stochastic Weather Generator Dataset

- Provides temperature and precipitation variables, for four future eras (2030, 2050, 2070, and 2090).
- Relies on application of 20 Global Climate Models for the Representative Concentration Pathway (RCP) 8.5 greenhouse gas emission scenario.

Cornell University's Scaled Intensity-Duration-Frequency (IDF) Curve Dataset

- Provides projections for extreme precipitation, separate from the Cornell's Stochastic Weather Generator.

Region	Baseline	2030	2050	2070	2090
Berkshires & Hilltowns	29	29	30	30	31
Greater Connecticut River Valley	31	31	32	32	33
Central	32	32	32	33	33
Eastern Inland	32	32	32	33	33
Boston Harbor	31	31	32	32	33
North & South Shores	31	31	32	32	33
Cape, Islands, & South Coast	31	31	32	32	33
Statewide	**31**	**31**	**31**	**32**	**33**
Statewide Percent Change	*0%*	*1%*	*2%*	*4%*	*6%*

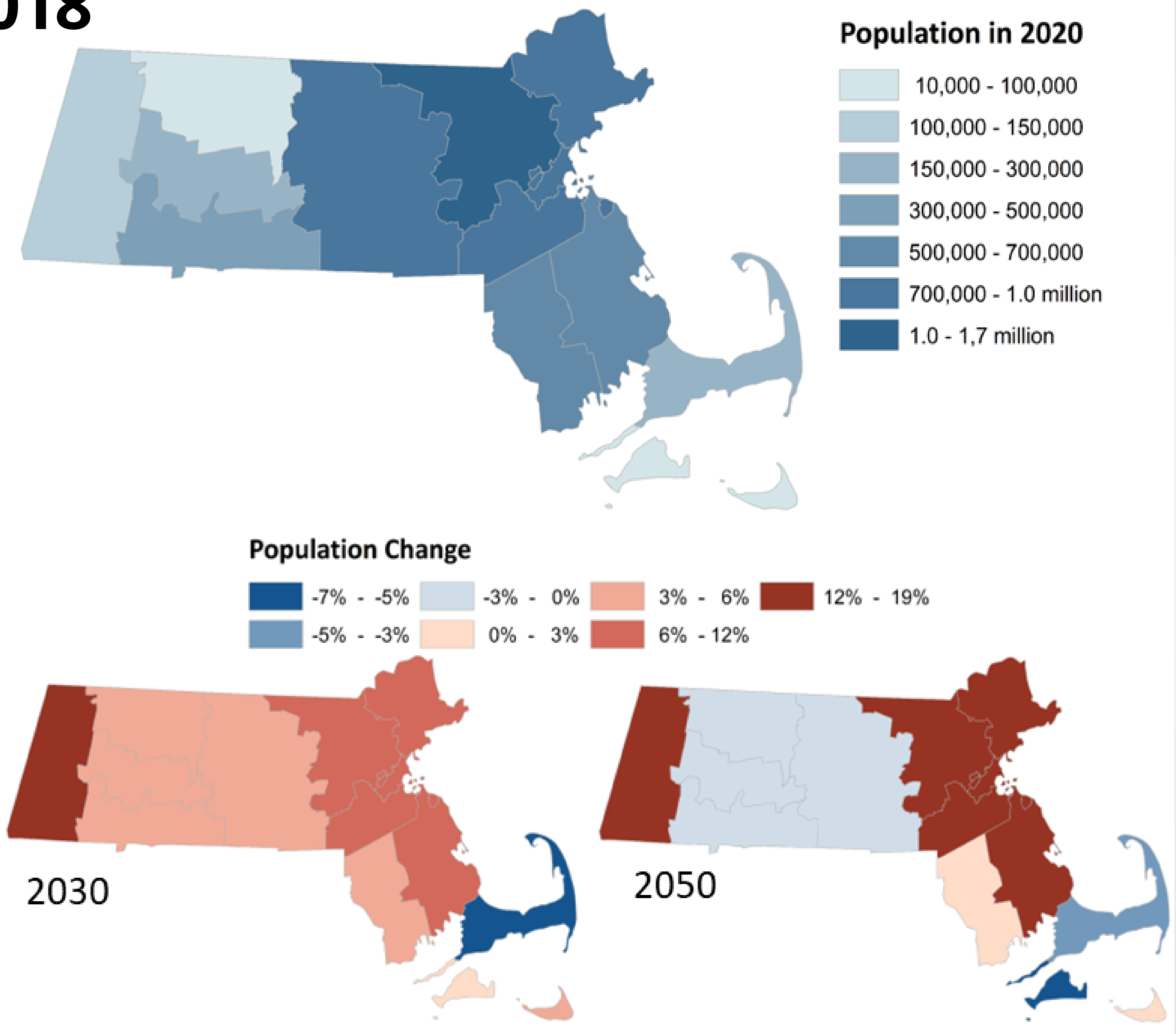
Source: Stochastic Weather Generator

Key Updates Since 2018

Improvements in Science and Data

Projected Future Populations

- Climate Assessment uses U.S. EPA's ICLUS forecasts through 2090 (county level).
- County growth rates can be resolved to Census block groups.
- 2023 SHMCAP will use updated Census data from 2010 to 2020.
- Alternative population forecast through 2040 from UMass-Amherst's Donahue Center, at town level.

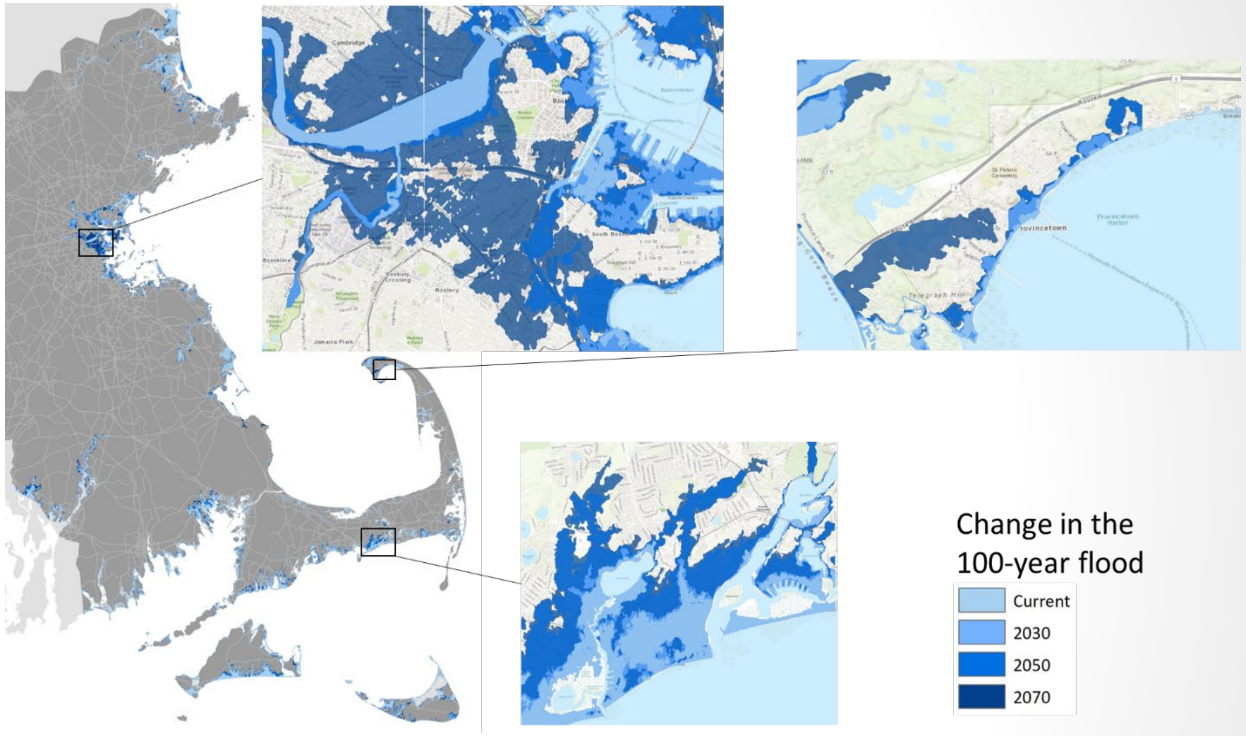


Key Updates Since 2018

Improvements in Science and Data

Massachusetts Coast Flood Risk Model (MC-FRM)

- Also used by Climate Assessment.
- Improvement over past "bathtub models."
- Dynamic model including the complex processes of storm flooding: winds, waves, wave-setup, storm surge, wave run-up, and overtopping.



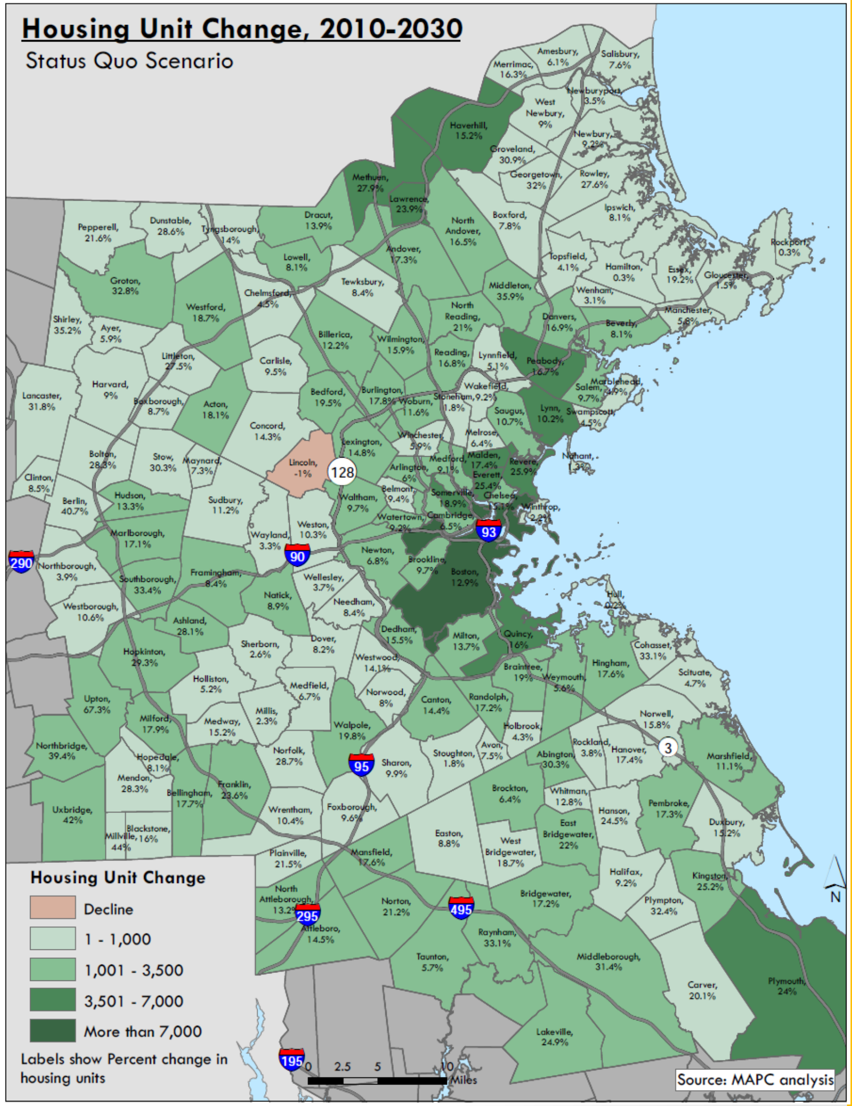
Map: IEc
Data source: Woods Hole Group

Key Updates Since 2018

Improvements in Science and Data

Projected Land Use and Development Patterns

- Regional Planning Agencies (13 in MA)
- MAPC (2014 – shown at right) has Regional and Municipal projections of :
  - Population - Age/Race/Scenario (Status Quo and Strong scenarios)
  - Housing
  - Other RPAs have more qualitative development and growth statements,
- Data collection ongoing



Key Updates Since 2018

Improvements in Science and Data

2023 SHMCAP will run HAZUS for three hazards–earthquakes, coastal flooding, and hurricanes.

FEMA Hazus 6.0

- Updated US Census demographics data from 2010 -> 2020
  - Used for Casualty Modeling and Public Shelter Needs
- New data source for time-of-day population by occupancy type
  - Education and working industrial populations are directly tied to building types at tract level
- Buildings and infrastructure inventory updated and more complete

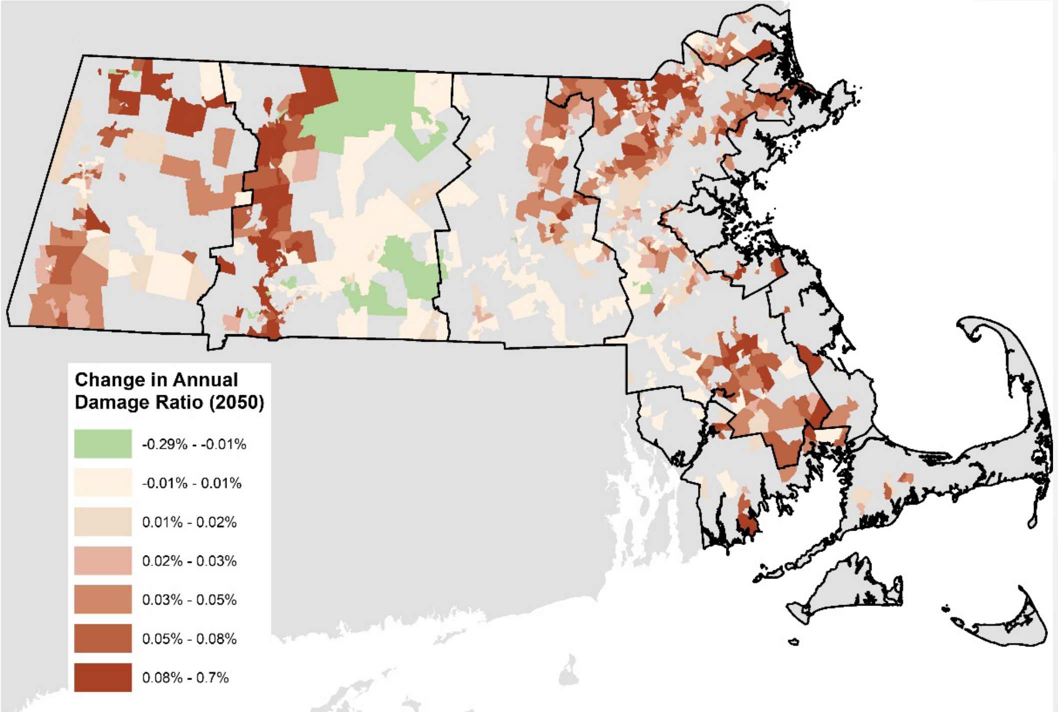
Key Updates Since 2018

Improvements in Science and Data

Inland Flooding

- Climate Assessment used First Street Foundation block group level flood risk data
- Consistent projections available for 2030, 2050, 2070, 2090
- Can be cross-referenced to MA EEA's EJ Block Groups

Changes in Annual Residential Structure Inland Flooding Damage Ratio in 2050, by Massachusetts Block Group (Damage Ratio is AED/structure value)



Source: U.S. EPA data at www.epa.gov/CIRA and project team analysis

Key Updates Since 2018

Improvements in Science and Data

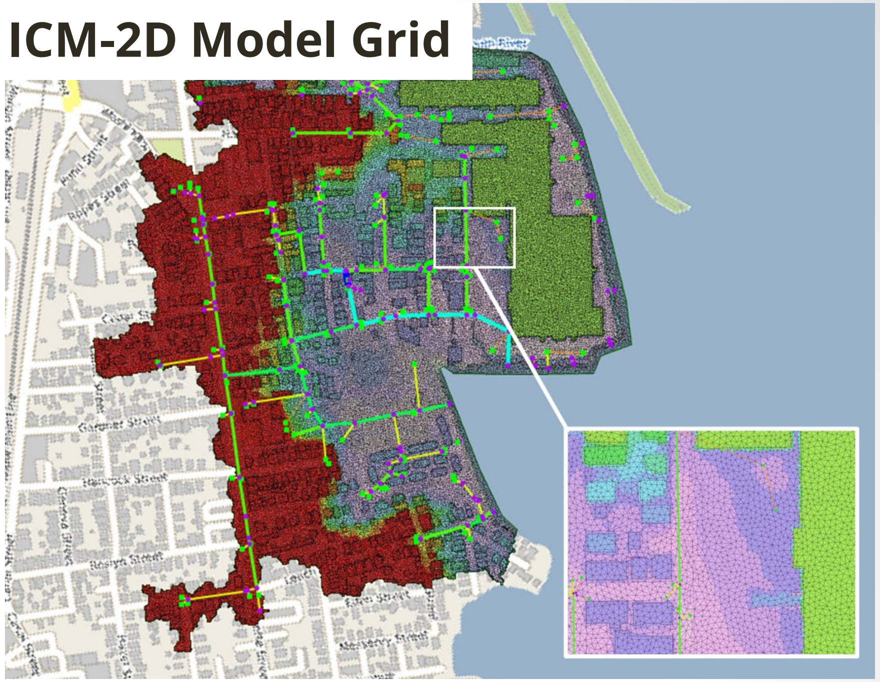
Flood Risk and Impact from Urban Drainage and Rainfall

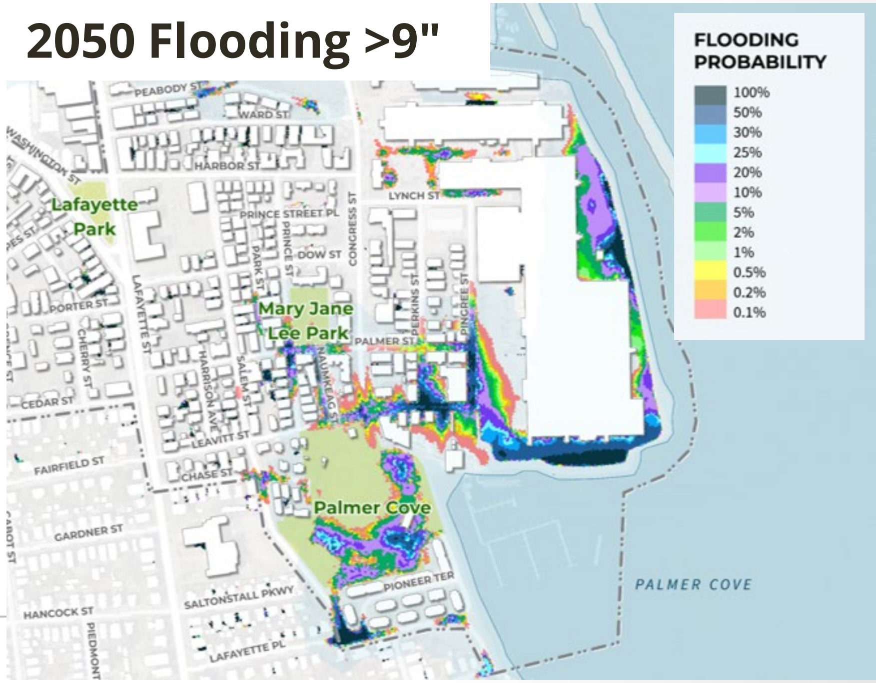
Modeling approach

- Hydrodynamic and probabilistic stormwater model
- Hi-res model grid (topo/buildings/drainage system)
- Monte-Carlo probabilistic approach
- Dynamic tailwater phasing (high tide and short storms)
- Re-run for 2050 precipitation and SLR

Findings

- Ability to project probability of street-scale flooding.
- Able to test effectiveness of grey/green adaptations





Findings from the 2022 Climate Assessment

Public comment period now underway on bit.ly/maclimate through 11/16

The time to provide final input is now!

Climate Assessment Urgent Risk Identification

- The Project Working Group and public stakeholders contributed to impact list brainstorming **across five sectors**. A final set of **37 impacts** was identified through a series of surveys, workshops and public meetings.
- The 37 impacts were scored and ranked based on **urgency** using the following framework:

Magnitude of Consequence		Disproportionality of Exposure		Need for Effective Adaptation		
How large of a climate effect do we expect from this impact?		*Will populations living in environmental justice areas be affected more than the rest of the population?*		*Are we currently doing enough to adapt to this impact or are there gaps in effective adaptation actions? How soon is action needed?*		
Extreme Level of Consequence		Disproportionate Exposure		Extreme Adaptation Gap		High Priority
Major Level of Consequence				Moderate Adaptation Gap		
Moderate Level of Consequence	+	Potential For Disproportionality	+		=	Medium Priority
Minimal Level of Consequence				Minimal Adaptation Gap		
Insignificant Level of Consequence		Limited Disproportionality		Insignificant Adaptation Gap		Lower Priority

Climate Assessment Statewide Urgent Impacts

MOST URGENT

Human	Infrastructure	Natural Environment	Governance	Economy
Health and Cognitive Effects from Extreme Heat	Damage to Inland Buildings	Freshwater Ecosystem Degradation	Reduction in State and Municipal Revenues	Reduced Ability to Work
Health Effects from Degraded Air Quality	Damage to Electric Transmission and Utility Distribution Infrastructure	Coastal Wetland Degradation	Increase in Costs of Responding to Climate Migration	Decrease in Marine Fisheries and Aquaculture Productivity
Emergency Service Response Delays and Evacuation Disruptions	Damage to Rails and Loss of Rail/Transit Service	Marine Ecosystem Degradation	Increase in Demand for State and Municipal Government Services	Reduction in the Availability of Affordably Priced Housing
Reduction in Food Safety and Security	Loss of Urban Tree Cover	Forest Health Degradation	Damage to Coastal State and Municipal Buildings and Land	Economic Losses from Commercial Structure Damage and Business Interruptions
Increase in Mental Health Stressors	Damage to Coastal Buildings and Ports	Shifting Distribution of Native and Invasive Species	Increase in Need for State and Municipal Policy Review and Adaptation Coordination	Damage to Tourist Attractions and Recreation Amenities
Health Effects from Aeroallergens and Mold	Reduction in Clean Water Supply	Coastal Erosion	Damage to Inland State and Municipal Buildings and Land	Decrease in Agricultural Productivity
Health Effects of Extreme Storms and Power Outages	Damage to Roads and Loss of Road Service	Soil Erosion		
Damage to Cultural Resources	Loss of Energy Production and Resources			
Increase in Vector Borne Diseases Incidence and Bacterial Infections	Increased Risk of Dam Overtopping or Failure			

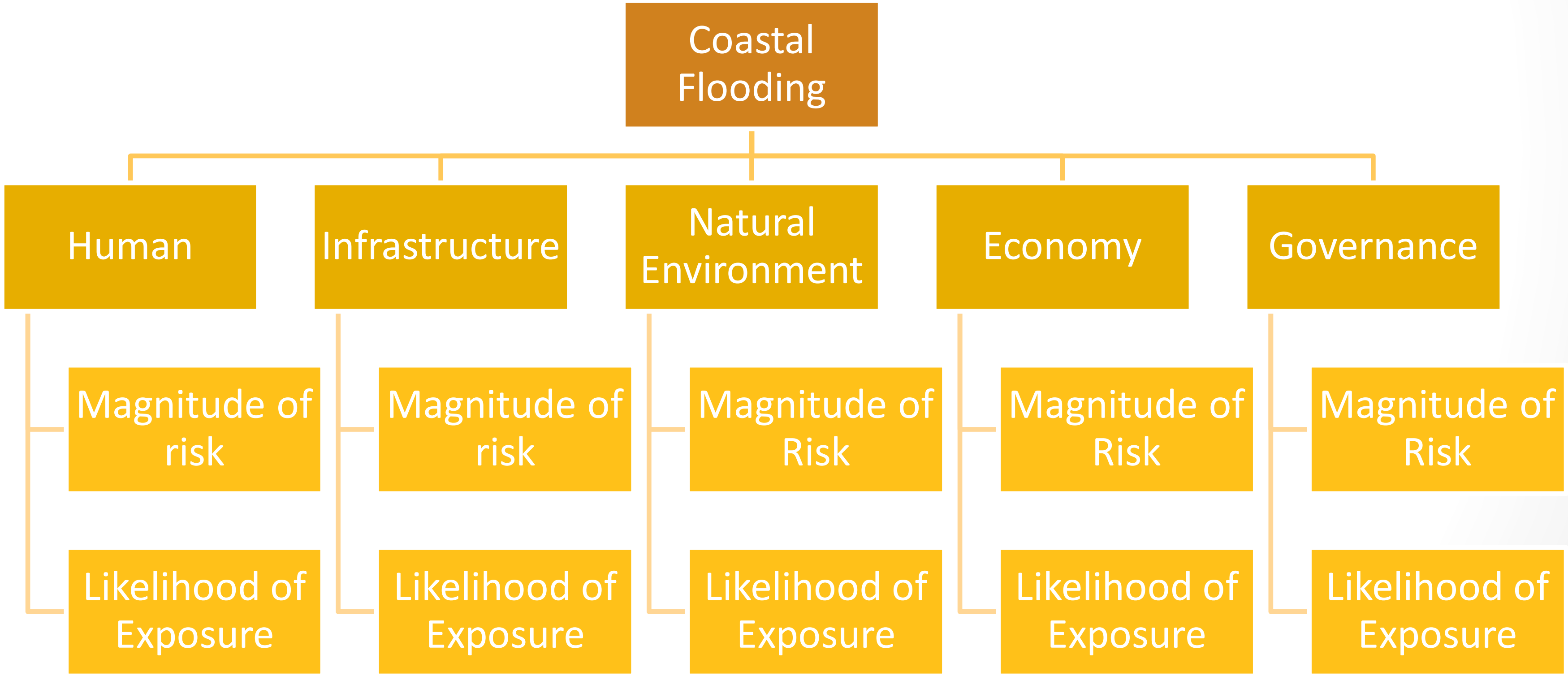
Climate Assessment Data and Findings

Climate Assessment is a key source of data and information for 2023 SHMCAP

2023 SHMCAP will incorporate as much of the Climate Assessment framework as possible, including **use of the five sectors, the data and information used to assess the impacts and findings regarding magnitude and exposure by Sector**.

Climate Assessment Sector:

CA Data & Information + Risk Assessment Analysis:



Risk Assessment: Key Preliminary Results

Risk Assessment Key Preliminary Findings

1. **Introduction:** We will include an overview of the hazard and highlight updates since 2018.

2. **Overview of information on exposure and vulnerability.** Discussions on vulnerability; share information relating to sectors, populations, and geographical distributions of impacts.

3. **Overview of data availability**, maps, and illustrations of hazard impacts.

4. **Next steps**, data needs, and questions.

Sector Analyses

Sector datasets applied to all hazards as relevant

Human Sector
- Current population numbers and distribution
- Demographic information (e.g., minority, low income)
- Environmental justice communities
- Projections for future population growth
- Projections for future development
- Affordable housing
- Cultural resources

Governance Sector
- Government owned and operated buildings
- Replacement values of governance facilities
- Critical facilities

Infrastructure Sector
- Road network
- Rail network
- Utilities: water, storm water, wastewater, power
- Ports
- Airports
- Communications systems

Natural Environment Sector
- Biodiversity and native species
- Core habitat and critical natural landscape
- Parks and recreation areas

Economic Sector
- Building replacement values
- Job centers
- Agricultural lands

Wildfire

Overview and updates since 2018

- Wildfires in the Commonwealth are caused by natural events, human activity, or prescribed fire.
- Over 100 wildfires in August 2022, compared to a monthly average of less than 50.
- Precipitation changes, prolonged drought, rising temperatures, and increased frequency of lightning are all expected to contribute to increased frequency and severity of wildfire.
- Will include additional sectors and analysis from those included in 2018.
- Wildfire will likely become a more consequential hazard in Massachusetts due to climate change effects.

FEMA Updates since 2018:
New emphasis on wildfires for FMAG program eligibility:

- FMAG1. Does the plan address wildfire risks? [44 CFR 201.4(c)(2); 44 CFR § 204.51(d)(2)]
- FMAG2. Does the plan's mitigation strategy contain wildfire-related mitigation initiatives? [44 CFR 201.4(c)(3); 44 CFR § 204.51(d)(2)]

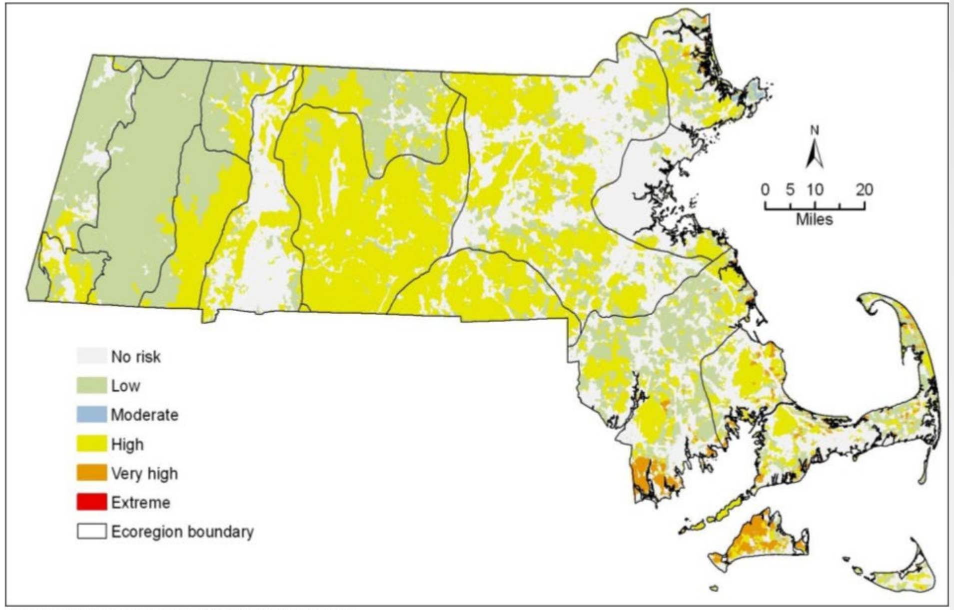
Wildfire

Exposure and vulnerability

Early findings:

- Wildfire will likely become a more consequential hazard in Massachusetts due to climate change effects.
- Pitch pine, scrub oak and oak forests located in sandy, low-nutrient soil areas are most fire-prone.
- Areas in Barnstable and Plymouth Counties are the most fire-prone due to their vegetation and the presence of a drying wind.
- Secondary and related hazards include mudslides, flooding, and invasive species.

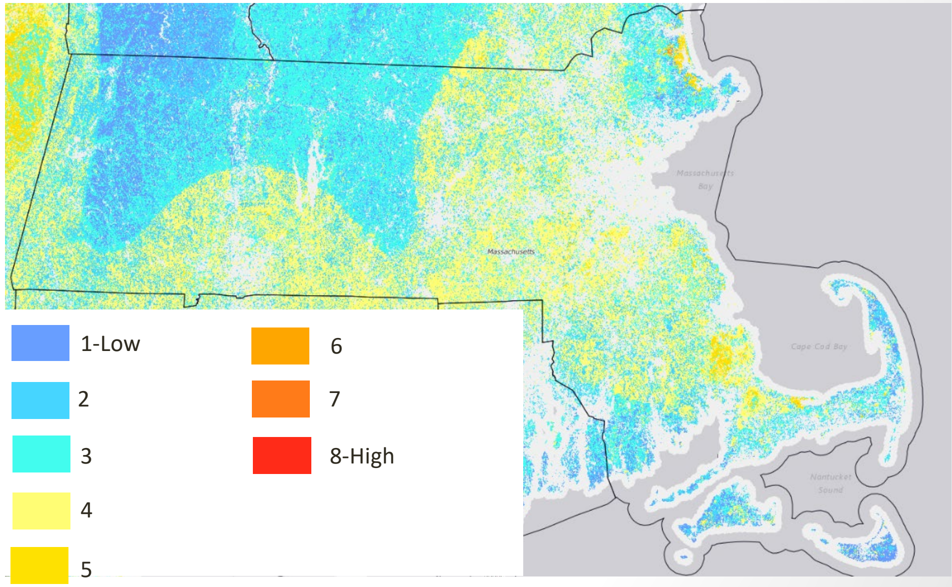
2018



Source: Northeast Wildfire Risk Assessment Geospatial Work Group, 2009

Wildfire Hazard Potential

2022



Northeastmidwestfirerisk.com

Wildfire

Key data sources:

- Northeast-Midwest State Foresters Alliance Wildfire Risk Area
- Northeast Wildfire Risk Assessment Geospatial Work Group
- Massachusetts Climate Assessment
- 2018 SHMCAP

Next steps:

- Update exposure analysis to identify current populations, state-owned buildings, critical facilities, and transportation infrastructure located in high wildfire hazard areas. Identification of climate change projections of wildfire over the next 70 years.

Wildfire

2023 SHMCAP Draft Problem Statement

- **Most at risk ecosystems**: Pitch pine, scrub oak, and oak forests.
- **Most fire prone areas:** Barnstable and Plymouth counties (due to vegetation, sandy soil, and wind conditions).
  - Due to climate change projections that include increased drought and warmer temperatures and increased invasives—which will result in dry, damaged, and more flammable vegetation—the risk of wildfire throughout the Commonwealth is likely to be heightened.
- **Community impact**: Damage and loss of life to communities living at the wildland-urban interface, as well as ecological resources, water sources, infrastructure, and buildings in these areas.
- **Economic impact**: Substantial, due to the initial loss of structures, agricultural resources, losses in revenue from business and tourism, as well as the cost of clean-up, debris removal, restoration, and rebuilding.

Wildfire

2022 Climate Assessment Wildfire Related Priority Impacts

Human	Infrastructure	Natural Environment	Governance	Economy
• Health Effects from Degraded Air Quality (**Most Urgent**) • Emergency Service Response Delays and Evacuation Disruptions (**Most Urgent**) • Increase in Mental Health Stressors • Damage to Cultural Resources	• Damage to Electric Transmission and Utility Distribution Infrastructure (**Most Urgent**) • Damage to Roads and Loss of Road Service • Loss of Energy Production and Resources	• Freshwater Ecosystem Degradation (**Most Urgent**) • Forest Health Degradation • Shifting Distribution of Native and Invasive Species • Soil Erosion	• Increase in Costs of Responding to Climate Migration (**Most Urgent**) • Increase in Demand for State and Municipal Government Services (**Most Urgent**) • Increase in Need for State and Municipal Policy Review and Adaptation Coordination • Damage to Inland State and Municipal Buildings and Land	• Reduced Ability to Work (**Most Urgent**) • Reduction in the Availability of Affordably Priced Housing (**Most Urgent**) • Economic Losses from Commercial Structure Damage and Business Interruptions • Damage to Tourist Attractions and Recreation Amenities • Decrease in Agricultural Productivity

Wildfire

Requested feedback from SHMCAP Working Group

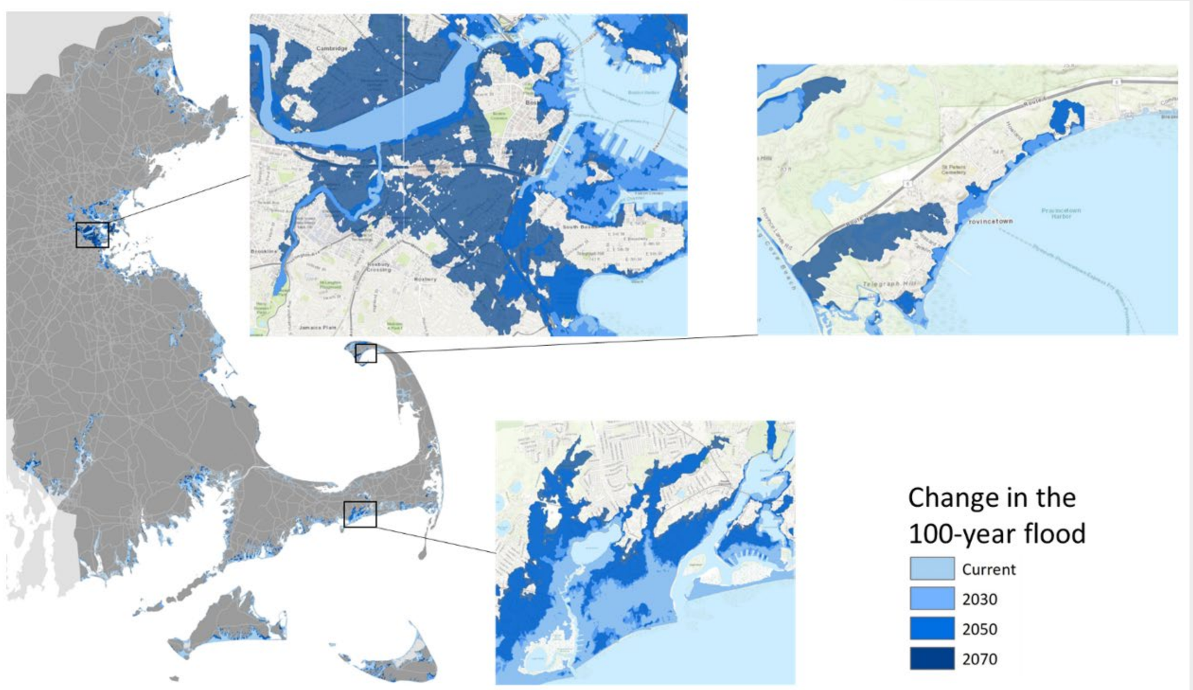
- Which regions or area in the Commonwealth is your agency most worried about in relation to wildfire?
- Has your agency noticed an increase in frequency, intensity, duration, or areas affected by wildfire in the last five to 10 years?
- Do you think that there is adequate time and available resources to evacuate areas with high wildfire risk now? As that risk increases due to climate change?
- Do you know of any data, analysis, or reports on wildfire that we should include in the 2023 SHMCAP update that you have not yet provided?

Coastal Flooding and Storm Surge

Overview and updates since 2018

- Coastal flooding can impact all areas of the Massachusetts coastline.
- Climate change impacts on sea level rise and storm surge are expected to increase intensity, frequency, duration, and exposure area of flooding.
- Shorelines of southern Cape Cod and Buzzards Bay more impacted by tropical storms while region north of Cape Cod, especially Boston Harbor are more influenced by extra-tropical storms.
- Road delays could result in over four million vehicle hours of delay by 2030 and 40 million vehicle hours of delay by 2050.

Example MC-FRM output. Area Extent of 1 Percent Annual Chance (100-year) Flood.

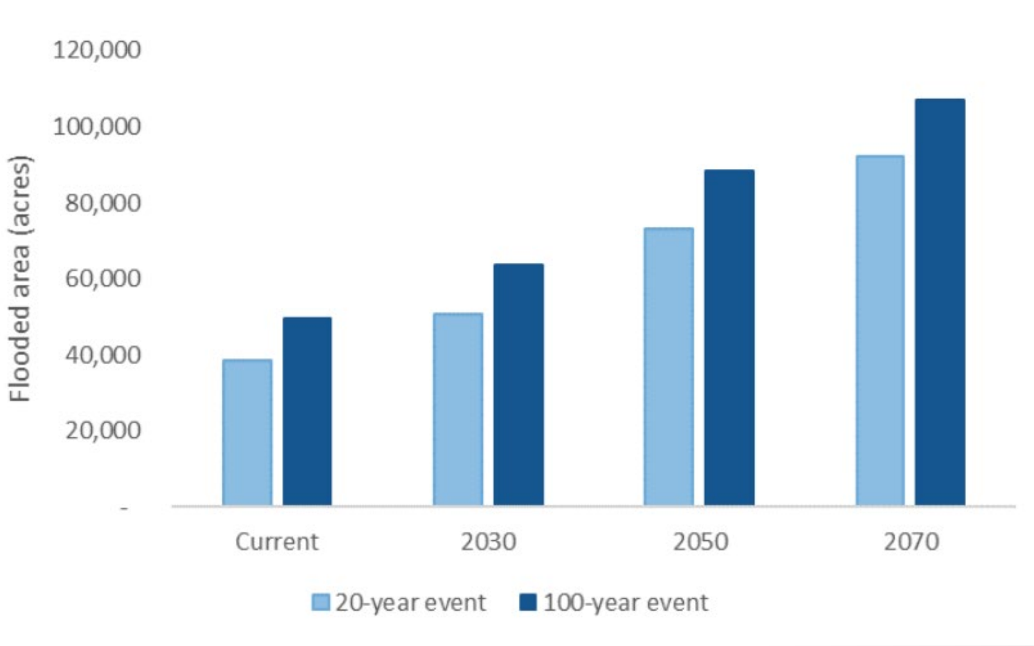


Coastal Flooding and Storm Surge

Exposure and vulnerability

Early findings:

- Historically, highest concentration of coastal flooding events has occurred in Eastern Plymouth County.
- Low income and linguistically isolated populations have a greater risk of exposure from coastal flooding and storm surge and are more vulnerable.
- Frequency, intensity, duration, and geographic areas are increasing due to climate change with areas that already flood experiencing longer durations and higher flood waters, and new areas being exposed to flooding.
- **Coastal flooding is most consequential hazard in coastal zone**, sea level rise increases this.



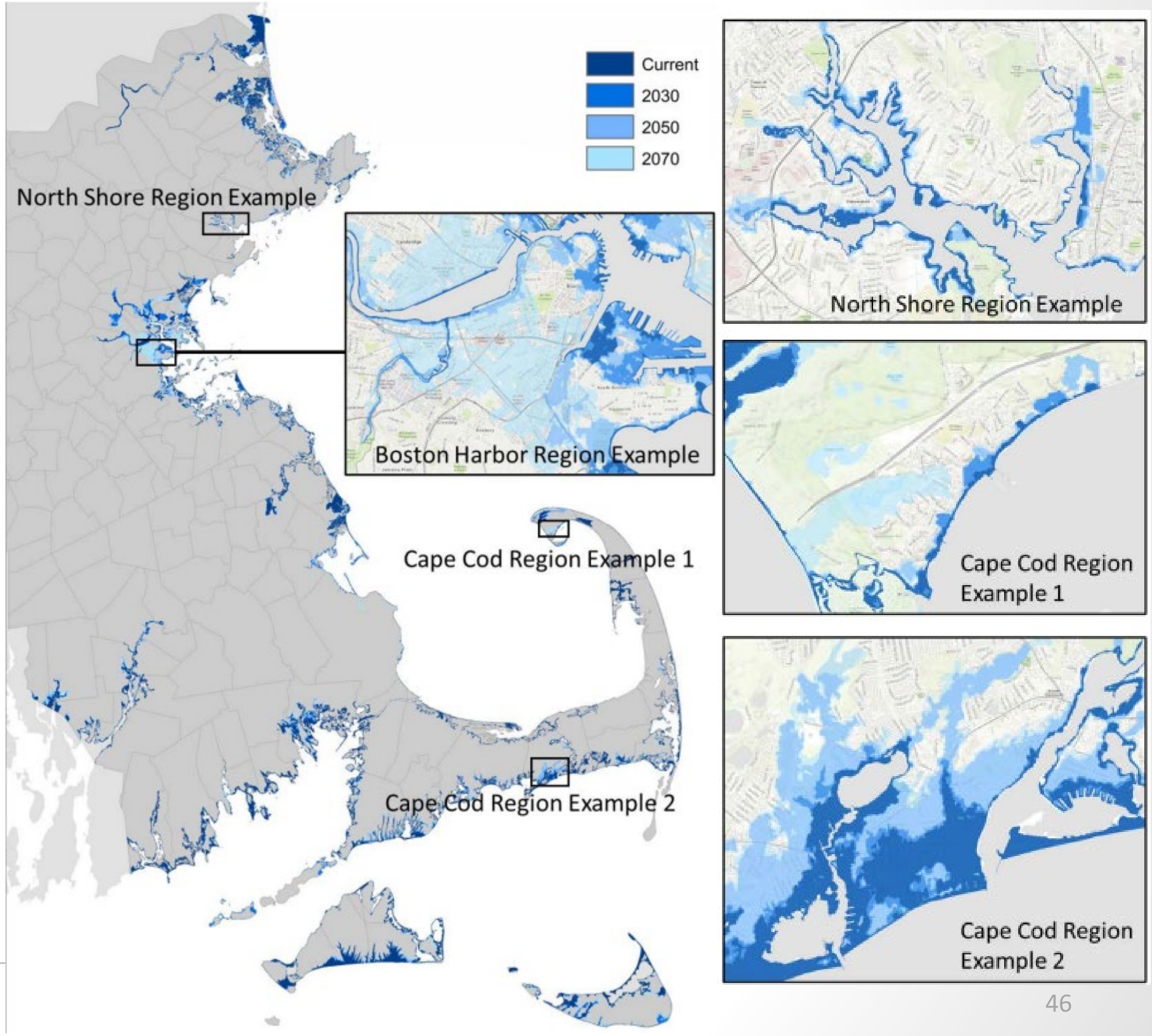
Areas Flooded Coastwide with One Foot or Higher Water Depth Comparison of areas flooded with one foot or greater water depth. Current period is 2008.

Coastal Flooding and Storm Surge

Key Data Sources:

- **Massachusetts Coast Flood Risk Model (MC-FRM)**
  - Integrates changes in sea level, tropical storm activity, and "sunny-day flooding."
  - New flood depth grids from MC-FRM will improve predictions of where flooding could occur to feed into Hazus 6.0.
  - Hazus 6.0 analysis will include updated information from 2020 Census, as well additional assets and functions.

Example MC-FRM output. Area Extent of 1 Percent Annual Chance (100-year) Flood.



Coastal Flooding and Storm Surge

Next Steps:

- Run Hazus 6.0 using new MC-FRM data, and 2020 Census data.
- Review survey responses for vulnerabilities and capacities related to coastal flooding and storm surge, including issues related to warning systems and evacuation capacity.
- Assess vulnerability and consequences for assets within all five sectors (*see slide 36*), environmental justice map layers, and regional and sub-regional trends and findings.
- Identify changes in vulnerabilities and consequences over time due to climate change.

Coastal Flooding and Storm Surge

2023 SHMCAP Draft Problem Statement

- **Most at risk areas**: Entire coastline.
- **Impacts**: With expected increases in global mean sea level rise due to climate change of 2 ft by 2050 and 4 ft by 2070, impacts include:
  - Increased duration, intensity, frequency, and extent of tidal flooding and storm-related flooding.
  - Increased frequency of extreme weather.
  - Stronger and more frequent storm surges and coastal flooding.

These hazards are likely to result in the following concerns **(*see next slides*).**

Coastal Flooding and Storm Surge

SHMCAP Problem Statement (continued)

- **Geographic impact (counties):** Eastern Plymouth, Suffolk, Plymouth, Essex, Norfolk, and Barnstable.[1]
- **Community impact:** Low socioeconomic status, people over the age of 65, renters, people with compromised immune systems, children under the age of 5, people with low English language fluency.
  - Includes public health impacts (e.g., increased exposure to toxic mold buildup, limited or interrupted access to hospital and medical providers, downed powerlines or fast-moving debris danger, contamination of well water).

[1]Note that these locations will be updated upon receipt of new HAZUS data.

Coastal Flooding and Storm Surge

SHMCAP Problem Statement (continued)

- **Economic impact:** Damage incurred to buildings, infrastructure, and natural and working lands, interrupted business activity and operations and impacts on tourism and the tax base.
  - Recent estimates from a variety of science journals put the estimated the total cost of projected sea level rise by 2100 at between $930 billion to $14 trillion depending upon mitigation and adaptation actions taken and associated level of the rise in water levels.[1]
- **Sector impact:** There are many key sectors that will be impacted by coastal flooding and storm surge, examples include:
  - Agriculture impacted by saltwater intrusion into aquifers in agricultural areas. Saltwater intrusion also poses a risk to water and wastewater infrastructure and may result in the need for facility relocation.
  - Critical facilities infrastructure (e.g., energy facilities, ports, natural gas terminals, chemical storage facilities) may suffer hampered or disabled operations.
  - Transportation (bridges, culverts, roads, interchanges) and neighborhoods and community assets are at risk and can be more difficult to adapt.
  - Sensitive assets (e.g., hospitals, schools, prisons, care facilities, and underground and at grade living quarters) will have significant risks and consequences from inundation.

[1]Note that these locations will be updated upon receipt of new HAZUS data.

Coastal Flooding and Storm Surge

Climate Assessment Coastal Flooding and Storm Surge Draft Priority Impacts

Human	Infrastructure	Natural Environment	Governance	Economy
• Emergency Service Response Delays and Evacuation Disruptions (**Most Urgent**) • Increase in Mental Health Stressors • Health Effects from Aeroallergens and Mold • Health Effects from Extreme Storms and Power Outages • Damage to Cultural Resources • Increase in Vector Borne Diseases Incidence and Bacterial Infections	• Damage to Electric Transmission and Utility Distribution Infrastructure (**Most Urgent**) • Damage to Rails and Loss of Rail/Transit Service (**Most Urgent**) • Damage to Coastal Buildings and Ports • Damage to Roads and Loss of Road Service • Loss of Energy Production and Resources	• Freshwater Ecosystem Degradation (**Most Urgent**) • Coastal Wetland Degradation (**Most Urgent**) • Marine Ecosystem Degradation (**Most Urgent**) • Coastal Erosion	• Reduction in State and Municipal Revenues (**Most Urgent**) • Increase in Costs of Responding to Climate Migration (**Most Urgent**) • Increase in Demand for State and Municipal Government Services • Damage to Coastal State and Municipal Buildings and Land	• Reduced Ability to Work (**Most Urgent**) • Decrease in Marine Fisheries and Aquaculture Productivity (**Most Urgent**) • Reduction in the Availability of Affordably Priced Housing (**Most Urgent**) • Economic Losses from Commercial Structure Damage and Business Interruptions • Damage to Tourist Attractions and Recreation Amenities • Decrease in Agricultural Productivity

Coastal Flooding and Storm Surge

Requested feedback from SHMCAP Working Group

- Are there regions or subregions where your agency is more concerned about coastal flooding and storm surge?
- Are there populations or communities that your agency is more concerned about related to the ability to prepare for, respond to, and recover from coastal flooding?
- Do you have any additional recommendations related to data, information, findings, or analysis that would be helpful in the drafting of the risk assessment?

Inland Flooding

Overview and updates since 2018

- Historically, MA experiences a substantial flood event once every three years.
- Inland flooding has been increasing in low-lying areas outside of traditional and mapped floodplains.
- Changes in precipitation patterns due to climate change will continue to affect the frequency, duration, and intensity of inland flooding.
- Since 2018 new data is available for inland flooding based on the Climate Assessment work that used:
  - **First Street Foundation**
  - **Cornell Scaled Intensity-Duration-Frequency Curve dataset**
  - **Cornell Stochastic Weather Generator Dataset**

Inland Flooding

Exposure and vulnerability

Early Findings:

- Below ground and at-grade living spaces and utilities, low-lying roads, and railroads are particularly vulnerable.
- Under resourced and overburdened populations in the Greater Connecticut River Valley and Eastern Inland regions are more vulnerable.
- Flooding leads to many cascading consequences, such as power outages, roadway and transportation closures, disruption to communications and technology, and other impacts.
- **Inland flooding is one of the most consequential and widespread risks in the Commonwealth.**

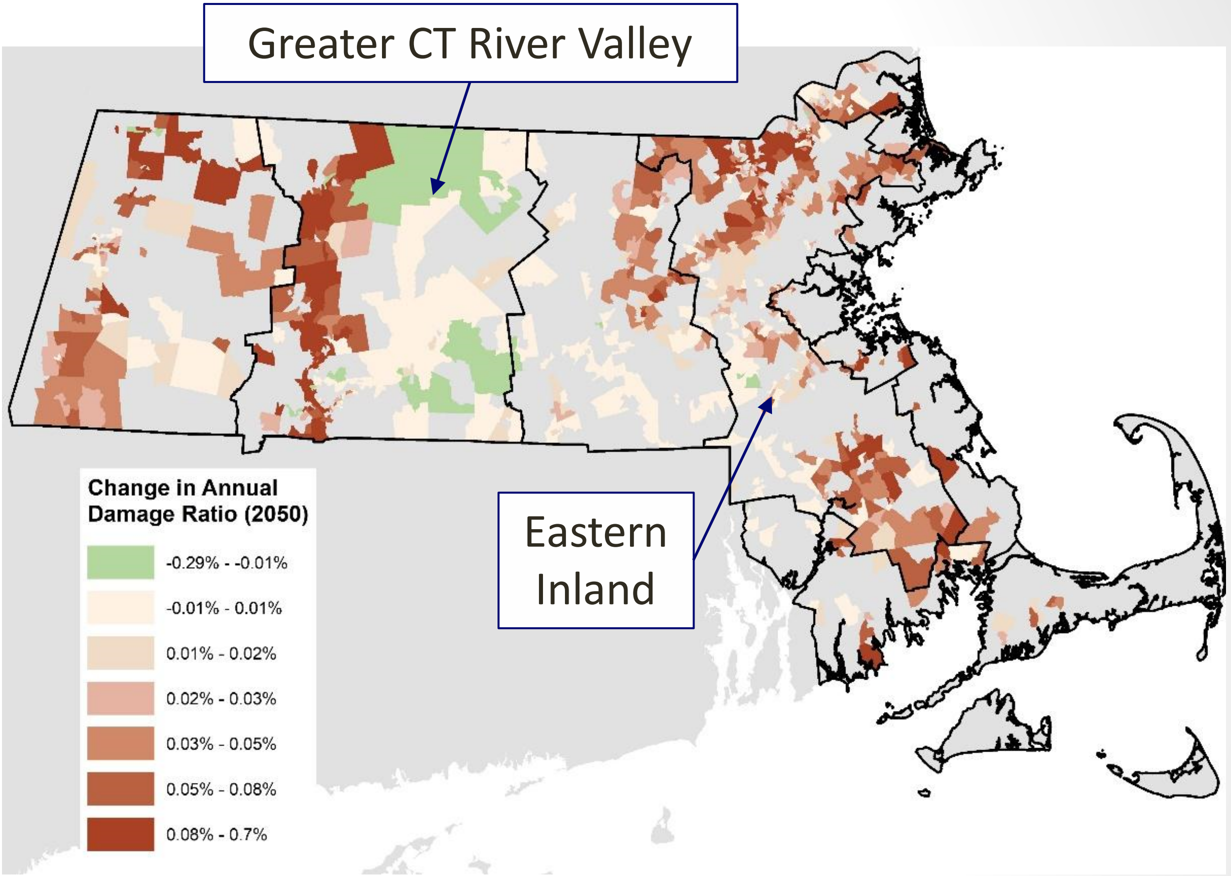


Figure: Changes in Annual Residential Structure Damage Ratio in 2050, by Massachusetts Block Group (Source: US EPA CIRA data and project analysis). Red areas in the map show an increase in damages relative to baseline climate, and green areas show reduction in damages.

Inland Flooding

Key Data Sources:

- First Street Foundation
- U.S. EPA CIRA
- Cornell University's Scaled Intensity-Duration-Frequency (IDF) Curve Dataset
- FEMA Declared Disasters
- Digital Flood Insurance Rate Map (DFIRM)

Next steps:

- Analyze vulnerabilities based on new population data, Climate Assessment data and findings, and survey responses.
- Identify additional sources of data and information related to areas and populations affected by flooding currently and in the future due to climate change.

Inland Flooding

SHMCAP Problem Statement

- **Causes**: Occurs through several meteorological processes that are impacted by a changing climate including:
  - Nor'easters, hurricanes, tropical storms, heavy precipitation events, riverbank overtopping, spring snowmelt and ice jams.
  - Changes in freeze thaw cycles, snowmelt, and precipitation patterns interact with changes in land use, impervious surfaces, and slopes can exacerbate flooding, as can drought, wildfire, and landslides.
- **Most at risk areas**: Along rivers, watersheds, and areas with near steep inclines.

Inland Flooding

Climate Assessment Priority Impacts

Human	Infrastructure	Natural Environment	Governance	Economy
• Emergency Service Response Delays and Evacuation Disruptions (**Most Urgent**) • Increase in Mental Health Stressors • Health Effects from Aeroallergens and Mold • Health Effects from Extreme Storms and Power Outages • Increase in Vector Borne diseases Incidence and Bacterial Infections	• Damage to Inland Buildings (**Most Urgent**) • Damage to Electric Transmission and Utility Distribution Infrastructure (**Most Urgent**) • Damage to Rails and Loss of Rail/Transit Service (**Most Urgent**) • Damage to Roads and Loss of Road Service • Increased Risk of Dam Overtopping or Failure	• Coastal Erosion • Soil Erosion	• Increase in Demand for State and Municipal Government Services (**Most Urgent**) • Increase in Need for State and Municipal Policy Review and Adaptation Coordination • Damage to Inland State and Municipal Buildings and Land	• Reduced Ability to Work (**Most Urgent**) • Reduction in the Availability of Affordably Priced Housing (**Most Urgent**) • Economic losses from Commercial Structure Damage ad Business Interruptions • Damage to Tourist Attractions and Recreation Amenities • Decrease in Agricultural Productivity

Inland Flooding

Requested feedback from SHMCAP Working Group

- Are there regions or subregions where your agency is most concerned about inland flooding? Is this due to elevation, infrastructure or something else?
- Do you think that there is adequate time and capacity to evacuate areas at risk from inland flooding? As this flooding increases due to climate change?
- Is your agency concerned about the ability of any communities or populations to prepare for, respond to, and recover from inland flood events?
- Is there additional data, analysis, findings, reports or other information that we should include in our work on the risk assessment?

Invasive Species

Overview and updates since 2018

- Plant pests and invasive species are becoming more destructive to important crops.
- Increasing temperatures, rainfall, humidity, wildfire, and drought can facilitate the spread and establishment of invasive species while native species struggle to survive.
- Changes to temperature levels and their duration will shift growing seasons such that some invasive species will gain a competitive advantage.
- Some examples of problem species include:
  - **Gypsy Moth, which eats the foliage of over 300 tree species**
  - **Dutch Elm disease, which kills all American Elms**
  - **Wooly adelgid, which kills Eastern and Carolina Hemlock**

Invasive Species

Exposure and vulnerability

Early Findings:

- Invasive species are a widespread occurrence in the Commonwealth.
  - 72 invasive plant species (up from 69 in 2018).
  - At least 15 invasive insects.
  - At least 14 aquatic invasive species, three potential invaders.
- Threaten biodiversity and natural resources.
- Aquatic invasive species threaten water quality, wildlife habitat, coastal infrastructure, and economically important fisheries and agriculture.
- Climate change will increase the risks associated with invasive species from aquatic landscapes to forests affecting human health, the environment and the economy across Massachusetts.

Asian long-horned beetles infest maple, birch and horse chestnut trees. Since 2008, at least $50 million in federal and state funds has been spent to try and control this species

Invasive Species

Key Data Sources:

- MA Executive Office of Energy and Environmental Affairs (EOEEA) invasive species distribution
- Massachusetts Invasive Plant Advisory Group – invasive plant list

Next steps:

- Additional research on invasive animals and microbes.
- Updated estimates of annual cost of invasive species control.
- Conduct analysis of areas of greatest exposure with likely vulnerability and consequences for key sectors and populations.
- Assess interaction between invasive species and secondary and related hazards such as wildfire, heat, and flooding.

Invasive Species

SHMCAP Problem Statement

- **Most at risk areas**: Native and/or minimally managed ecosystems throughout the Commonwealth.
- **Ecological impact:** Changing climatic conditions shift suitable habitat for native species (flora and fauna), increase the risk of new species introductions, and increases competition from established invaders, potentially causing losses in native biodiversity and loss of culturally important species.
- **Economic impact:** Widely considered to be one of the costliest natural hazards in the U.S., given extensive control efforts and damage to crops, cultural resources, ecological systems, recreational amenities, water quality and increase in public health concerns and fire risk.

Invasive Species

Climate Assessment Priority Impacts

Human	Infrastructure	Natural Environment	Governance	Economy
• Reduction in Food Safety and Security • Increase in Vector Borne Disease Incidence and Bacterial Infections		• Coastal Wetland Degradation (**Most Urgent**) • Marine Ecosystem Degradation (**Most Urgent**) • Forest Health Degradation • Shifting Distribution of Native and Invasive Species	• Increase in Demand for State and Municipal Government Services (**Most Urgent**) • Damage to Coastal State and Municipal Buildings and Land • Increase in Need for State and Municipal Policy Review and Adaptation Coordination • Damage to Inland State and Municipal Buildings and Land	• Decrease in Marin Fisheries and Aquaculture Productivity (**Most Urgent**) • Damage to Tourist Attractions and Recreation Amenities • Decrease in Agricultural Productivity

Invasive Species

Requested feedback from SHMCAP Working Group

- Are there regions or sub-regions where invasive species pose the biggest problem for Massachusetts?
- Are there impacts to your agency's functions and assets due to invasive species impacts? Have there been increased costs due to increased demands on management and maintenance?
- Do you know of additional data, information, analysis or reports related invasive animal species in the Commonwealth?
- Are there any national-level estimates on the costs to managing invasive species (animal and plant) in the Commonwealth?

Next Steps: Risk Assessment

1. **HAZUS updates on November 14, 2022** will allow us to conduct HAZUS analysis on earthquakes, coastal storms, and hurricanes.
2. **Integrate findings and information** from 2023 SHMCAP agency survey responses into risk assessment to share at 12/14 meeting.
3. **Advance flooding from precipitation and urban drainage case studies**.
4. **Conduct population and growth analysis**.
5. **Continue to collect geospatial data** on assets and services such as job centers, updated environmental justice maps, etc.
6. **Refine problem statements** based on input and comments from meeting and post meeting.
7. **Hold SHMCAP working group/RMAT Risk Assessment Part 2 meeting** on December 14, which will include updates described above.

Massmatt/Flickr

Wrap Up and Next Steps

Wrap Up and Next Steps

- Public review period for draft Climate Change Assessment Report -**November 2 – 16**.
- Share feedback on Goals Document Draft 2 by **November 23**.
- Share feedback on risk assessment questions, problem statements, and relevant priority impacts by **November 23**.
- Risk Assessment Meeting Part 2 to be held on **December 14** with revised problem statements and draft final risk assessment vulnerabilities and consequences.

Thank you

For SHMCAP Working Group
Review 2023 SHMCAP Goals Document (Draft 2)

November 2022

Dear SHMCAP WG,

Establishing a shared mission and goals for the 2023 State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) update is a critical step in ensuring we have a shared vision and level of ambition. Draft 1 of the goals was presented and discussed during the September 14 SHMCAP WG meeting. We received comments on the goals during discussion, through chat participation, using virtual engagement tools (mentimeter) and through email. Thank you to everyone who shared feedback of the 2023 Mission and Goals.

Your feedback was critical to the development of "2023 Mission Statement and Goals Draft 2" included in this packet. The document includes the revised mission and goals. Information relating to draft 1 is in *italics* and includes a copy of the Draft 1 text followed by a summary of the feedback received and changes made to draft 1.

We invite you to share your feedback on Draft 2 of the Goal Document through email. Please send feedback via email to AndreaCristina.Ruiz@erg.com by **November 30.**

We will incorporate this round of feedback into the next version of the Goals Document, which will be the working version used to inform strategy development. The Mission and Goals document will remain a draft working document and finalized after stakeholders beyond the SHMCAP Working Group have an opportunity to comment on goals between November 2022 – March 2023. Stakeholders will have the opportunity to share reactions, feedback, and suggestions. We will need to be open to update and amend the goals based on stakeholder feedback. Stakeholders we will reach out as part of the stakeholder engagement plan include municipalities, tribal governments, regional organizations, NGOs, and communities, among others.

As you read through the document, please consider the following questions:

- Are we covering all the critical issues?
- Are the goals measurable and meaningful to your agency?

Thank you in advance for your participation,

SHMCAP Project Management Team

Draft 2, 2023 Goals and Mission

Introduction:
Due to climate change, natural hazards are increasing in intensity, frequency, and duration—in addition to affecting larger geographic areas. The 2023 SHMCAP's mission statement and goals represent the vision of the Commonwealth of Massachusetts for a future in which communities and the environment have enhanced resilience and reduced vulnerabilities from natural hazards and climate change impacts. The Commonwealth will reduce the consequences of hazards and climate change to communities and the environment equitably and collaboratively through specific hazard mitigation and climate adaptation actions and partnerships.

The mission statement and goals reflect the needs identified in the risk and vulnerability assessments including the Massachusetts Climate Change Assessment, and the ongoing state agency vulnerability assessment and state capability and adaptive capacity analysis.

Mission statement: The mission for the 2023 MA State Hazard Mitigation Climate Adaptation Plan (SHMCAP) is as follows: Prepare the Commonwealth for the urgent need to increase resilience, respond to, adapt to, and reduce the risk of natural hazards and climate impacts in an equitable & sustainable manner that enhances the environment and the well-being of those living in and visiting Massachusetts.

> *Previous Draft (Draft 1): Increase the capacity of the Commonwealth to prepare for, adapt to, and reduce the risk of natural and other hazards and climate impacts through the development of a comprehensive and integrated hazard mitigation and climate adaptation program. This program will ensure an equitable and just approach to reduce loss of life; protect social, environmental, and economic wellbeing; and ensure health and safety of Massachusetts, including the built and natural environment that sustains it.*
>
> *Feedback on Draft 1: Several WG members felt this statement was too long and too detailed for a mission statement. We shortened the statement to be more succinct and used broader, more inclusive language.*

Goals: These goals provide a framework to implement the Commonwealth's (state's) vision for mitigating risk and increasing social, environmental, and economic resilience from natural and other hazards and the effects of climate change on these hazards. Reviewers, please read the footnote.[1]

1. **Strengthened Collaboration and Partnership** - Successfully integrate hazard mitigation and climate adaptation actions in programs, policies and services provided by state agencies and improve state coordination and collaboration with government and non-governmental partners.

    > ***D**raft 1 Strengthened Collaboration and Partnership: Increase the state's institutional capacity to integrate hazard mitigation and climate adaptation actions in programs, policies and services through enhanced coordination and collaboration among state agencies and with local jurisdictions, regional agencies, Tribal governments, and community organizations.*

[1] Note to reviewer: The focus of the section below is to develop robust, complete goals and allow for the language to provide context as to the intent of the goal. As was done in 2018, we will use formatting (bold and italics) and consider developing an abridged executive version of the goals. We are also piloting the use of titles to the goals to make them easier to skim and more accessible to web/print.

Feedback on Draft 1: Several comments recommended we shift the focus of this goal to successful outcomes. There were also several suggestions of partnership types to include. To avoid adding a laundry list of partners, we changed the language to be more inclusive and less government focused.

2. **Science-based and Informed Decision-Making**: Invest in enhancing and advancing the state's understanding of current and future vulnerability and risks from hazards and climate change impacts, as well as the mitigation and adaptation actions. Integrate and build on the 2022 Massachusetts Climate Change Assessment and incorporate the latest scientific findings and include local knowledge to develop coordinated and collaborative actions that address short, medium, and long-term vulnerabilities.

   Draft 1 Science-based and Informed Decision-Making: Enhance and advance the state's understanding of current and future vulnerability and risks from natural and other hazards and climate impacts. Integrate and build on the 2022 Massachusetts Climate Change Assessment and incorporate the latest scientific and local knowledge to develop coordinated and collaboratively identified actions that address short, medium, and long-term vulnerabilities and are implementable, comprehensive, and equitable.

   Feedback on Draft 1: We received one comment that noted investment in research is needed to support adaptation and mitigation measures. We adjusted the goal to reflect investment in advancing vulnerability and risks.

3. **Enhanced Protection and Management of Assets and Services**: Enhance the Commonwealth's ability to protect and improve state assets, services, and natural and cultural resources to maintain continuity of service, community lifelines, state functions, and infrastructure.

   Draft 1 Enhanced Protection of Assets and Services: Continue and enhance the Commonwealth's ability to protect state assets and services to maintain continuity of service, community lifelines, state functions, and infrastructure. Use strategies and actions that advance community resilience, reduce community stressors, and promote sustainable development.

   Feedback on Draft 1: Comments suggested adding natural resources in addition to assets and services. Several comments also mentioned that there could be less of an emphasis on infrastructure for those that can work from home. One comment suggested adding cultural resources. Removed the last sentence - one commenter felt it was confusing to the rest of the goal. The sentiment of the last sentence is also captured in goal 8.

4. **Long-Term Hazard and Climate Impact Reduction**: Increase community safety and natural environment health and biodiversity by reducing hazard and climate change impacts through equitable, risk-informed plans, policies, regulations, codes, and land use planning, as part of short- and long-term hazard mitigation and adaptation strategies.

   Draft 1 Long-Term Hazard and Climate Impact Reduction: Work collaboratively at the State and local level to reduce natural and other hazard and climate impacts. Increase community safety *through equitable, risk-informed plans, policies, regulations, codes, and land use planning, as part of short- and long-term hazard mitigation and adaptation strategies.*

Feedback on Draft 1: There were some concerns this goal fell too much into emergency response, we have updated the language to reflect long-term planning and strategies.

5. **Equitable climate adaptation and hazard mitigation**: Safeguard the right of all people, especially the most vulnerable populations, to participate in and benefit from the 2023 SHMCAP's development and implementation. Ensure the plan provides meaningful and measurable approaches to build community resilience, improve community safety and well-being, and address past underinvestment.

   Draft 1 Equitable climate adaptation and hazard mitigation: Safeguard the right of all people, especially environmental justice populations, to enjoy equal protection, equitable distribution of benefits, and meaningful involvement in the 2023 SHMCAP's development and implementation. Ensure the plan provides meaningful and measurable approaches to build community resilience and reduce community stressors.

   Feedback on Draft 2: Comments were divided on use of EJ populations - one comment wanted to make sure this goal was inclusive of all vulnerable groups, another comment suggested we use language of the most recent climate bill (which refers to "EJ populations" and "low-income"). Suggested we reframe to who is part of the plan vs who receives benefits.

6. **Ongoing Communication and Engagement**: Support implementation and evolution of this plan through increased education, awareness, and partnership among state agencies, local governments, private industry, non-profits, and the public.

   Draft 1 Ongoing Communication and Engagement: Support implementation and evolution of this plan through increased education, awareness, and partnership among state agencies, local governments, private industry, non-profits, and the public.

   Feedback on Draft 1: Most comments agreed with this goal, a couple of comments suggested we add examples of what this means, which we felt were too specific to be mentioned in the goal but will be considered when draft actions.

7. ***Climate mitigation***: Recognize and support greenhouse gas reduction measures that would reduce the impacts from long-term climate risks

   Draft 1 Climate mitigation: Recognize and support climate mitigation actions and strategies that could reduce long-term climate risks.

   Feedback on Draft 1: Most comments agreed with this goal, though the use of mitigation/mention of GHG reduction confused some people. We reworded to clarify and make the connection between long term climate risks and greenhouse gas reduction.

8. **Resilient infrastructure and communities**: Ensure the 2023 SHMCAP results in actions and strategies that account for past under investment, incorporates shared and collaborative decision making and consent, improves community engagement, and result in measurable increases in the health and safety of communities, the resilience of infrastructure and the enhancement of the natural environment.

    Draft 1 Resilient infrastructure and communities: Ensure the 2023 SHMCAP is designed to result in actions and strategies to reduce the most significant consequences to communities, infrastructure, environment, and economy and that can result in measurable increases in community and infrastructure resilience.

    Feedback on Draft 1: Comments recommended we clarify/shorten, include natural environment, weave in something social capacity/social networks and integrate equity/need for focus on most vulnerable.

Although not specifically referenced in the goal statements, the need to build resilient infrastructure and communities, hazard mitigation post-fire, and high hazard potential dams, as identified by the Federal Emergency Management Agency (FEMA), is recognized by the Commonwealth in our specific actions and in our funding prioritization criteria for Hazard Mitigation Assistance (HMA) grants.

State Hazard Mitigation and Climate Adaptation Plan: Risk Assessment

Purpose

The purpose of the risk assessment portion of a State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) is to identify those hazards that are likely to pose risks to the Commonwealth based on current and future projections of the hazards and, if relevant, the changes to hazards from the influence of climate change. The risk assessment includes three critical components that serve as a foundation for the rest of the SHMCAP:

1. **Exposure analysis:** Identifies the nature of which and degree a hazard will affect the Commonwealth. Includes findings regarding the range of intensity, frequency, duration, location, and timing of the hazard. Includes an analysis of the influence that climate change has on this hazard, including the climate projections for this hazard.
2. **Vulnerability assessment:** Determines which populations, assets and services are susceptible to which of the hazards and at what scale. Identifies how hazards are likely to affect critical assets, impact communities differently or disproportionately, and affect geographies, land uses or natural areas differently than others. Also considers whether these vulnerabilities are likely to increase due to climate change influences on the hazards which may be projected to make hazards more intense, more frequent, longer in duration, and/or impact new geographic areas.
3. **Prioritize risks and consequences**: Determines the risks and consequences resulting from the vulnerabilities identified in the exposure analysis and vulnerability assessment. Assesses which risks should be addressed to limit or eliminate the highest consequence risks to the assets and services that are most important to the Commonwealth. Evaluates how the draft goals developed for the 2023 SHMCAP update align with the findings on risks and consequences. Identifies how the findings on risks and consequences inform the development and prioritization of actions for the 2023 update to the SHMCAP.

The risk assessment is the foundation of any state hazard mitigation plan and draws from other steps in the process, including the state vulnerability and capabilities assessment, and informs other steps in the process such as the design and prioritization of hazard mitigation actions. As FEMA describes it, a risk

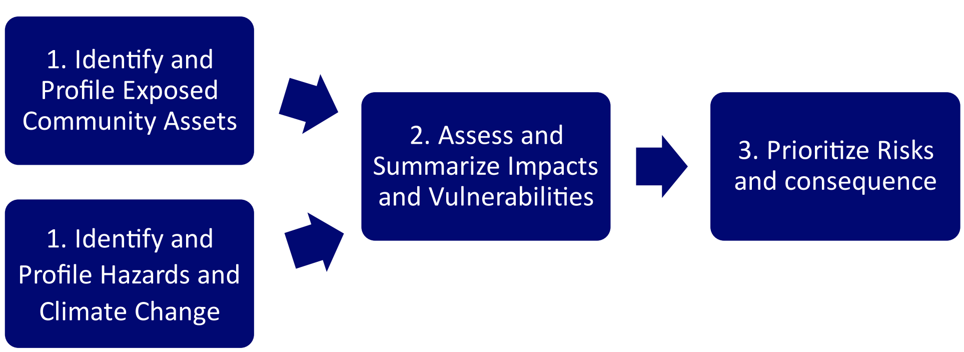


Figure 1. Risk Assessment Components

assessment is "a process that helps communities: understand how natural events and climate change can impact them, helps communities communicate vulnerabilities to partners and stakeholders, informs decision-making, and serves as the basis for the mitigation strategy to reduce" damage, disruption, and loss from hazards and climate change.

The 2023 SHMCAP is designed as a strategic update to the risk assessment completed for the 2018 plan. The 2023 risk assessment will be updated based on the outcomes and findings of the 2022 MA Climate Change Assessment, new State Hazard Mitigation Plan FEMA requirements, and updates to best available science and information. The following sections provide more details of these updates.

SHMCAP Hazards

- Inland flooding
- Dam overtopping
- Urban drainage and pluvial flooding
- Drought (including impacts to groundwater)
- Landslides and mudflows
- Coastal flooding and storm surge
- Ground water rise
- Coastal erosion
- Tsunami
- Average and extreme temperatures
- Wildfires
- Invasive species
- Hurricanes/tropical storms
- Winter storms/Nor'easter
- Tornados
- Other Severe Weather
- Earthquake
- Ground failure

blue=draws heavily on Climate Assessment; green=new analysis outside of Climate Assessment

Integration with the Climate Change Assessment

The 2022 Climate Change Assessment includes the following information that will inform the 2023 update of the SHMCAP:

- A comprehensive survey of the latest climate data and projections available for Massachusetts, identifying the best available projections for coastal flooding, precipitation, and temperature. This data and modelling were not available in 2018.
- Risk assessments for the hazards listed in blue in the graphic above.
- The climate change assessment analyzes the vulnerability and consequences of hazard and climate exposure across five main sectors: human, governance, infrastructure, natural environment, and economic.

What's new since 2018?

As described above, there have been significant improvements in climate and natural hazard science and data as well as updated information on population and development since the 2018 SHMCAP. These improvements include:

- Updated information on climate impacts through the Sixth International Panel on Climate Change, including new insights on climate change impacts and human responses.
- Improved understanding of sea level rise and coastal flooding based on the development of the Massachusetts Coast Flood Risk Model (MC-FRM) and EEA's Climate and Hydrologic Risk Project. The MC-FRM includes physical processes of tides, waves, wave run-up, storm surge, winds, and currents and applies high resolution predictions for inundation for combined sea level rise and storm surge events.
- Improved understanding of precipitation and temperature based on the work done in EEA's Climate and Hydrologic Risk Project which provides better information about likely variabiity and extremes.
- New census data and updated projections of future populations and development.
- New soils data which will improve our modeling of earthquake damages.
- State agency staff provided new data and expanded assessment of some risks (e.g., groundwater rise).

- Updated biological diversity data. BioMap3 data will be applied to help understand the impacts of hazards to critical to rare and other native species and their habitats in MA.

2023 MA SHMCAP
RMAT Meeting 4

2023 SHMCAP Working Group Meeting #4
Risk Assessment – Part II and Introduction to Action Development
Tuesday, January 24, 2023
2:00—4:00pm EST

Meeting Objectives:

1) Discussion of select Risk Assessment results and connection to action development. Presentation of the results of high impact hazards focusing on measures of magnitude, scale, and consequence of hazards.
2) Overview of SHMCAP action development process, focusing on high consequence vulnerabilities and priority impacts.
3) Introduce agency homework to be completed between January 24th and February meeting and prepare RMAT members for review and revision of 2018 actions and development of new actions that will reduce risk from Climate Assessment priority impacts and SHMCAP high consequence vulnerabilities.

Time ET	Agenda Item

2:00 – 2:10 pm	**Welcome and Updates**
	• Announcements from PMT
	• Recap of work since 11/8
	  ○ Draft 1 of Capacity and Capabilities
	  ○ Subject matter review of SHMCAP Risk Assessment Hazard Sections
	  ○ Draft 1 Vulnerability Assessment Chapter
	• Upcoming deliverables for review that will be delivered on January 31:
	  ○ Vulnerability Assessment Draft 1
	  ○ Capabilities Assessment Draft Chapter
	  ○ Risk Assessment Draft 1

2:10 – 2:45 pm	**Risk Assessment Summary**
	• A summary of the results, methods used, and information reviewed
	• Present snapshots highlighting the magnitude, scale, and consequence of high consequence hazards.
	  ○ Coastal flooding, coastal erosion, and related hazards
	  ○ Inland flooding and related hazards
	  ○ Hurricanes
	  ○ Extreme temperatures
	• Discuss how risks inform actions
	  ○ How priority impacts, high consequence vulnerabilities, and agency capacity and capabilities will inform actions
	• Provide overview of next steps for review of all hazards
	• Questions and discussion

2:45 – 3:00 pm	**Framework and Process for Action Development** • Overview of process for action development • FEMA framework for defining and developing actions

<table>
<tr><th>Time ET</th><th>Agenda Item</th></tr>
<tr><td></td><td>Present overview of high consequence vulnerabilities and priority impacts by sectors (human, infrastructure, economy, governance, natural environment)
Discuss development of actions to address high consequence vulnerabilities and priority impacts
Review 2018 SHMCAP actions and actions initiated since 2018 based on applicability to priority impacts and high consequence vulnerabilities. How do 2018 actions and agency actions since 2018 respond to priority impacts and high consequence vulnerabilities? Do they need to be revised to be more responsive? Are some no longer relevant and should not be carried forward into 2023?</td></tr>
<tr><td>3:00-3:40 pm</td><td>Breakout room discussion
Provide overview of breakout group approach
Breakout groups (five groups, one per sector) that address the following questions:
Are there hazards and vulnerabilities that are missing from our list of high consequence vulnerabilities or priority impacts missing from those identified here? What makes them critical for Massachusetts to prioritize?
Based on the 2018 SHMCAP actions and agency specific actions developed since 2018, and the capabilities and capacity of your agency and others you work with, what do you see as gaps that exist in relation to addressing the high consequence vulnerabilities and priority impacts?
Based on your agency’s capabilities and capacities what types of actions can your agency take the lead or support on to address the high consequence vulnerabilities and priority impacts?
What types of cross agency actions would be useful to address the high consequence vulnerabilities and priority impacts?</td></tr>
<tr><td>3:40 – 3:50 pm</td><td>RMAT Homework: 2018 Action Updates
Overview of RMAT homework in advance of February meeting to review and identify actions for the 2023 SHMCAP</td></tr>
<tr><td>3:50 – 4:00 pm</td><td>Wrap Up and Next Steps
Summary of homework for RMAT members
Deliverables, reviews, and dates
Upcoming meetings and engagements
SHMCAP timeline</td></tr>
</table>

2023 SHMCAP Update

RMAT Working Group Meeting #4
Risk Assessment – Part II and Introduction to Action Development

January 24, 2023

Executive Office of Energy and Environmental Affairs

ERG IEc WOODS HOLE GROUP CBI

Photo: Marblehead Harbor, Wikimedia Commons

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Welcome and Introductions

Please put your affiliation in the webinar participant list or chat

Photo: Kevin Gill/Flickr

2

2

Agenda

Welcome and Introductions
Risk Assessment Summary and Next Steps
Framework and Process for Action Development
Action Development Discussion
Round 1 2023 SHMCAP Action Development Next Steps
Wrap Up and Next Steps

3

3

Recap Since 11/8/22 Meeting

- Draft 1 of Capacity and Capabilities Analysis Chapter to PMT on **12/21/22**
- Subject matter expert review of SHMCAP Risk Assessment Hazard Sections completed **1/13/23**
- Meetings and discussions with subject matter experts where needed
- Design framework for 2023 SHMCAP action development
- Draft 1 of Vulnerability Assessment Chapter – **in development**
- Draft final 2023 SHMCAP goals
- Design stakeholder engagement meetings to occur in spring 2023

4

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RMAT Reviews and Responsibilities

Review the following deliverables that will be provided:

- DRAFT 2 of SHMCAP Capacity and Capabilities Analysis Chapter delivered on **1/31/23 and reviews due on 2/28/23**
- SHMCAP Risk Assessment Chapter delivered on **1/31/23 and reviews due on 2/28/23**

Round 1 SHMCAP Action development tasks

- Determine whether revisions to existing 2018 SHMCAP actions are necessary to address Climate Assessment Priority Impacts and Risk Assessment Vulnerabilities
  - Provide status update on all 2018 SHMCAP actions
- At a high level, identify new actions for the 2023 SHMCAP that address Climate Assessment Priority Impacts and Risk Assessment Vulnerabilities relevant to your agency

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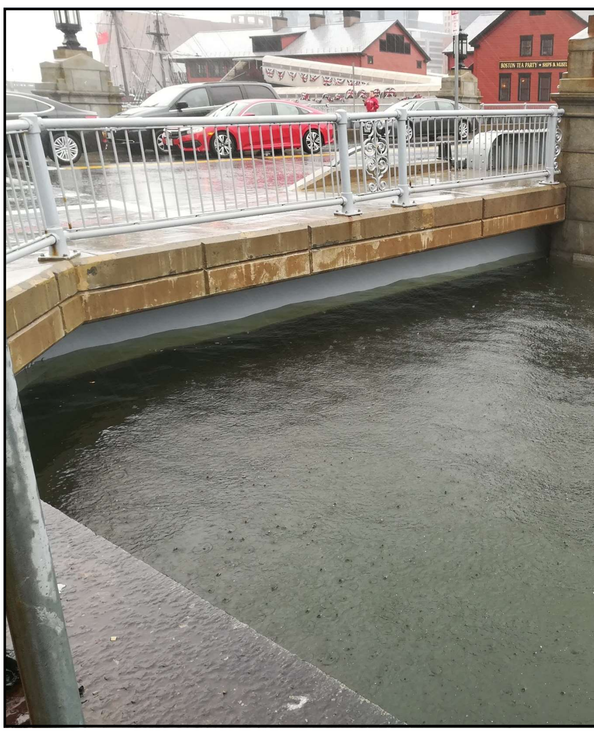

Risk Assessment Summary

Photo: Kate Adams

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2023 SHMCAP Risk Assessment

Process and review timelines

Sources of Data and Information for the Risk Assessment

- Climate Assessment
  - For many hazards: climate projections, impacts, maps, and data. Discussion of priority impacts.
- State developed studies and reports
- Scientific studies and reports
- Local hazard Mitigation Plans
- Input and data from state agencies
- Geospatial analysis (including state agency layers)
- HAZUS 6.0 (released Nov. 2022)
- MA Environmental Justice maps released Dec. 2022
- Population data from U.S. Census

State Agency Feedback Incorporated

- Feedback opportunities during drafting process:
  - Small group meetings with subject matter experts (Oct. through Dec.)
    - Groundwater rise, Earthquakes, and Wildfire.
  - RMAT Meeting #3 input (Nov. 8)
  - Problem statement feedback (Nov. 23)
  - Hazard profile review (Dec. 12)
  - Subject matter expert review of hazard section drafts (Jan. 13)

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2023 SHMCAP Risk Assessment

Hazards included in assessment

2023 SHMCAP Hazards	
Flooding from precipitation	Tornados
Groundwater rise [new]*	Tsunami
Coastal flooding and storm surge	Wildfires
Average and extreme temperatures	Tornados
Coastal erosion	Hurricanes and Tropical Cyclones
Dam overtopping*	Winter storms/Nor'easter
Drought (including impacts to groundwater)	Other Severe Weather**
Earthquake	
Landslides and mudflows (Ground failure)	blue=draws heavily on Climate Assessment green=new analysis
Invasive species	

*Groundwater and dam overtopping was added as a new hazard chapter to reflect changing conditions
**Defined in 2018, this hazard section discusses risk from a collection of severe weather events including high winds, thunderstorms, extreme precipitation.

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Risk Assessment

Introducing the Hazard snapshot

Snapshot is a consistent summary and comparison of all the hazards, including ranking, statements, maps.

Approach

Hazard snapshot: rolled up summary and comparison of all hazards using consistent categories.

A way to allow for the consideration of all hazards.

- Using categories and rubrics to classify hazards across dimensions that capture location, impact, scale of consequences
- Snapshots are based on Risk Assessment which includes:
  - Analysis: detailed analysis and hazard write up (reviewed by SME)
  - Summary tools: problem statements and hazard profile (2-pager) (Reviewed by RMAT)
  - Information and data from Climate Assessment where available

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Risk Assessment

Hazard snapshot: rolled up summary of all hazards using high-level categories

Concepts covered :

- **Vulnerability:**
  - Used Climate Assessment sectors and cross-walk of priority impacts
  - Discussed disproportionate impacts
  - Identified risk to state assets and critical facilities
  - Discussion on risk and impact to community lifelines
- **Location:**
  - Hazards were classified on local, county, regional, statewide, and multi-state scales
- **Changing conditions:**
  - Considered climate change effects for relevant hazards, with projections for mid and end of century

Indicators used in Snapshot

Location: geospatial reach and geographic descriptions

Likelihood: likelihood of the hazard happening (considering a changing climate)

Magnitude of consequence: magnitude of impact and ability to respond (Warning time).

Qualitative: Discussion of adaptive capacity and disproportionate impacts*

*Used the Climate Assessment (CA) rankings for *disproportionality* for hazards covered by the CA

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Risk Assessment: Hazard Snapshot

Location

- Exposure and areas impacted

Scale/ categories:

- Hazard and impacts span multiple states simultaneously
- Impacts felt through the entire state
- Regional impacts, impacting an area or series of jurisdictions in the state that share a definable characteristic
- County or group of counties experiencing localized impacts
- Hazard experienced at a discrete, localized area

Note: Complemented with qualitative information

Magnitude of consequence

Geospatial reach and scale for magnitude of consequence (table below)

	Very high	High	Medium	Low	Very Low
Human	Loss of human life.	Any injuries. Disruptions of emergency routes	Disruption in ability to work or carry out daily life and activities.	Limited effects, inconvenience, minor power outages	Minimal injury and inconvenience
Econ.	Disruption to entire state and beyond, long-term impacts to the economy at the scale and severe economic losses across multiple sectors	Long-term disruption, multiple sector impact, likely to result in economic decline	Deep or light prolonged disruption, limits or restricts growth, risk of economic decline	Economic costs to people, state, and business requiring significant expense	Economic costs to people, state, and business can be planned and sustainable
Natural Env.	Irreversible loss of ecosystem function or health	Extensive damage to ecosystem and/or key organisms; unlikely to recover to pre-disaster state	Damage to ecosystems or organisms, but likely to recover to pre-disaster state	Some losses to individual organisms but unlikely to permanently impact ecosystem	Minimal risk of impact to individual organisms or overall ecosystems

Risk Assessment

Snapshot approach to summarizing location

Likelihood of exposure

- Likelihood that a hazard occurs in a given year.
- Hazard chapters use appropriate scientific scale and consider climate change. This scale adapts those estimates using IPCC likelihood conventions.

Scale/ categories:

- **Very high:** Nearly certain
- **High:** Likely
- **Medium:** About as likely as not
- **Low:** Unlikely
- **Very Low:** very unlikely to exceptionally unlikely

Warning time

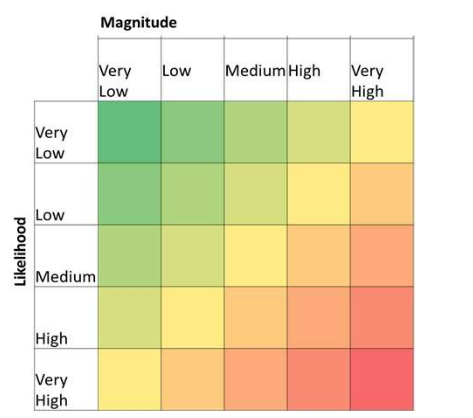
Captures ability to reliably predict and respond

No warning	Very difficult to predict and anticipate location, severity, and onset. Information available does not enable preparation.
Hours	Occurs with little warning that provides a limited number of hours to adjust behavior or prepare
1 (24 hours)	Reliable information on impact available within a 24-hour period with at least about a day to prepare
1-5 days	Predictions of impact are accurate within one to two days before the hazard occurs
One week	Predictions of impact are accurate enough within one week enabling several days for preparation
Week or more	Reliable, accurate prediction of hazard onset several weeks, specific enough to direct action

Risk Assessment

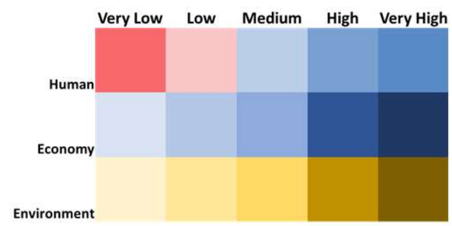
Visuals used in hazard snapshot

Magnitude and Likelihood



Warning Time

Potential for Consequence by Sector



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Hazard Snapshot: Hurricanes

Data used in RA analysis

- Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model
- Hazus Hurricane Probabilistic Analysis

Methods used in RA analysis

- SLOSH intersection with population, EJ communities, state owned buildings, critical facilities, roads, and BioMap
- Ran a probabilistic Level 1 Hazus hurricane analysis to estimate shelter requirements and building-related economic losses

Snapshot components

Warning Time

Potential for Consequence by Sector

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Hazard Snapshot: Hurricanes

Additional information

Areas most at risk:

- Storm surge: coastal areas (especially South Shore and Cape Cod)
- Additional flood risk: low-lying inland areas
- High winds and rainfall: Entire Commonwealth

Distribution of impact and vulnerability

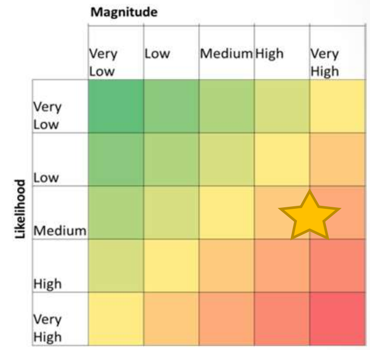
- People living in flood-prone areas, socially vulnerable populations, mobile home residents, and emergency response workers

Priority Impacts Drawn from the Climate Assessment

- Damage to inland buildings; damage to coastal buildings and ports
- Emergency service response delays and evacuation disruptions
- Damage to electric transmission and utility distribution infrastructure

Snapshot components

Magnitude and Likelihood



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Hazard Snapshot: Inland Flooding

Data used in RA analysis

- Maps and data from FEMA flood zones (FIRM, DFIRMs, NFIP and repetitive loss)
- LOCA downscaled GCM precipitation projections

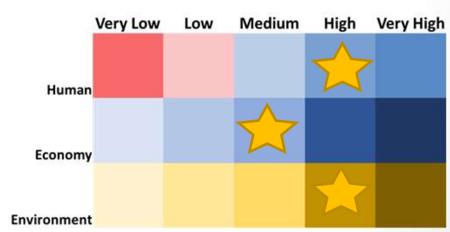
Methods used in RA analysis

- Estimated population, infrastructure, and solar electric production exposed to inland flooding using FEMA flood zones
- Calculated change in precipitation and change in intensity and frequency of extreme precipitation events using LOCA precipitation projections

Snapshot components

Warning Time

Potential for Consequence by Sector



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Hazard Snapshot: Inland Flooding

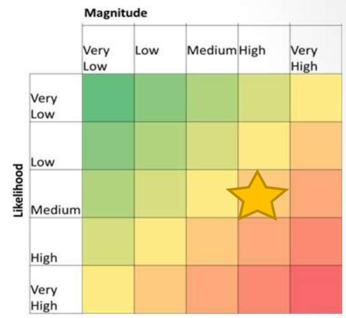
Additional information

Areas most at risk:
- Areas near rivers and wetlands or were previously rivers
- Areas near high-hazard dams
- Urban areas experiencing excessive rainfall and over-capacity systems

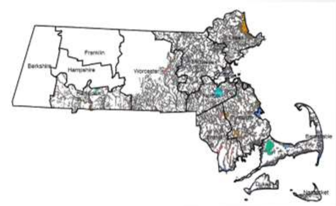
Distribution of impact and vulnerability
- Populations with limited ability to evacuate are at higher risk
- Flooding, especially recurring flooding pose burdens on low-income households.

Snapshot components

Magnitude and Likelihood



Priority Impacts Drawn from the Climate Assessment
- Emergency service response delays and evacuation disruptions
- Health effects from aeroallergens and mold
- Increase in vector borne diseases incidence and bacterial infections
- Reduction in clean water supply and freshwater ecosystem degradation/
- Damage to inland state and municipal buildings and land
- Economic losses from commercial structure damage and business interruptions



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Hazard Snapshot: Coastal Flooding

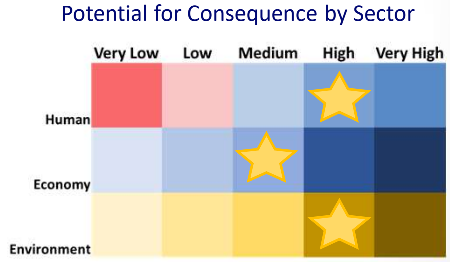
Data used in RA analysis
- Massachusetts Coastal Flood Risk Model (MC-FRM)
- FEMA flood zones
- FEMA Standard Digital Flood Insurance Rate Maps
- National Coastal Property model
- Traffic delay data (EMS response impacts)

Methods used in RA analysis
- MC-FRM outputs to calculate area flooded with SLR, annual expected flood damages to coastal properties, and emergency response service impacts from traffic delays
- FEMA flood maps to calculate number of people and infrastructure, in different flood zones in each county
- Analyzed economic vulnerability to coastal flooding using the National Coastal Property model

Snapshot components

Warning Time

Potential for Consequence by Sector



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Hazard Snapshot: Coastal Flooding

Additional information

Areas most at risk:

- Areas along state coastline
- Impacts may extend throughout state depending on flood intensity and duration.

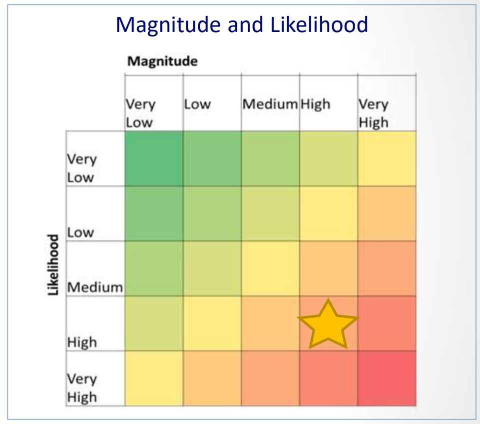
Distribution of impact and vulnerability

- Increased risk of injury and death for communities living near the coast with limited ability to evacuate (elderly, young, linguistic isolation, transit dependency)

Priority Impacts Drawn from the Climate Assessment

- Damage to coastal buildings and ports
- Coastal erosion and coastal wetland degradation
- Marine ecosystem degradation
- Damage to coastal state and municipal buildings and land
- Damage to tourist attractions and recreation amenities
- Emergency service response delays and evacuation disruptions
- Health effects from aeroallergens and mold

Snapshot components



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Hazard Snapshot: Extreme Temperature

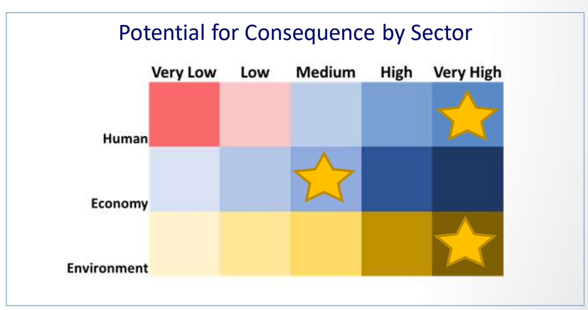
Data used in RA analysis

- Temperature projections from Cornell Stochastic Weather Generator (from CA), downscaled CMIP6 forecasts (NEX-GDDP, 2022)
- Health risk factors from MA. Environmental Public Health Tracking
- Locations of road and rail

Methods used in RA analysis

- Predicted changes to mortality and worker productivity from temperature changes and historical rates (from CA)
- Projected damages to road and rail infrastructure from modeled engineering cost by Neumann et al. (2021)
- Estimated extent of loss for fisheries based on model by Moore et al. (2021), from CA

Snapshot components



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Hazard Snapshot: Extreme Temperature

Additional information

Areas most at risk:

- Higher temperatures in central and coastal regions.
- Areas prone to heat-island effect.

Distribution of impact and vulnerability

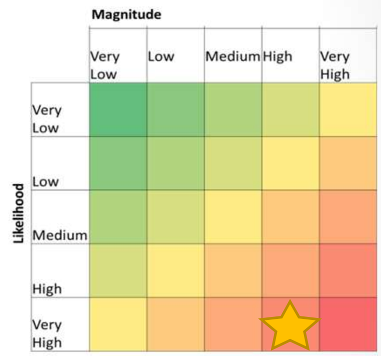
- Differences in access/ability to afford heating or cooling can impact exposure and magnify negative impacts.

Priority Impacts Drawn from the Climate Assessment

- Health and cognitive effects from extreme heat and health effects from degraded air quality. Increase in mental health stressors
- Loss of energy production and resources
- Forest health degradation and shifting distribution of native and invasive species
- Increase in costs of responding to climate migration
- Reduced ability to work with most exposure to outdoor workers
- Decrease in marine fisheries and aquaculture productivity and agricultural productivity

Snapshot components

Magnitude and Likelihood



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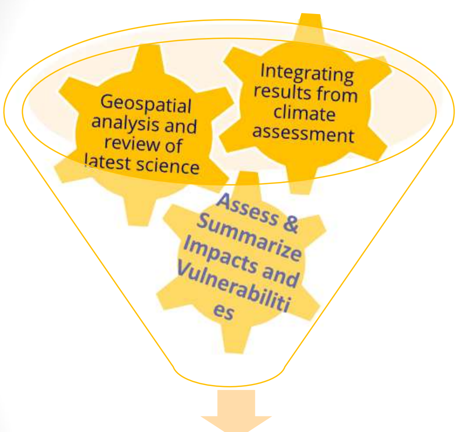
From Risk Assessment to Action Development



Risk Assessment purpose: To develop risk informed strategies must directly address vulnerabilities discussed in the risk assessment (FEMA policy guide p.4)

Risk Assessment summary components:

- **Problem statements are used to identify actions and solutions**
  - They are an understanding of hazards, exposure, and vulnerability, including the most significant risks and vulnerabilities.
- **Hazard Snapshots compare hazards**
  - Indicators compare hazard intensity, impacts, vulnerabilities, and adaptation capacity to support action development

Risk Assessment Overview → Problem Statements

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Next Steps for the Risk Assessment

Important dates for the Risk Assessment Chapter

Prior to today

Feedback opportunities during drafting process:

- Small group meetings with subject matter experts as needed and requested (Oct. through Dec.)
- RMAT Meeting #3 input (Nov. 8)
- Problem statement worksheet (Nov. 23)
- Hazard profile review (Dec. 12)
- Subject matter expert review of hazard section drafts (Jan. 13)

Next steps

Future opportunities for input - Review Timelines

- **January 31 –** Draft 1 Risk Assessment
  - **February 28 –** Deadline to submit comments on Risk Assessment
- **March 22 –** Draft 2 update showing incorporated feedback.
  - Revisions to Draft 2 will be included in the 2023 SHMCAP.

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Questions and Discussion

Photo: Lance Cheung

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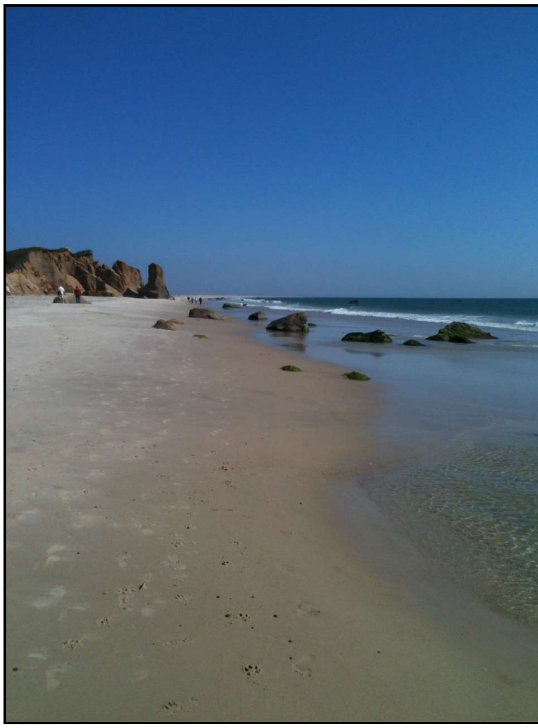

Framework and Process for Priority Impact/Vulnerability Action Development

Photo: Irena Draksic

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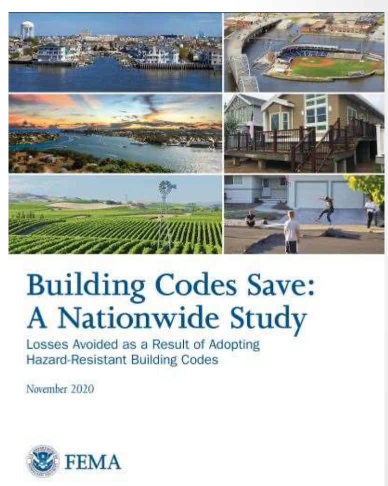
Introduction to SHMCAP Actions

FEMA definitions of hazard mitigation and climate adaptation actions

Requirements:
- Consistent with 2023 SHMCAP goals
- Ranks as a priority based on selected method for priority setting including required FEMA criteria of cost effectiveness, environmental soundness, and technical feasibility

Type:
- Plans and regulations
- Structure and infrastructure projects
- Natural systems protection projects
- Education and awareness programs



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Introduction to SHMCAP Actions

FEMA definitions of hazard mitigation and climate adaptation actions

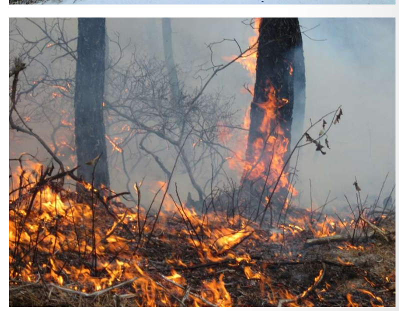
Content for 2023 SHMCAP Actions:

- Priority impact or vulnerability action addresses
- Hazard addressed
- Populations, assets (focus on critical assets, lifelines), locations action addresses
- Project title and description, timeline or estimated completion date
- Lead agency and partners, support entities
- Available resources and capacity to carry out action, including funding source
- Category of action
- Priority ranking

2023 SHMCAP Action Approach

Key information for action development

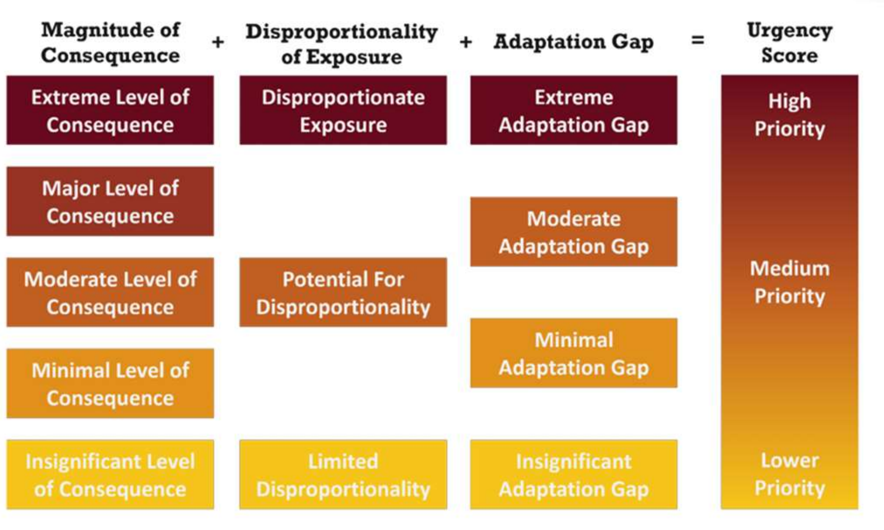
- **Use Priority Impacts identified in MA Climate Assessment to begin action development**
- **Develop actions that include:**
  - High consequence or priority impacts/vulnerabilities
  - Under-resourced populations
  - Critical assets and community lifelines
  - Preservation and enhancement of biodiversity and ecosystem health
  - Sustainability and climate mitigation
  - Climate change projections and adaptation
  - Effectiveness, feasibility, and environmental soundness
  - Specific assets, locations, and service populations



Photos: Ali Stevenson (top); Catherine J. Hibbard/USFWS (bottom)

Priority Impacts and Vulnerabilities

Definition of Priority Impacts from the Climate Assessment



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Priority Impacts and Vulnerabilities

Definition of Priority Impacts and High Consequence Vulnerabilities

Risk Assessment High Consequence Vulnerabilities

Magnitude of Consequence

- Five scale ranking from very high to very low
- Quantitative and qualitative measures
- Impacts to human life and health, economy, and natural environment
- Considers scale
- Considers critical assets and lifelines

Likelihood

- Five scale ranking from very high to very low
- Includes historic frequency
- Includes climate projections
- Considers scale and geography
- Considers critical assets and lifelines

Disproportionate Impacts

- No ranking included but identification of populations projected to be disproportionately impacted and why

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Human Sector

Priority Impacts and High Consequence Vulnerabilities

- Health and cognitive effects from extreme heat *(most urgent)*
- Health effects from degraded air quality *(most urgent)*
- Emergency service response delays and evacuation disruptions *(most urgent)*
- Reduction in food safety and security
- Increase in mental health stressors
- Health effects from aeroallergens and mold
- Health effects of extreme storms and power outages
- Damage to cultural resources
- Increase in vector borne diseases incidence and bacterial infections

- Loss of life or injury due to high vulnerability dams, hurricanes, wildfires, extreme flooding, or extreme temperatures *(RA High consequence vulnerability)*
- Disproportionate impacts on unhoused populations from extreme temperatures or extreme flooding *(RA High consequence vulnerability)*

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Infrastructure

Priority Impacts and High Consequence Vulnerabilities

- Damage to inland buildings *(most urgent)*
- Damage to electric transmission and utility distribution infrastructure *(most urgent)*
- Damage to rails and loss of rail/transit service *(most urgent)*
- Loss of urban tree cover
- Damage to coastal buildings and ports
- Reduction in clean water supply
- Damage to roads and loss of road service
- Loss of energy production and resources
- Increased risk of dam overtopping or failure

- Damage or loss of unreinforced masonry buildings due to earthquakes *(RA High Consequence Vulnerability)*
- Damage to infrastructure, utilities, and buildings in liquefaction zones due to earthquakes *(RA High Consequence Vulnerability)*
- Damage or loss to homes and critical facilities in the wildland urban interface *(RA High Consequence Vulnerability)*

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Natural Environment

Priority Impacts and High Consequence Vulnerabilities

- Freshwater ecosystem degradation *(most urgent)*
- Coastal wetland degradation *(most urgent)*
- Marine ecosystem degradation *(most urgent)*
- Forest health degradation *(most urgent)*
- Shifting distribution of native and invasive species
- Coastal erosion
- Soil erosion

- Loss of biodiversity, habitats, and native species due to climate change impacts *(RA High Consequence Vulnerability)*

Photos: Irena Draksic (top); Amanda McNeill (bottom)

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Governance

Priority Impacts and High Consequence Vulnerabilities

- Reduction in state and municipal revenues *(most urgent)*
- Increase in costs of responding to climate migration *(most urgent)*
- Increase in demand for state and municipal government services *(most urgent)*
- Damage to coastal state and municipal buildings and land
- Increase in need for state and municipal policy review and adaptation coordination
- Damage to inland state and municipal buildings and land

- Inability to carry out mission and services due to damage, disruption, or loss of state assets and services. *(RA High Consequence Vulnerability)*

Photo: Wikimedia Commons

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Economy

Priority Impacts and High Consequence Vulnerabilities

- Reduced ability to work *(most urgent)*
- Decrease in marine fisheries and aquaculture productivity *(most urgent)*
- Reduction in the availability of affordably priced housing *(most urgent)*
- Economic losses from commercial structure damage and business interruptions
- Damage to tourist attractions and recreation amenities
- Decrease in agricultural productivity

- Damage, disruption, or loss of coastal infrastructure such as seaports, airports, and maritime industries *(RA High Consequence Vulnerabilities)*

Photos: Flickr

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2023 SHMCAP Critical Assets

Categories of Critical Assets and Lifelines per Sector

Human Sector

- Demographics and census data
- Population projections
- Environmental justice data
- Social vulnerability index

Infrastructure

- Affordable housing units and residential units
- Hospitals, police, fire, colleges
- Government owned and operated buildings
- Road network, rail network
- Utilities
- Dams
- Ports

Natural Environment

- Biodiversity and native species
- Core habitat and critical natural landscape
- Parks and recreation areas

Governance

- Government owned and operated buildings (see infrastructure)
- Government services (see infrastructure)

Economy

- Building replacement values
- Job centers
- Agricultural lands

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2023 SHMCAP Lifelines

Lifelines Categories

Safety and Security
- Law Enforcement/ Security
- Fire Service
- Search and Rescue
- Government Service
- Community Safety

Health and Medical
- Medical Care
- Public Health
- Patient Movement
- Medical Supply Chain
- Fatality Management

Transportation
- Highway/Roadway/ Motor Vehicle
- Mass Transit
- Railway
- Aviation
- Maritime

Food, Water, Shelter
- Food
- Water
- Shelter
- Agriculture

Communications
- Infrastructure
- Responder Communications
- Alerts Warnings and Messages,
- Finance
- 911 and Dispatch

Hazardous Material
- Facilities
- HAZMAT
- Pollutants and contaminants

Energy
- Power Grid
- Fuel

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2023 SHMCAP Final Draft Goals

Revised 2023 SHMCAP Goals Based on RMAT Input

Collaboration, communication, and engagement: Strengthen collaboration and communication between state agencies, all levels of government including tribes, communities, and diverse partners to develop strategic, effective, and inclusive policies, programs, and projects. Ensure the accessibility of this plan to all populations across the state to provide for an engaged, educated, aware, involved, and safe population, including language accessibility and disadvantaged communities.

Science based and informed decision making: Develop programs to support, collect, and disseminate climate data and findings to inform mitigation and adaptation strategies and increase communication and engagement with all audiences.

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2023 SHMCAP Final Draft Goals

Revised 2023 SHMCAP Goals Based on RMAT Input

Resilient state assets and services: Identify and reduce risks to critical natural and built state assets and services —including infrastructure, housing, public safety, and natural and cultural resources—to preserve and enhance safety, cultural assets, and quality of life. Reduce risks to critical assets and lifelines from high consequence vulnerabilities such as high hazard dams, inland and coastal flooding, wildfire, and extreme temperature.

Implement adaptation actions for communities and ecosystems: Increase community resilience, environmental health, ecosystem functions, and biodiversity by implementing adaptation actions that reduce risk to the most vulnerable natural and human communities. Reduce risks to socially vulnerable or underserved communities from high consequence vulnerabilities such as high hazard dams, inland and coastal flooding, wildfire, and extreme temperature.

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2023 SHMCAP Final Draft Goals

Revised 2023 SHMCAP Goals Based on RMAT Input

Climate mitigation: Ensure that hazard mitigation and climate adaptation actions consider greenhouse gas reduction and carbon sequestration and storage measures that would reduce climate change and therefore its risks and impacts. Ensure that nature-based solutions are prioritized and used when feasible.

Equitable and resilient actions for infrastructure, ecosystems, and communities: Promote meaningful and collaborative participation in and benefit from the 2023 SHMCAP to ensure a plan that provides equitable community and environmental resilience for our natural and built environments, improves community safety and well-being, and addresses the past disproportionate provision of burdens and benefits. Ensure that nature-based solutions are prioritized and used when feasible to promote community and ecosystem health in recognition that healthy ecosystems are critical to the provision of community and environmental resilience.

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2023 SHMCAP Action Development

Timeline and Framework

Round 1:

1. Consider agency role and sort priority impacts and vulnerabilities to determine which your agency should lead, support, partner, or not participate in.
2. Provide status update on 2018 SHMCAP actions and evaluate need to refine or remove based on ability to address priority impacts/vulnerabilities.
   - Identify agency actions developed since 2020 and evaluate need to refine or remove based on ability to address priority impacts/vulnerabilities.
3. Develop new, high-level actions to respond to priority impacts/vulnerabilities.

Round 1 considerations:

- What is your agency role related to priority actions and vulnerabilities?
- Does your agency have new capabilities or capacities?
- Did the understanding of the hazard or impacts change since 2018?
- Are there new funding sources or partners?
- Can you bring your existing actions closer to implementation? Locations? Specific assets? Ability to focus on lifelines and disproportionate impacts?

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2023 SHMCAP Action Development

Timeline and Framework

Round 2:

1. Identify gaps between priority impacts/vulnerabilities and actions to reduce risk, with a focus on urgent priority impacts and other high consequence vulnerabilities.
2. Assess actions consistency with 2023 SHMCAP goals, including disproportionate impacts, adaptability to increasing risks due to climate change, and reduction of risks to critical assets, lifelines, and underserved communities. Use performance metrics to evaluate and refine.

Round 2 considerations:

1. How action will reduce risks to specific critical assets, populations, locations?
2. Be as specific as possible regarding funding, partners, capability and capacity present and lacking.
3. Which other agencies should be included when developing actions for an issue or geography? Can you coordinate actions for a bigger impact?
4. Do actions meet FEMA requirements?
5. How does the action rank against performance metrics?

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2023 SHMCAP Action Development

Timeline and Framework

Round 3:

1. Agencies meet with MEMA and EEA staff to refine actions, develop any additional actions needed, and discuss capabilities and capacities.
2. Draft actions to be presented to local jurisdictions, MPOs and others for input and opportunities to partner and leverage state and local action into a whole community approach.
3. Final draft actions to be shared with RMAT agencies for review and final concurrence.

Round 3 considerations:

1. Are there opportunities to leverage state and local actions or for state agencies to work together to address priority impact/vulnerability comprehensively?
2. Is my agency missing needed capability or capacity? How can it be filled?
3. What changes were made based on local jurisdictions, MPOs and other input?

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Action Development Discussion

Photo: Irena Draksic

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Discussion Overview

- **Review** example Climate Assessment Priority Impact *(health and cognitive effects from extreme heat)*

Discuss:

1. Considering your agency's roles and responsibilities, which **priority impacts and vulnerabilities should your agency lead, support, or be a partner to address?**
2. What **new actions** can your agency lead, support, or partner on to address the relevant priority impacts or vulnerabilities?
3. Do any of your **2018-2020 SHMCAP actions address the relevant priority impacts and vulnerabilities?** Do they need revisions? Are some no longer relevant?
4. What **capacities or capabilities does your agency need** to lead, support or partner to address the relevant priority impacts and vulnerabilities?

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Survey: Agency's Roles and Responsibilities

Considering your agency's roles and responsibilities, which **priority impacts and vulnerabilities should your agency lead, support, or be a partner to address?**

Agency Roles Survey:
https://www.surveymonkey.com/r/SHMCAP23Impact

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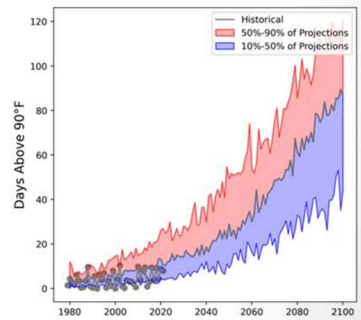
Health and Cognitive Effects from Extreme Heat: Magnitude of Consequence

- Extreme magnitude and likelihood
- Learning and cognition are negatively impacted by high ambient temperature and extreme heat, which may lead to decreases in cognitive function in schools and workplaces with climate change.
- Increase in premature death and heat-related illness due to increasing frequency and severity of days with extreme temperatures.
- Asthma and other chronic illness complications associated with extreme heat events.

"Using survey and other economic estimates of individual values for reduction of changes in the risk of fatality, the economic impact of **these additional premature deaths could be as large as $200 million in 2030, and well over $6 billion by the end of the century**." – Climate Change Assessment



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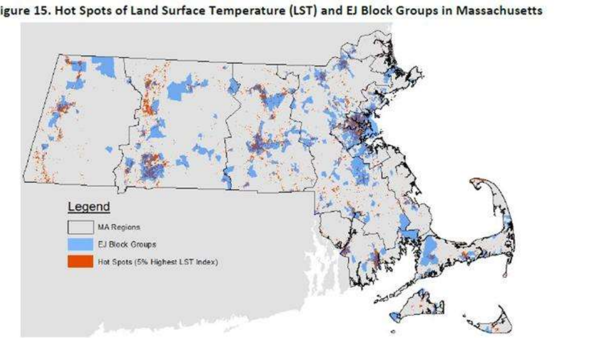
Health and Cognitive Effects from Extreme Heat: Disproportionality

- Disproportionate impact to lower income areas, linguistically-isolated individuals, and highly-urbanized areas
- Differences in access/ability to afford heating or cooling can impact exposure and magnify negative impacts.

Figure 15. Hot Spots of Land Surface Temperature (LST) and EJ Block Groups in Massachusetts



Human Sector: Urgent Impact #1

Health and Cognitive Effects from Extreme Heat

Impacts of extreme heat episodes on health, learning, and workplace injuries – covers all health aspects of changes in frequency and severity of days with extreme temperatures.

Extreme Level of Consequence	Disproportionate Exposure	Moderate Adaptation Gap
• Over 400 additional deaths anticipated by end of century.	• Linguistically isolated individuals are 28 percent more likely to experience premature mortality as a result of extreme heat.	• Increasing tree canopy cover is a favored solution to combat impacts of extreme heat, especially in urban areas.

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Health and Cognitive Effects from Extreme Heat: Adaptation Gap

- Moderate adaptation gap

Potential actions/approaches for reducing impacts from extreme heat:
- Urban tree planting
- Education programs
- Network of cooling centers
- Green, blue, and white roofs
- Increased vegetation/green infrastructure
- Planning, assessment, and exploration (less implementation)

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slido

Does your agency have a role in addressing health and cognitive effects from extreme heat?

ⓘ Start presenting to display the poll results on this slide.

50

slido

Is your agency already implementing actions to address this priority impact?

ⓘ Start presenting to display the poll results on this slide.

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slido

If yes, how is your agency already implementing actions to address this priority impact?

ⓘ Start presenting to display the poll results on this slide.

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What new actions could your agency develop to address this priority impact?

ⓘ Start presenting to display the poll results on this slide.

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slido

What new capacities (if any) does your agency need to address this priority impact (Health and Cognitive Effects from Extreme Heat)?

ⓘ Start presenting to display the poll results on this slide.

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RMAT Tasks: Action Development Survey & Worksheet

Survey due: 1/27/23, Worksheet due: 2/24/23

1. **Please review the Climate Assessment Priority Impacts and additional vulnerabilities and identify those that your agency should lead, support, or partner in this SurveyMonkey by 1/27.** *We will use your responses to populate the worksheet you will receive on 2/1.*
2. **Please review your agency actions on the '2023 SHMCAP Action Development Worksheet' that you will receive on 2/1 and provide updates by 2/24.** Each agency tab is split into 2 sections:

- **2018 Agency Actions**: This is populated with information from the SHMCAP Action Tracker, which reflects status updates for 2019 and 2020, as well as the addition of any new actions or deletions identified during those update periods.
  - Please add any agency actions that were started or completed since Fall of 2020 in this section.
- **Proposed Agency Actions for 2023 SHMCAP**: These are new proposed agency actions for the 2023 SHMCAP.

more detailed instructions will be provided with the worksheet on 2/1

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Wrap Up and Next Steps

Photo: Wikimedia Commons

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Wrap Up and Next Steps

- Capacity and Capabilities Analysis Chapter on **1/31 to RMAT**
- Risk Assessment Chapter on **1/31 to RMAT**
- Vulnerability Assessment Chapter on **1/31 to PMT**
- **RMAT** to complete SurveyMonkey on 2023 Priority Impacts and Vulnerabilities Roles by **1/27**
- **RMAT** to complete 2023 Action Development Worksheets by **2/24**
  - *Worksheets will be sent to the RMAT by 2/1. Office hours will be scheduled to answer any questions; calendar invite to be sent out.*
- SHMCAP team will develop draft performance metrics to evaluate and refine actions to be shared at next RMAT meeting
- Next RMAT meeting is **3/1** for Round 2 of hazard mitigation and climate adaptation actions

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Breakout Room Slides

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Slide from

Magnitude of consequence
Disproportionality
Adaptation gap

Ask:
- Does your agency have a role in this action? (poll y/n)
- Is your agency already implementing actions to address this impact? (poll y/n)
  - If yes, how?
- What new actions could your agency develop to address high heat? (open ended)
- - what additional capacity (if any) does your agency need to address this impact?

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Human

Discuss:
- Considering your agency's roles and responsibilities, **which priority impacts and vulnerabilities should your agency lead, support, or be a partner to address?**
- What **new actions** can your agency lead or support to address priority impacts and vulnerabilities in the human sector? Other sectors?
- **Do any of your existing 2018 - 2020 SHMCAP actions address these impacts and vulnerabilities?**
- **What capacities or capabilities does your agency need** to lead, support or partner to address the relevant priority impacts and vulnerabilities?

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Human Sector

Priority Impacts and High Consequence Vulnerabilities

- Health and cognitive effects from extreme heat *(most urgent)*
- Health effects from degraded air quality *(most urgent)*
- Emergency service response delays and evacuation disruptions *(most urgent)*
- Reduction in food safety and security
- Increase in mental health stressors
- Health effects from aeroallergens and mold
- Health effects of extreme storms and power outages
- Damage to cultural resources
- Increase in vector borne diseases incidence and bacterial infections

- Loss of life or injury due to high vulnerability dams, hurricanes, wildfires, extreme flooding, or extreme temperatures *(RA High consequence vulnerability)*
- Disproportionate impacts on unhoused populations from extreme temperatures or extreme flooding *(RA High consequence vulnerability)*

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Scenario 5: Human

- **Extreme magnitude**
- **Disproportionate impact**
- **Moderate adaptation gap**

Health and Cognitive Effects from Extreme Heat (MOST URGENT)

- Impacts of extreme heat episodes on health, learning, and workplace injuries – covers all health aspects of changes in frequency and severity of days with extreme temperatures.

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Economy

Discuss:

- Considering your agency's roles and responsibilities, **which priority impacts and vulnerabilities should your agency lead, support, or be a partner to address?**
- What **new actions** can your agency lead or support to address priority impacts and vulnerabilities in the economic sector? Other sectors?
- **Do any of your existing 2018 - 2020 SHMCAP actions address these impacts and vulnerabilities?**
- **What capacities or capabilities does your agency need** to lead, support or partner to address the relevant priority impacts and vulnerabilities?

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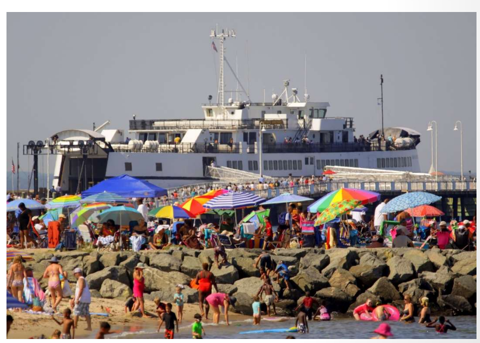
Economy

Priority Impacts and High Consequence Vulnerabilities

- Reduced ability to work *(most urgent)*
- Decrease in marine fisheries and aquaculture productivity *(most urgent)*
- Reduction in the availability of affordably priced housing *(most urgent)*
- Economic losses from commercial structure damage and business interruptions
- Damage to tourist attractions and recreation amenities
- Decrease in agricultural productivity
- Damage, disruption, or loss of coastal infrastructure such as seaports, airports, and maritime industries *(RA High Consequence Vulnerabilities)*



Photos: Flickr

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Scenario 1: Economic

- Extreme magnitude
- Disproportionate impact
- Moderate adaptation gap

Reduced Ability to Work (MOST URGENT)

- **More frequent extreme heat days** lead to:
  - Lost wages and decreased productivity
  - Increasing incidence of climate-induced health effects (e.g., asthma, allergies, vector borne disease, extreme heat)
  - Weather-induced disruptions to transportation and ability to work may also lead to lost wages and worker productivity
  - Impacts are felt most by workers in outdoor industries, those who rely on public transportation, and those who care for others at home

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Governance

Discuss:

- Considering your agency's roles and responsibilities, **which priority impacts and vulnerabilities should your agency lead, support, or be a partner to address?**
- What **new actions** can your agency lead or support to address priority impacts and vulnerabilities in the governance sector? Other sectors?
- **Do any of your existing 2018 - 2020 SHMCAP actions address these impacts and vulnerabilities?**
- **What capacities or capabilities does your agency need** to lead, support or partner to address the relevant priority impacts and vulnerabilities?

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Governance

Priority Impacts and High Consequence Vulnerabilities

- Reduction in state and municipal revenues *(most urgent)*
- Increase in costs of responding to climate migration *(most urgent)*
- Increase in demand for state and municipal government services *(most urgent)*
- Damage to coastal state and municipal buildings and land
- Increase in need for state and municipal policy review and adaptation coordination
- Damage to inland state and municipal buildings and land
- Inability to carry out mission and services due to damage, disruption, or loss of state assets and services. *(RA High Consequence Vulnerabilities)*

Photo: Wikimedia Commons

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Scenario 2: Governance

- **Extreme magnitude**
- **Disproportionate impact**
- **Moderate adaptation gap**

Increase in Costs of Responding to Climate Migration (MOST URGENT)

- Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures.
- Includes intra-state, inter-state, and international in- and out-migration, and generally is more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).

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Natural Environment

Discuss:

- Considering your agency's roles and responsibilities, **which priority impacts and vulnerabilities should your agency lead, support, or be a partner to address?**
- What **new actions** can your agency lead or support to address priority impacts and vulnerabilities in the natural environment sector? Other sectors?
- **Do any of your existing 2018 - 2020 SHMCAP actions address these impacts and vulnerabilities?**
- **What capacities or capabilities does your agency need** to lead, support or partner to address the relevant priority impacts and vulnerabilities?

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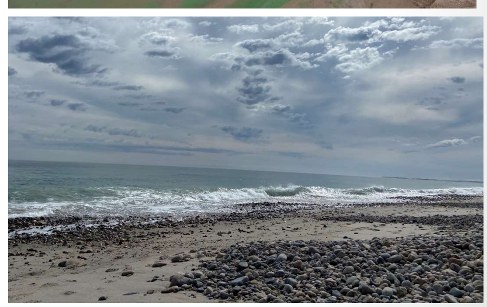
Natural Environment

Priority Impacts and High Consequence Vulnerabilities

- Freshwater ecosystem degradation *(most urgent)*
- Coastal wetland degradation *(most urgent)*
- Marine ecosystem degradation *(most urgent)*
- Forest health degradation *(most urgent)*
- Shifting distribution of native and invasive species
- Coastal erosion
- Soil erosion

- Loss of biodiversity, habitats, and native species due to climate change impacts *(RA High Consequence Vulnerability)*



Photos: Irena Draksic (top); Amanda McNeill (bottom)

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Scenario 3: Natural Environment

- Extreme magnitude
- Disproportionate impact
- Moderate adaptation gap

Marine Ecosystem Degradation (MOST URGENT)

- Changing sea surface temperatures,
- Ocean acidification, and
- Increased runoff nearshore that alters habitat conditions in marine environments (including submerged aquatic vegetation) leading to changing marine species distribution.

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Infrastructure

Discuss:

- Considering your agency's roles and responsibilities, **which priority impacts and vulnerabilities should your agency lead, support, or be a partner to address?**
- What **new actions** can your agency lead or support to address priority impacts and vulnerabilities in the infrastructure sector? Other sectors?
- **Do any of your existing 2018 - 2020 SHMCAP actions address these impacts and vulnerabilities?**
- **What capacities or capabilities does your agency need** to lead, support or partner to address the relevant priority impacts and vulnerabilities?

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Infrastructure

Priority Impacts and High Consequence Vulnerabilities

- Damage to inland buildings *(most urgent)*
- Damage to electric transmission and utility distribution infrastructure *(most urgent)*
- Damage to rails and loss of rail/transit service *(most urgent)*
- Loss of urban tree cover
- Damage to coastal buildings and ports
- Reduction in clean water supply
- Damage to roads and loss of road service
- Loss of energy production and resources
- Increased risk of dam overtopping or failure

- Damage or loss of unreinforced masonry buildings due to earthquakes *(RA High Consequence Vulnerability)*
- Damage to infrastructure, utilities, and buildings in liquefaction zones due to earthquakes *(RA High Consequence Vulnerability)*
- Damage or loss to homes and critical facilities in the wildland urban interface *(RA High Consequence Vulnerability)*

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Scenario 4: Infrastructure

- **Extreme magnitude**
- **Disproportionate impact**
- **Moderate adaptation gap**

Damage to Inland Buildings (MOST URGENT)

- Addresses the risk of flooding to inland structures from:
- Rainfall (pluvial flooding)
  - Particularly when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding)

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RMAT – Meeting 4 Summary Notes
January 24, 2022

Agenda:

- Welcome and introductions
- Risk Assessment Summary and Next Steps
- Framework and Process for Action Development
- Action Development Discussion
- Round 1 2023 SHMCAP Action Development and Next Steps
- Wrap up and Next Steps

Welcome and Introductions

- Requested participants to identify themselves and their affiliation
- Overview of updates since RMAT 3 meeting
- Reminder of RMAT Reviews and associated responsibilities

Risk Assessment Summary and Next Steps

- Sources of data and information for the risk assessment and a highlight of the State agency feedback that is in the process of being addressed/incorporated.
- PMT will be in touch with subject matter experts (SMEs) if additional information is needed after the Draft 1 review.
- PMT/ERG has added hazards to the risk assessment. We will provide four examples of hazards during the presentation and identify how they relate to the risk assessment.

Highlight of Hazards

- 15 hazards have been reviewed, 12 of which include new analysis

Hazard Snapshot

- The risk assessment will include hazard snapshots, which is a summary or comparison of all hazards at once. The snapshot provides a way to for the reader to consider all of the hazards. The hazards snapshots are new and were not part of the Climate Assessment.
- Concepts covered in the risk assessment: vulnerability, location, changing conditions.
    - Indicators used in the snapshot: Location, likelihood, magnitude of consequence (including warning time), and a qualitative ranking for disproportionality based on information from the Climate Change Assessment.
- Magnitude of consequence:
    - Defined by climate assessment
    - Rubric updated by literature reviews and expert advice
    - Rating
        - from very high to very low.
        - Very high example: loss of human life
        - Very low example: sunny day flooding

- Likelihood of exposure: captures ability to reliably predict and respond.
    - How likely are you to experience this hazard if you like in MA?
    - Physical speed at which hazard takes place and the reliability of technology to evaluate when it is taking place and when to respond. Examples: timing when hurricanes may hit a certain area.
- Hazard Snapshot Examples:
    - Hurricanes: Risk for human life, one week warning time, high consequence for the economy and medium impact for the environment.
        - Localized but can have repercussions throughout the state.
        - Likelihood: medium with a high risk.
        - Priority impacts: damage to inland and coastal buildings, emergency services, and damage to utility distribution infrastructure.
    - Inland Flooding
        - Warning time: over a week
        - Consequence by sector: Human (high), economy (medium), environment (high)
        - Areas with most risk: rivers and wetlands, areas near high-hazard dams, urban areas.
        - Priority impacts: emergency services, health effects, vector-borne diseases, reduction in clean water supply, economic losses.
    - Coastal Flooding
        - Warning time: within 24 hours (tidal) and over a week (SLR)
        - Consequence by sector: human (high), economy (medium), and environment (high)
        - Areas with most risk: coastal areas, areas throughout the state depending on flood intensity and duration
        - Priority impacts: coastal buildings, coastal erosion, wetland degradation, marine ecosystem degradation, damage to state and municipal buildings and land, damage to tourist attractions
    - Extreme Temperature
        - Warning time: almost a week
        - Consequence by sector: human (very high), economy (medium), environment (very high)
        - Areas with most risk: central and coastal regions, areas prone to heat-island effect
        - Priority impacts: health and cognitive effects from extreme heat; health effects from degraded air quality; increase in mental health stressors; loss of energy production and resources; forest health degradation and shifting distribution of native and invasive species; increase in costs of responding to climate migration; reduced ability to work; and decreases in marine fisheries and aquaculture productivity

Framework and Process for Action Development

- Using the risk assessment as a basis for action development through problem statements and hazard snapshots to compare hazards. Actions will be developed to address the various priority impacts and high consequence vulnerabilities.

Next Steps for the Risk Assessment

- January 31: Draft 1 Risk Assessment
- March 22: Draft 2 update to Risk Assessment

Introduction to SHMCAP Actions

- Actions must be:
    - Aligned with 2023 SHMCAP goals
    - Designed to address priority impacts and high consequence vulnerabilities
    - Consider technical feasibility, cost effectiveness, and environmental soundness.
- Examples of action types include plans/regulations, infrastructure projects, natural systems protection projects, educational awareness programs

The 2023 SHMCAP Actions should focus on:

- Under-resourced populations
- Critical assets and services, community lifelines
- Preservation and enhancement of biodiversity and ecosystem health
- Sustainability and climate mitigation
- Climate change projections and adaptation
- Effectiveness, feasibility, and environmental soundness
- Specific assets, locations, and service populations.

Reminder of Priority Impacts by Sector, including most urgent priority impacts at the top 2-3 in each slide, highlighted in yellow (refer to the slides).

- Human Sector
- Infrastructure Sector
- Natural Environment Sector
- Governance Sector
- Economy Sector
- Agency 1:1 calls in March and in April
- Focused on agency actions and will discuss global actions across state agencies

Reminder of Critical Assets and Lifelines to consider

- Human: demographics and census data; populations; EJ mapper; social vulnerability index
- Infrastructure: affordable housing, hospitals, schools, utilities, dams, ports, roads, utilities, etc.
- Natural Environment: native species, critical natural landscape, parks and recreation areas
- Governance: properties owned/operated by the government; government services
- Economy: job centers; agricultural lands; aquaculture; building replacement values

Internal Meeting Notes

Reminder of 2023 SHMCAP Lifelines (by category)

- Safety and security
- Food, Water, and Shelter
- Energy
- Health and Medical
- Communications
- Transportation
- Hazardous Materials

Recap of SHMCAP Final Goals and their alignment with the 2023 SHMCAP Actions

- Collaboration, communication, and engagement
- Science based and informed decision-making
- Resilient state assets and services
- Implement adaption actions for communities and ecosystems
- Climate mitigation
- Equitable and resilient actions for infrastructure, ecosystems, and communities

There will be three rounds for action development:

- Round 1. Consider agency role and identify which actions your agency should lead, support, partner, and participate in. Review 2018-2020 actions and revise as needed to better align with 2023 SHMCAP goals and addressing impacts/vulnerabilities. Develop new actions to address impacts and vulnerabilities.
- Round 2. Identify gaps between actions and priorities/vulnerabilities. Assess the consistency of the actions with the 2023 SHMCAP goals. Use performance metrics to evaluate and refine. Identify capacity, resources, and funding that will be used or are needed to support actions.
- Round 3. Agencies meet with MEMA and EEA staff to refine actions, develop additional actions, and discuss capabilities and capacities. Draft actions to be presented to local jurisdictions. Develop final draft actions to be shared with RMAT agencies for review and concurrence.

Round 1 2023 SHMCAP Action Development Discussion and Brief Survey

- Consider:
    - Given your agency's roles and responsibilities, which priority impacts and vulnerabilities should your agency lead, support, or be a partner to address?
    - What new actions can your agency lead, support, or partner on to address the relevant priority impacts or vulnerabilities?
    - Do any of your 2018-2020 SHMCAP actions address the relevant priority impacts and vulnerabilities? Do they need revisions? Are some no longer relevant?
    - What capacities or capabilities does your agency need to lead, support or partner to address the relevant priority impacts and vulnerabilities?

Next Steps

- Complete the survey by 1/27.

- The team will share the 2023 Action Development Worksheet for agencies to begin populating based on the 2018 SHMCAP action status and new proposed actions for the 2023 SHMCAP.
- The team will provide additional instructions for populating the worksheet and will hold an office hour session to answer questions from RMAT members.

Wrap Up and Next Steps

- surveys to be completed by end of day on Friday (1/27/23)
- PMT will send out meeting documents to RMAT
- Initial action worksheet updates are due by 2/24/23
- SHMCAP team will develop draft performance metrics
- Next RMAT meeting is scheduled for 3/1 to introduce Round 2 of action development.

2023 MA SHMCAP
RMAT Meeting 5

2023 SHMCAP Working Group Meeting #5
Risk Assessment – Round 2 Action Development
Tuesday, March 14, 2023
2:00—4:00 pm EST

Meeting Objectives:

1) Support agency action development.
2) Share identified gaps between priority impacts/vulnerabilities and actions to reduce risk, with a focus on urgent priority impacts and other high consequence vulnerabilities.
3) Collaborate on global action development, which will help provide guidance on how to align agency actions with 2023 SHMCAP goals, including disproportionate impacts, adaptability to increasing risks due to climate change, and reduction of risks to critical assets, lifelines, and underserved communities.

Time ET	Agenda Item

2:00 – 2:05 pm	**Welcome and Updates**
	• Recap of work since 1/24 meeting
	  ○ Draft Capacity and Capabilities for RMAT review (1/31 – 2/14)
	  ○ Round 1 action development worksheet (1/31 – 2/22)
	  ○ Draft Risk Assessment Chapter: RMAT reviewing Draft 1 by 3/3/23
	• Upcoming deliverables for review:
	  ○ Draft Vulnerability Assessment Chapter: share with RMAT on 3/14

2:05 – 2:20 pm	**2023 Action Development Worksheet Synthesis**
	• 2018 Actions
	  ○ Status of actions (percentage as of 12/31/22)
	  ○ Question: *For 2018 actions not started, not completed, or deferred, what was the barrier?* (can identify multiple causes)
	• 2023 Actions
	  ○ Impacts/vulnerabilities breakdown and identification of gaps
	  ○ High-level overview of action categories *(analyzed by ERG 3/7/2023)*
	  ○ Scale and Regions breakdown and identification of gaps
	  ○ Goals breakdown and how well actions meet the goals

2:20 – 2:25 pm	**Recap Qualitative Findings on perceived gaps** • Based on the Capabilities & Capacity Analysis, Risk Assessment, and Vulnerability Assessment • Common themes and trends of agency actions received as of 3/7/2023 • Examples of robust actions and those needing revisions (for consideration during Round 2 of action development)
2:25 – 2:40 pm	**Overview of Next Steps: Action Development** • Round 2 action development (and due dates) • Series 2 meeting (March 2023) • EEA/MEMA and state agency meetings • Round 3 overview/action development (and due dates) • Q&A

<table>
<tr><th>Time ET</th><th>Agenda Item</th></tr>
<tr><td>2:40 – 3:50 pm</td><td>Global Action Development

Introduce concept and definition of MA global action

Current definition: Cross-cutting or global actions are intended to reduce risk across state government and the Commonwealth
Review examples of 2018 global actions (from action tracker)
Question: What were challenges related to design, implementation, and/or tracking progress of the 2018 global actions?

Review of four draft 2023 example global actions based on:

Capabilities & Capacity, Risk Assessment, and Vulnerability Assessment Findings analysis findings
2023 Action Development Worksheet input (as of 3/7/23)

Interactive component: review the following questions for the four draft 2023 example global actions:

Question 1: How can these global actions make it easier for your agency to advance climate resilience and hazard mitigation?
Question 2: What modifications would you make to these global actions to make them more relevant to your agency's priorities and concerns?
Question 3: How can these global actions help reduce risks for socially vulnerable communities?
Question 4: Who should be part of the partnership to implement these global actions?
Question 5: How would Massachusetts work with local jurisdictions and interested parties to implement these global actions?
Question 6: What additional types/topics of global actions should be considered in the 2023 SHMCAP?

</td></tr>
<tr><td>3:50 – 4:00 pm</td><td>Wrap Up and Next Steps

Round 2 Action Development steps and deadlines
Draft 2 of VA ready for review on 3/14
1:1 meeting with MEMA and EEA throughout March
Series 2 meetings in April
Round 3 Action Development steps and deadlines
Review of remaining materials in late April
</td></tr>
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2023 SHMCAP Update

RMAT Working Group Meeting #5
Round 2 Action Development

March 14, 2023

Executive Office of Energy and Environmental Affairs

ERG IEc WOODS HOLE GROUP CBI

Photo: Marblehead Harbor, Wikimedia Commons

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Welcome and Introductions

Please put your affiliation in the webinar participant list or chat

Photo: Kevin Gill/Flickr

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Agenda

Welcome and Recap since Last RMAT Meeting
2023 Action Development Worksheet Synthesis
Recap Qualitative Findings (based on current assessments and analysis)
Next Steps and Timeline related to Action Development
Global Action Development
Wrap Up and Next Steps

Meeting Objectives:

- Support agency action refinement.
  - Share identified gaps between priority impacts/vulnerabilities and actions to reduce risk, with a focus on urgent priority impacts and other high consequence vulnerabilities.
- Collaborate on global action development to determine "whole of government" priorities that can help advance all agency efforts.

3

3

Recap Since 1/24/23 Meeting

- ✓ **Draft Capacity and Capabilities Analysis Chapter**: RMAT reviewed Draft 1 (1/31-23 – 2/14/23)
- ✓ **Round 1 Action Development Worksheet**: RMAT reviewed (1/31-23 –2/22/23)
- ✓ **Draft Risk Assessment Chapter**: RMAT reviewing Draft 1 by 3/3/23

- Draft Vulnerability Assessment Chapter – **Draft 1 reviewed by PMT; undergoing revisions; will revise and share with RMAT by 3/16**
- Continue building and revising 2023 SHMCAP goals
- Continued to develop approach for stakeholder meetings

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2023 Action Development Worksheet Synthesis

Photo: Irena Draksic

2018 Actions[1]

Status of Actions (as of 12/31/22)

Action Status	Total % out of 107 Actions
Complete: Initiative is implemented and may be ongoing	22%
In Progress: Initiative is currently being implemented	55%
In Development: Initiative is being prepared for implementation	8%
Modified or Deferred: Initiative with project scope that has been slightly changed or has been postponed	4%
Not Started: Initiative has not started	7%
Should be Deferred or Deleted: Initiative should be deferred or deleted	3%
Should be Modified: Initiative should be slightly changed	1%

[1]The 2018 Action list was populated with information from the SHMCAP Action Tracker, which reflects status updates for 2019 and 2020, as well as updated/revised actions added to the worksheet. The total % are based on worksheet responses as of 3/8/23.

2023 Proposed Actions

Climate Assessment Priority Impacts and Additional Vulnerabilities

Impacts/Vulnerabilities with Proposed Actions from Multiple Agencies

- **Reduction in the Availability of Affordably Priced Housing***
  - Housing and Economic Development (HED), Energy and Environmental Affairs (EEA)
- **Reduction in Clean Water Supply**
  - EEA (Department of Environmental Protection [DEP], Department of Conservation and Recreation [DCR], Department of Agricultural Resources [DAR])
- **Coastal Wetland Degradation***
  - EEA (Coastal Zone Management, DCR, DEP, MassWildlife)
- **Increase in Need for State and Municipal Policy Review and Adaptation Coordination**
  - Administration and Finance, EEA (DAR, DCR)

*Information based on worksheet responses as of 3/8/23. * denotes **urgent** priority impact from the Climate Assessment.* 7

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2023 Proposed Actions (cont.)

Climate Assessment Priority Impacts and Additional Vulnerabilities

Impacts/Vulnerabilities with 7+ Actions

- **Loss of biodiversity, habitats, and native species due to climate change impacts^** (19)
- **Freshwater ecosystem degradation*** (17)
- **Reduction in clean water supply** (14)
- **Coastal wetland degradation*** (12)
- **Shifting distribution of native and invasive species** (12)
- **Damage to roads and loss of road service** (10)
- **Damage to cultural resources** (8)

*Information based on worksheet responses as of 3/8/23. * denotes **urgent** priority impact from the Climate Assessment; ^denotes **high consequence** vulnerability from Risk Assessment* 8

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2023 Actions – Gaps (cont.)

Climate Assessment Priority Impacts and Additional Vulnerabilities

Impacts/Vulnerabilities with 0 or 1 Proposed Action from the Agencies

- **Decrease in marine fisheries** and aquaculture productivity* (1)
  - **HED**, DMF
- **Damage or loss to homes and critical facilities** in the wildland urban interface^ (1)
  - **DHCD/DPH**
- **Damage or loss of unreinforced masonry** buildings due to earthquakes^ (1)
  - **DCAMM**, EOE EO
- **Damage, disruption, or loss of coastal infrastructure** such as seaports, airports, and maritime industries^ (1)
  - **HED**, CZM
- **Health effects** of extreme storms and power outages (1)
  - **DPH**
- **Loss of energy production** and resources (0)
  - DOER

*Information based on worksheet responses as of 3/8/23. * denotes **urgent** priority impact from the Climate Assessment; ^denotes **high consequence** vulnerability from Risk Assessment; **bolded** agency name has an action developed*

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2023 Actions – Action Categories

Action Types

- Administrative support — 1%
- Assessment, research, analysis, science, and mapping — 33%
- Capital planning — 5%
- Changes to maintenance and operations, replacements — 0%
- Funding and financing — 6%
- Natural systems protections & enhancements (e.g., conservation, restoration, and management) — 12%
- Outreach and education — 6%
- Planning and policy — 17%
- Regulations, codes, and zoning — 6%
- Structure and infrastructure retrofits/new projects — 4%
- Technical support and assistance — 9%

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2023 Actions (cont.)

Scale and Region

Scale	Total % out of 115 Actions
Statewide	67%
Regional	23%
Coastwide	10%

Region*	Total % out of 57 Actions
Coastwide	5%
Berkshires and Hilltowns Region	9%
Greater Connecticut River Valley Region	9%
Central Region	9%
Eastern Inland Region	4%
Boston Harbor Region	25%
North and South Shores Region	47%
Cape, Islands, and South Coast Region	25%

**Regions based on the 2022 MA Climate Change Assessment; respondents could select up to 2 regions that apply.*

Information based on worksheet responses as of 3/8/23.

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2023 Actions (cont.)

Goals

2023 SHMCAP Goals	Total % out of 120 Actions
#1: Collaboration, Communication, Funding, and Engagement	53%
#2: Science-based and Informed Decision-Making	73%
#3: Resilient State Assets and Services	73%
#4: Implement Adaptation Actions for Communities and Ecosystems	64%
#5: Climate Mitigation Consideration	19%
#6: Resilient and Equitable Infrastructure, Ecosystems, and Communities	67%

Information based on worksheet responses as of 3/8/23; respondents could select all goals that apply.

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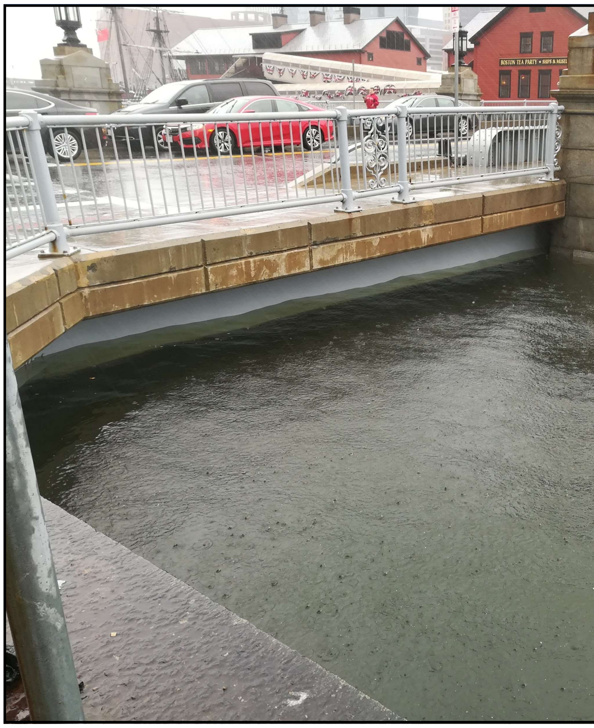

Recap Qualitative Findings on Perceived Gaps (based on current assessments and analysis)

Photo: Kate Adams

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Recap: Qualitative Findings on Perceived Gaps

Based on Capabilities & Capacity Analysis, Risk Assessment, and Vulnerability Assessment

- **Direct actions to strengthen the resilience of physical assets:** Many agencies are concerned about damage and disruption to physical assets. Upgrades are costly, and agencies have limited capital and operating budgets to address needed actions.

- **Technical and financial capacity for nature-based solutions:** Nature-based solutions may be the best approach to strengthen resilience; however, they require skills and knowledge that are lacking, and these approaches are perceived to be costly to implement.

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Recap: Qualitative Findings on Perceived Gaps *cont.*

Based on Capabilities & Capacity Analysis, Risk Assessment, and Vulnerability Assessment

- **Enhanced capacity, availability, and redundancies of staff:** Agencies have begun to train staff and create redundancies in staffing; however, many agencies still lack adequate staff to address hazard mitigation and climate adaptation.

- **Data and information related to climate projections and losses avoided:** There is a need for more data on climate impacts, adaptation, risk, and damage prevented or benefits provided. Agencies indicated they are lacking data in relation to project vulnerabilities and recovery times.

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Recap: Qualitative Findings on Perceived Gaps *cont.*

Based on Capabilities & Capacity Analysis, Risk Assessment, and Vulnerability Assessment

- **Ability to address socially vulnerable communities:** A recurring survey theme was the potential for disproportionate impacts to socially vulnerable communities. It will be necessary to provide opportunities for community participation to ensure actions reflect their needs and vulnerabilities.

- **Management of natural resources:** Given the amount of natural areas within the Commonwealth, there are relatively small number of agencies that are responsible for managing a large amount of land. Mitigation actions will need to consider how to best promote coordination among these agencies.

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2023 Actions: Common Themes and Trends

Majority of proposed 2023 actions are statewide actions and focus on:

- Assessment, research, analysis, science, and mapping
- Planning and policy
- Natural systems protections & enhancements

Gaps in addressing urgent impacts and high consequence vulnerabilities:

- Decrease in marine fisheries and aquaculture productivity
- Damage or loss to homes and critical facilities in the wildland urban interface
- Damage or loss of unreinforced masonry buildings due to earthquakes
- Damage, disruption, or loss of coastal infrastructure such as seaports, airports, and maritime industries

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Example of Actions

High-quality action:

- *Develop a multi-jurisdictional/multi-disciplinary working group that will be convened and led by a facilitator hired by the Commonwealth utilizing NEHRP Direct State Assistance funding. Working group members will represent a wide variety of disciplines, levels of government, and sectors. The primary goals of this diverse group will be to establish a robust earthquake mitigation program for the Commonwealth that will develop and implement strategies to increase earthquake awareness, preparedness and education, and mitigate earthquake-related risks.*

Action in need of revisions:

- *Consider climate change impacts throughout the agency.*

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Overview of Next Steps: Action Development

Photo: Amanda McNeill

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2023 SHMCAP Action Development

Timeline and Framework

Round 2:

1. **ERG and PMT are reviewing round 1 actions and identifying gaps** between priority impacts/vulnerabilities and actions.
   - Assessing actions consistency with 2023 SHMCAP goals.
2. RMAT will receive revised 2023 SHMCAP Action Development worksheet (round 2), with specific comments by action on **3/16.**
   - Revised actions due on **3/31**
   - **PMT will hold agency one-on-one meetings as needed between 3/16-31.**
3. Draft actions may **be presented at Stakeholder Meetings** for input and opportunities to partner and leverage actions.

Round 2 considerations:

1. How will the action reduce risks to specific critical assets and populations?
2. Be specific regarding funding, partners, capability and capacity present and lacking.
   - *Which other agencies should be included when developing actions for an issue or geography? Can you coordinate actions for a bigger impact?*
3. Do actions meet FEMA requirements? (ERG, MEMA, and EEA will assist with this question).

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2023 SHMCAP Stakeholder Meetings (April 2023)

Local and regional input on draft 2023 SHMCAP actions

- **April 4 and 6**
  - Participants will be local municipalities, regional agencies, MPOs, and others.
  - Two 2-hour meetings
    - 1st hour: background/introduction information
      - Climate change assessment findings
      - Risk assessment findings
      - Roles and responsibilities
    - 2nd hour: gathering feedback on actions
      - Feedback on selected draft agency and global actions that respond to top priority impacts
      - Obtain feedback through Mentimeter and jamboards on:
        - ✓ Experience with priority impacts
        - ✓ Actions taken to address priority impact
        - ✓ Response to proposed actions (help to identify gaps, refine)
        - ✓ How can the state better support you with actions to address these priority impacts?

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EEA/MEMA and State Agency Meetings

- **Check-in meetings with agencies (March 16 – March 31)**
  - **Review proposed actions and walk through Round 2 considerations to ensure that the level of detail is appropriate, including:**
    - Does the agency have the authority, skills, and staff availability to complete the action? If not, what is needed?
    - Will the action address a disproportionate impact? If not, can it be designed to do so?
    - How will the action, once completed, measurably reduce risk in the Commonwealth?
- **Based on agency roles, identify gaps relevant to agency responsibilities and discuss role in developing actions to address impacts and vulnerabilities:**
  - Urgent impacts and vulnerabilities without actions will be discussed with the relevant agencies to determine options for new actions designed to address them.
- **Next Steps**
  - Agencies will submit revised actions by **3/31**

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2023 SHMCAP Action Development

Timeline and Framework

Round 3:

1. **Agencies refine actions, develop any additional actions,** as needed.
   - **Consider input and comments received** from the stakeholder meetings (to be provided during the week of 4/10) and revise, as needed**.**
2. **Prioritize** actions within your agency based on prioritization framework delivered to RMAT on **3/31**.
3. **Complete revisions and obtain agency sign off on final list of agency actions by 4/28.**

Round 3 considerations:

1. Are there opportunities to leverage state and local actions or for state agencies to work together to address priority impact/vulnerability comprehensively?
2. Is my agency missing needed capability or capacity? How can it be filled?
3. Which of my agency's actions are the highest priority?
4. What changes were made based on local jurisdictions, MPOs and other input?

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Questions and Discussion

Photo: Lance Cheung

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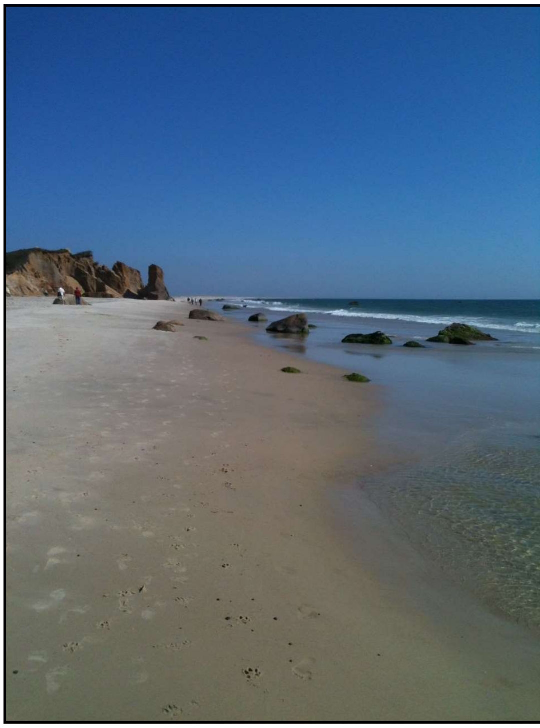

Global Action Development

Photo: Irena Draksic

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Concept and Definition

Global Actions

Concept: Global actions, which are also known as statewide or cross-cutting actions are actions that include the following attributes:

- Multi-agency and/or multi-sector
- Addresses risk at a multi-region, coastwide, and/or statewide scale
- Often unlock other actions and provide capacity or capability for others to take further actions
- Can leverage or be leveraged to enhance local, region, or federal actions and programs
- Can be organized around a specific issue, geographic hotspot, specific assets, or disproportionately affected communities or populations

Action Tracker Definition: Cross-cutting or global actions are intended to reduce risk across state government and the Commonwealth.

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Example 2018 Global Actions (from Action Tracker)

From a total of 17 global actions

- **MEMA:** Update the State Hazard Mitigation and Climate Adaptation Plan and submit for FEMA review and approval every 5 years.
- **A&F:** Incorporate climate change vulnerability, resiliency, and adaptation standards into budgeting, coordination, and capital planning.
- **DCAMM:** Incorporate hazard and climate change vulnerability into capital management functions.
- **OPSI:** Review the state building code to assess feasibility of incorporating hazard mitigation and resilience.

2018 Global Actions[1]

Status of Global Actions (as of 12/31/22)

Action Status	Total % out of 17 Global Actions
Complete: Initiative is implemented and may be ongoing	30%
In Progress: Initiative is currently being implemented	57%
In Development: Initiative is being prepared for implementation	13%
Modified or Deferred: Initiative with project scope that has been slightly changed or has been postponed	0%
Not Started: Initiative has not started	0%
Should be Deferred or Deleted: Initiative should be deferred or deleted	0%
Should be Modified: Initiative can be slightly changed to address impact(s)	0%

[1]The 2018 Action list was populated with information from the SHMCAP Action Tracker, which reflects status updates for 2019 and 2020, as well as updated/revised or new actions added to the worksheet. Information based on worksheet responses as of 3/8/23.

Draft Example Global Actions

- **Global Action Example 1:** Build out climate resilience metrics that the Commonwealth can track statewide and through local grant programs to monitor success on climate resilience goals.
- **Global Action Example 2:** Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on statewide climate data and models and supports consistent application across agencies.

Draft Example Global Actions *cont.*

- **Global Action Example 3:** Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts.
- **Global Action Example 4:** Conduct a statewide loss avoidance study to help quantify the losses avoided (e.g., damage prevented or benefits) due to the implementation of the Commonwealth's hazard mitigation and climate adaptation projects and run scenarios of the different risks and vulnerabilities associated with varying implementation strategies.

JAMBOARD ACTIVITY

Link to Jamboard:

https://jamboard.google.com/d/1MhGQif29dtKP4XwHq8ue5aznVu_WMKXnUgwK4e9JX5M/viewer?f=4

Questions:

1. *How can these global actions make it easier for your agency to advance climate resilience and hazard mitigation?*
2. *What modifications would you make to these global actions to make them more relevant to your agency's priorities and concerns?*
3. *How can these global actions help reduce risks for socially vulnerable communities?*
4. *Who should be part of the partnership to implement these global actions?*
5. *How would Massachusetts work with local jurisdictions and interested parties to implement these global actions?*
6. *What additional types/topics of global actions should be considered in the 2023 SHMCAP?*

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Wrap Up and Next Steps

Photo: Wikimedia Commons

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Wrap Up and Next Steps

- Draft Vulnerability Assessment ready for review **by 3/14**
  - Edits on Draft Vulnerability Assessment due by **4/6**
- Round 2 Action Development Steps (Global Actions)
  - Will provide revised 2023 Action Development Worksheet by **3/16**
  - Deadlines for actions items (Round 2) by **3/31**
- One-on-one meeting with MEMA and EEA throughout March
- Round 3 Action Development Steps
  - Will provide prioritization framework on **3/31**
  - **Sign off on agency actions by 4/28**
- 2023 Stakeholder meetings planned for April 4 and 6
- **RMAT Meeting #6 on April 25th**

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How can these global actions make it easier for your agency to advance climate resilience and hazard mitigation?

Global Action Example 1: Build out climate resilience metrics that the Commonwealth can track statewide and through local grant programs to monitor success on climate resilience goals.

- ome up with statewide adaptation metrics to help guide some action with concrete deadlines and quantities (stormwater comes to mind, for instance)
- Would Action 1 be led by Action 2 Office? For Action 1, my mind goes immediately to colleges and universities, as a lot of them are considering this already, and students/ classes are h
- **Grant programs, specific projects**
- Discussion of state of the bay. What metrics are used? Focus on the outcomes: targets/goals for habitat extent and condition. Metrics should point toward the outcome.
- Score card completed by locality when looking at grant funding to identify priorities and track who is applying for grants.
- What are other ways we can track progress towards resilience goals?
- First, we need a good, updated, searchable list of state grant programs!

Global Action Example 2: Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on statewide climate data and models and supports consistent application across agencies.

- common data source: SLR for BCA to receive funding
- Data for environmental justice, equity, and vulnerable populations

Global Action Example 3: Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts.

- For Global Action 3: to preserve undeveloped floodplain, does Fisheries and Wildlife support purchase of flood easements, and would they fund them?
- Project prioritization: dam restoration to removal, would align with floodplain management framework. Aligning.
- Begin with framework and over time plan to develop a plan with including all aspects of the floodplain (DCR)
- Need a framework to identify who is doing what in the floodplain and a method for collaborating and policy development.
- Challenges to encourage resilience through grant programs, not sure what other agencies are reviewing for resilience efforts for projects built in the floodplain.

Global Action Example 4: Conduct a statewide loss avoidance study to help quantify the losses avoided (e.g., damage prevented or benefits) due to the implementation of the Commonwealth's hazard mitigation and climate adaptation projects and run scenarios of the different risks and vulnerabilities associated with varying implementation strategies.

- his would be a wonderful addition for our agency who struggles to attach benefits to natural systems. Avoidance loss would be a great foil to quantifying ecosystem services.
- Determine strategy for property acquisition/elevation fitting within statewide goals.

What modifications would you make to these global actions to make them more relevant to your agency's priorities and concerns?

Global Action Example 1: Build out climate resilience metrics that the Commonwealth can track statewide and through local grant programs to monitor success on climate resilience goals.

Global Action Example 2: Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on statewide climate data and models and supports consistent application across agencies.

Global Action Example 3: Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts.

Global Action Example 4: Conduct a statewide loss avoidance study to help quantify the losses avoided (e.g., damage prevented or benefits) due to the implementation of the Commonwealth's hazard mitigation and climate adaptation projects and run scenarios of the different risks and vulnerabilities associated with varying implementation strategies.

☐ How can these global actions help reduce risks for socially vulnerable communities?

Global Action Example 1: Build out climate resilience metrics that the Commonwealth can track statewide and through local grant programs to monitor success on climate resilience goals.

Entry requirement: all global actions should address socially vulnerable communities.

Global Action Example 2: Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on statewide climate data and models and supports consistent application across agencies.

Our new EJ Secretary may be good to consult

Global Action Example 3: Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts.

Better floodplain management will more clearly identify where the flood-vulnerable communities are so that we can address the best mitigation measures for flood los

Global Action Example 4: Conduct a statewide loss avoidance study to help quantify the losses avoided (e.g., damage prevented or benefits) due to the implementation of the Commonwealth's hazard mitigation and climate adaptation projects and run scenarios of the different risks and vulnerabilities associated with varying implementation strategies.

Develop guidance for assessment (e.g. how Environmental justice is being addressed in MEPA permitting), data resources, and community engagement policies

identify areas where electricity loss is high, popns with electricity-dependent equipment or meds, and ways to deploy/distribute solar-powered energy storage units

☐ Who should be part of the partnership to implement these global actions?

Global Action Example 1: Build out climate resilience metrics that the Commonwealth can track statewide and through local grant programs to monitor success on climate resilience goals.

Global Action Example 2: Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on statewide climate data and models and supports consistent application across agencies.

Global Action Example 3: Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts.

Global Action Example 4: Conduct a statewide loss avoidance study to help quantify the losses avoided (e.g., damage prevented or benefits) due to the implementation of the Commonwealth's hazard mitigation and climate adaptation projects and run scenarios of the different risks and vulnerabilities associated with varying implementation strategies.

How would Massachusetts work with local jurisdictions and interested parties to implement these global actions?

Global Action Example 1: Build out climate resilience metrics that the Commonwealth can track statewide and through local grant programs to monitor success on climate resilience goals.

Global Action Example 2: Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on statewide climate data and models and supports consistent application across agencies.

Global Action Example 3: Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts.

Global Action Example 4: Conduct a statewide loss avoidance study to help quantify the losses avoided (e.g., damage prevented or benefits) due to the implementation of the Commonwealth's hazard mitigation and climate adaptation projects and run scenarios of the different risks and vulnerabilities associated with varying implementation strategies.

What additional types/topics of global actions should be considered in the 2023 SHMCAP?

Implementing Resilient Lands Initiative

Identifying new and long term revenue streams for resilience implementation

Affordable housing also slots in under an equity/EJ concept

Identifying and implementing framework to track progress to building resilience across agencies and municipalities

Combine public/private initiatives for intersecting projects that are constrained by private property ownership

Putting the state's efforts in a regional context that will cross state boundaries.

Promote more watershed-based efforts?

Developing a coastal resilience strategy

Looking at heat from a broader lens, at the interagency level. Heat flagging system to help others understand the risk from heat

Considering role of the building code and proposing amendments that enhance resilience

30% land & ocean protection by 2030 (aligned with the global 30x30 goal)

Updated school curriculum - to assist the next generation in understanding and developing skills needed to enter the workforce doing climate work

Bigger emphasis on shoreline migration and other areas migrating inland for people and habitats

Global action to integrate climate adaptation AND climate mitigation efforts

We need to figure out the role of the private sector and our ability to support work on private land

shift from generators, which produce air pollutants & CO poisoning risk to investment in mobile solar energy storage systems that can be used during emergencies

RMAT Meeting 5 – Summary Notes

March 14, 2023

Agenda

- Welcome and recap since last RMAT Meeting
- 2023 Action development Worksheet Synthesis
- Recap Qualitative Findings
- Next Steps and Timeline related to Action Development
- Global ("cross-government") Action Development
- Wrap Up and Next Steps

Meeting Objectives

- Supporting agency action refinement
    - Sharing gaps between priority impacts/vulnerabilities and current actions. Working with agencies to modify existing actions (or develop new ones) to address these gaps.
- Exercise to begin developing global ("cross-government") actions to determine "whole of government" priorities to help advance all agency efforts and reduce risk across the Commonwealth.

Recap Since 2/24/23 Meeting (RMAT Meeting 5)

- Draft 1 review of the Capacity and Capabilities chapter is complete.
- Received Round 1 of action development through the 2023 SHMCAP Action Development Worksheet.
- PMT reviewed draft Vulnerability Assessment chapter, will be sharing with RMAT by 3/16.
- Continue building and revising 2023 SHMCAP goals.
- Continue developing approach for Series 2 meetings with municipalities, regional planning agencies, and NGOs in addition to community focus groups.

2023 Action Development Worksheet Synthesis

- Review of 2018 action status (as of 12/31/22)
    - Complete: 22%
    - In progress: 55%
    - In Development: 8%
    - Modified or Deferred: 4%
    - Not started: 7%
    - Should be Deferred or Deleted: 3%
    - Should be Modified: 1%
- 2023 Proposed Actions
    - Impacts/vulnerabilities with proposed actions from multiple agencies:
        - Reduction in the availability of affordably priced housing
        - Reduction in clean water supply
        - Coastal wetland degradation

        - Increase in need for state and municipal policy review and adaptation coordination
    - Impacts/Vulnerabilities with over 7 actions (a lot of actions addressing impacts)
        - Loss of biodiversity, habitats, and native species due to climate change impacts
        - Freshwater ecosystem degradation
        - Reduction in clean water supply
        - Coastal wetland degradation
        - Shifting distribution of native and invasive species
        - Damage to roads and loss of road service
        - Damage to cultural resources
        - Note that Round 2 of the updated 2023 SHMCAP Action Worksheet includes columns with feedback and comments on the actions that have been developing, including considerations for including additional detail, refining, and considering partners for collaboration.
    - Gaps (priority impacts with 0 or 1 proposed actions from agencies)
        - Decrease in marine fisheries and aquaculture productivity
        - Damage or loss to homes and critical facilities in the wildland urban interface
        - Damage or loss of unreinforced masonry buildings due to earthquakes
        - Damage, disruption, or loss of coastal infrastructure such as seaports, airports, and maritime industries
        - Health effects of extreme storms ad power outages
        - Loss of energy production and resources
        - RMAT should consider these gaps when revising actions during Round 2 of Action development.
    - Action Types: Based on action categories identified in the 2023 SHMCAP Action Worksheet
        - Administrative support: 1%
        - Assessment, research, analysis, science, and mapping: 33%
        - Capital planning: 5%
        - Changes to maintenance and operations, replacements: 0%
        - Funding and financing: 6%
        - Natural systems protection and enhancements: 12%
        - Outreach and education: 6%
        - Planning and policy: 17%
        - Regulations, codes, and zoning: 6%
        - Structure and infrastructure retrofits/new projects: 4%
        - Technical support and assistance: 9%
    - Scale and Region
        - Statewide (67%)
        - Regional (23%)
        - Coastwide (10%)
    - Goals (120 actions) – 6 main goals
        - Most actions aligned with science-based and Informed decision-making in addition to resilient state assets and services

Recap Qualitative Findings on Perceived Gaps (based on current assessments and analysis)

- Direct actions to strengthen the resilience of physical assets.
- Technical and financial capacity for nature-based solutions. What are the opportunities and actions to be taken to address challenges with nature-based solutions?
- Enhance capacity, availability, and redundancies of staff. There are opportunities to develop actions to support continued capacity building across all staff and increase the number of staff who do this work daily.
- Data and information related to climate projections and losses avoided. Agencies have identified they are lacking data regarding project vulnerabilities and recovery times.
- Ability to address socially vulnerable communities. Provide opportunities for community participation to involve them and identify hazards they are facing.
- Management of natural resources. Action across lands to increase adaptation, how do you work across other state agencies to take the best approach for protecting natural assets and services?

2023 Actions: Common Themes and Trends

- Most actions focus on the following categories:
  - Assessment, research, analysis, science, and mapping
  - Planning and policy
  - Natural systems protection and enhancements
- There are current gaps in addressing the following urgent priority impacts and high consequence vulnerabilities, which should be considered during the next round of action development:
  - Decrease in marine fisheries and aquaculture productivity
  - Damage or loss to homes and critical facilities in the wildland urban interface
  - Damage or loss of unreinforced masonry buildings due to earthquakes
  - Damage, disruption, and loss of coastal infrastructure such as seaports, airports, and maritime industries

Developing high-quality actions

- Several of the proposed actions do not include enough detail/specificity to address risks.
- Remember: It’s not about the number of actions, its about the quality of the actions. We’ll be working on the comprehensiveness of the actions that are being proposed over the next two months. Considering likelihood and consequence. Do the actions address likelihood and consequence?
- High quality vs actions in need of revisions.
  - Low-quality actions are difficult to implement, hard to obtain buy-in, and

Overview of Next Steps: Action Development

- Identifying gaps between priority impacts and actions, particularly URGENT impacts.
- Evaluating the relevance of actions in comparison to 2023 goals.
- 1:1 agency meetings, Marybeth will be reaching out in the next few days to schedule these meetings with agencies.
  - Hoping to present Cross-government actions during the Series 2 Stakeholder meetings. State agencies are welcomed to join.

- Stakeholder Meetings
    - April 4 and 6
        - Participants: municipalities, regional planning agencies, and NGOs
        - Two-hour meeting
            - First hour: background on climate assessment, risk assessment, roles and responsibilities
            - Second hour: gather feedback from participants on proposed cross-government actions
- 1:1 Meetings led by EEA/MEMA with state agencies
    - Review actions and walk-through comments for consideration.
    - Ensure that they have the capabilities, resources, and abilities to implement the actions and address the priority impacts.
- Round 3 actions
    - Agencies refine actions based on comments provided and develop new actions, as needed, to address the gaps
    - Prioritize actions based on action scorecard, which will be provided with the updated Round 3 worksheet and scorecard by 3/31.
    - Complete revisions to agency actions and obtain sign-off by 4/28.

Cross-Government Action Development Exercise

- Defined as statewide actions across the agencies that address risk at a larger geography, can unlock other actions.
    - Example: CCA unlocking hazards and impacts an identify priorities for agencies to take additional action.
    - May be organized around a geographic hot spot or set of hot spots
    - Specific assets at a state-wide scale
- 2018 Cross-government Actions (17)
    - Complete: 30%
    - In progress: 57%
    - Modified or Deferred:
    - Not Started: 0%
    - Should be Deferred or Deleted: 0%
    - Should be Modified: 0%
- Potential 2023 SHMCAP Cross-Government Actions
    - Based on input received from agencies thus far (Round 2 of 2023 SHMCAP Action Development Worksheet)
        - Example 1: Build out climate resilience metrics that the Commonwealth can track statewide and through local grant programs to monitor success on climate resilience goals.
        - Example 2: Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on statewide climate data and models and supports consistent application across agencies.
        - Example 3: Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as

state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts.

- Example 4: Conduct a statewide loss avoidance study to help quantify the losses avoided (e.g., damage prevented or benefits) due to the implementation of the Commonwealth's hazard mitigation and climate adaptation projects and run scenarios of the different risks and vulnerabilities associated with varying implementation strategies.

Jamboard Questions for each Proposed Action (refer to attached Jamboard PDF)

1. *How can these global actions make it easier for your agency to advance climate resilience and hazard mitigation?*
2. *What modifications would you make to these global actions to make them more relevant to your agency's priorities and concerns?*
3. *How can these global actions help reduce risks for socially vulnerable communities?*
4. *Who should be part of the partnership to implement these global actions?*
5. *How would Massachusetts work with local jurisdictions and interested parties to implement these global actions?*
6. *What additional types/topics of global actions should be considered in the 2023 SHMCAP?*

Wrap Up and Next Steps

- Draft vulnerability assessment will be ready for RMAT review by 3/14.
- Round 2 Action Development will begin on 3/16, with updates due by 3/31.
- One-on-one agency meetings with MEMA/EEA will occur throughout March.
- Final actions (with leadership sign off) are due by 4/28.
- Series 2 meetings with municipalities, regional planning agencies, and NGOs are planned for April 4 and 6.
- The next RMAT meeting is tentatively scheduled for the end of April.

2023 MA SHMCAP
RMAT Meeting 6

2023 SHMCAP Working Group Meeting #6
Final Meeting: Strategy, Ongoing Implementation, and Maintenance
Wednesday, May 31, 2023
1:00—3:00 pm EDT

Meeting Objectives:

1) Report out on final agency actions and strategy.
2) Present approach for ongoing plan implementation and maintenance.

Time ET	Agenda Item

1:00 – 1:05 pm	**Welcome and Updates**
	• Recap of work since 3/14 meeting
	  ○ Capacity and Capabilities Assessment, Risk Assessment, and Vulnerability Assessment reviewed, currently with the Governor/OCIR
	  ○ Series 2 stakeholder engagement and community focus group meetings

1:05 – 1:30 pm	**2023 Final Actions**
	• Reflection on action development process
	  ○ Focus on addressing priority impacts
	  ○ Recap of round 1: updating 2018 action/status and brainstorming new actions
	  ○ Recap of round 2: refinement and partnerships
	  ○ Recap of round 3: further refinement (based on series 2 stakeholder engagement and community focus group meetings) and prioritization
	• Summary of 2023 final actions
	  ○ Types of actions
	  ○ Agency partnerships
	  ○ Cross-government actions
	  ○ Main focus areas

1:30 – 2:15 pm	**Presentation of Action Strategy**
	• Brief overview of methodology (how actions inform strategy)
	• Presentation of strategy
	  ○ Developed through priority impacts
	  ○ Evaluated for consistency with goals
	  ○ Refined based on partnerships and focus groups
	  ○ State agency action topics

2:15 – 2:50 pm	**Implementation and Maintenance**
	• Implementation roles and responsibilities
	• Considerations for action implementation
	• FY24 SHMCAP Implementation Funding
	• Staying engaged – maintenance process and schedule
	  ○ Action tracker
	  ○ Quarterly RMAT meetings
	  ○ Annual plan review

Time ET	Agenda Item
	○ Annual consultation with FEMA ○ Post-disaster review (as needed) ○ Five-year plan review and update
2:50 – 3:00 pm	**Wrap Up and Next Steps** • Governor Briefing June 2, 2023 • Deliver to FEMA on June 15, 2023 • Final plan available during Fall 2023

2023 SHMCAP Update

RMAT Working Group Meeting #6
Final Actions, Strategy, Implementation, and Maintenance

May 31, 2023

Photo: Marblehead Harbor, Wikimedia Commons

Welcome and Introductions

Please put your affiliation in the webinar participant list or chat

Photo: Kevin Gill/Flickr

Agenda

Welcome and Recap since Last RMAT Meeting
2023 Final Actions
Presentation of Action Strategy
FY24 SHMCAP Implementation Funding
Plan Implementation and Maintenance
Wrap Up and Next Steps

Meeting Objectives:

- Review and present high-level summary of actions
- Present the strategy
- Discuss next steps for plan implementation, maintenance, and report submittal

Recap Since 3/14/23 Meeting

- ✓ **Reviewed** Vulnerability Assessment Chapter
- ✓ **Revised, prioritized, and finalized** state agency and cross-government actions
- ✓ **Developed** strategy based on input from actions
- ✓ **Held** local and regional agency meetings and community focus groups
- ✓ **Briefed** EEA Secretary and Office of Climate Innovation

Next Steps:

- Compile final 2023 SHMCAP document
- Hold Governor's Office Briefing
- Submit to FEMA for review on 6/15
- Release plan in September
- Conduct RMAT engagements, action tracking, and SHMCAP updates

2023 SHMCAP Cross-government and State Agency Actions

Photo: Irena Draksic

2023 SHMCAP Cross-government and State Agency Actions

Total Number of Actions: 133

2023 SHMCAP Goals	Number of Actions Aligning with Goals*
#1: Collaboration, Communication, Funding, and Engagement	63
#2: Science-based and Informed Decision-Making	91
#3: Resilient State Assets and Services	89
#4: Implement Adaptation Actions for Communities and Ecosystems	83
#5: Climate Mitigation Consideration	30
#6: Resilient and Equitable Infrastructure, Ecosystems, and Communities	75

**Some actions address more than one goal.*

Recap: Action Development

Round 1

- **Cross-government actions:** PMT worked with state agencies to develop initial cross-government actions.
- **State Agency actions:** Reviewed and updated 2018 actions and status, developed new actions to address Priority Impacts and vulnerabilities and consistency with 2023 SHMCAP Goals.

Round 2

- **Cross-government actions:** RMAT Meeting 5 provided draft cross-government actions for input. Revised and refined cross-government actions based on agency feedback and shared with municipalities, NGOs, regional planning associations, and others.
- **State Agency actions:** Continued to refine actions based on input and meetings; considered partnerships and roles (lead, partner, support).

Round 3

- Further refined and revised actions based on input and discussion with state agencies and potential partners.
- Assigned leads and identified partner agencies.
- Organized cross-government actions based on 2023 SHMCAP goals. Organized state agency actions based on priority impacts.

Summary of Cross-government Actions by Goal

Goal 1: Collaboration, Communication, Funding, and Engagement

- Convene a climate resilience stakeholder working group.
- Increase funding to support municipal and agency resilience actions and access to funding opportunities.
- Launch a statewide Climate Communications Campaign.

- *Develop a framework for statewide resilience progress tracking.* Through a stakeholder process, identify statewide climate resilience goals and associated metrics that the Commonwealth can use to track progress statewide. These metrics should inform agency and municipal funding strategies and environmental permitting and reviews, including MEPA.

Summary of Cross-government Actions by Goal

Goal 2: Science-based and Informed Decision-Making

- Create a tool for Loss Avoidance Studies and Future Mitigation Projects.
- Develop a floodplain regulatory and coordination framework.
- Enhance consideration of resilience in the building code.

- *Launch an Office of Climate Science.* Launch an office of climate science that serves as an authoritative resource and provides subject matter expertise on statewide climate data and models and supports consistent application across agencies. Convene the academic climate science community and identify opportunities to partner with universities on climate science needs and next steps.

Summary of Cross-government Actions by Goal

Goal 3: Resilient State Assets and Services

- Formalize MEPA resiliency policy to ensure consideration of climate change during MEPA Reviews.
- *Expand evaluation of climate resilience for state capital investments.* Expand utilization of the RMAT Resilience Design Standards Tool to ensure climate vulnerability and resilient design is an evaluation criterion in determining state capital planning and grantmaking processes.

Summary of Cross-government Actions by Goal

Goal 4: Implementation of Adaptation Actions for Communities and Ecosystems

- Develop and implement a new Heat Flag System.
- Develop a coastal resilience strategy.
- Identify regulatory opportunities to improve cooling standards in buildings to address extreme heat impacts, through review of the State Sanitary Code.

- *Protect 30 percent of land and ocean by 2030.* Implement EEA's Resilient Lands Initiative and incorporate the Healthy Soils Action Plan. Develop a statewide approach and collaborative efforts to preserve and enhance forest health and conservation to enhance resilience and provide carbon sinks for GHG mitigation, including coastal sources.

Summary of Cross-government Actions by Goal

Goal 5: Consideration of Climate Mitigation (when designing hazard reduction actions)

- All actions will evaluate the opportunity to reduce GHG emissions and will select options that have the lowest GHG emissions possible.

Summary of Cross-government Actions by Goal

Goal 6: Resilient and Equitable infrastructure, Ecosystems, and Communities

- *Update school curriculum to include climate science and green workforce development.* To engage youth in climate and hazard mitigation more directly, implement pilot clean energy innovation pathways for high school students focused on helping students get applied learning experience in the renewal energy sector. Initial clean energy innovation pathway pilot will provide data to inform growth to additional schools. Clean energy projects will reduce greenhouse gas emissions and could also provide redundant energy supply in case of power outages due to disaster events.

Photo: MVP Warehouse

Action Development Outcomes

- **157 total actions proposed by state agencies.**
  - 15 cross-government
  - 142 agency actions
- **Prioritized actions:** all actions scored medium or high.
- **Evaluated completeness**, how well the actions addressed priority impacts and disproportionate impacts.
- **Removed or consolidated actions** through working with agencies.
- **Organized actions by Action Topic.**
  - Action Topics identify key collaborations among agencies and present a whole state approach.
  - Will walk through how to use the Action Topics to identify and connect with key collaborators.

Photo: I. Draksic

Strategy

Photo: Kate Adams

2023 SHMCAP Types of Actions

Infrastructure and Development

- Change regulations, codes, and zoning.
- Implement structure and infrastructure retrofits.
- Invest capital planning dollars in resilience to state-owned buildings, infrastructure, lands, and waters.

Assessment and Evaluation

- Research and identify vulnerabilities and risks.
- Build inventories of existing resources and assets and their condition.
- Conduct additional planning and policy development to frame actions.
- Model natural systems and incorporate climate projections.

Partnerships and Collaboration

- Guide, fund, and provide technical assistance to local, regional, community, and advocacy organization.
- Develop state funding sources and seek federal funding sources to support efforts at all scales.
- Create and share climate and hazard data, science, and modelling to support local and regional analysis.
- Conduct outreach and education to inform the public.

State Agency Action Topics

Action Topics are organized by Priority Impact and vulnerability, focus on the highest consequence hazards, and identify what issues will be addressed by the agency actions. Example Action Topics by sector include:

Human

- Assess heat vulnerabilities, develop an outreach strategy, and address heat related human health risks.
- Develop an inventory of cultural resources and evaluate their vulnerability to hazards and climate change.

Infrastructure

- Reduce flood risk and support equitable restoration projects with communities.
- Assess risks to transportation assets and services and develop approaches to reduce risk.
- Evaluate and increase the resilience of drinking water supplies to drought.


Photo: K. Adams

State Agency Action Topics

Natural Environment

- Develop ecological restoration partnerships and projects to evaluate and improve water quality.
- Improve coastal wetland mapping, resilience planning, and restoration efforts.

Governance

- Conduct a climate migration assessment.
- Develop a strategy to identify resilience funding needs and leverage federal funding to support adaptation projects.

Economy

- Establish grant programs to support farmers and agricultural productivity.
- Incorporate climate resilience into the Commonwealth's sustainable development principles.


Photo: I. Draksic

Significant Partnerships and Collaboration

Most actions include significant partnerships and collaboration, including:

Human

- DPH, DCAMM, LWD, AGO, EOPSS, DOER, MHC, MOTT

Natural Environment

- EEA, MEMA, DCR, MassDEP, Masswildlife, CZM, DFG, DER, DAR, DPU,
- **Others:** USGS, Conservation Commission, Northern Institute of Applied Climate Science, EPA, MassAudobon, localities

Photo: MVP Image Warehouse

Infrastructure

- MassDOT, DPU, EEA, DCAMM, EEA, MEMA, DCR, EOTSS, MA State Geologist,
- **Others:** FEMA, utilities, localities

Economy and Governance

- A&F, EEA, MEMA, DEP, OCIR, HED, HHS, DAR, DER, DFG, DCAMM, EOTSS

State Agency Action Topic Example

<table>
<tr><td colspan="4">Human Sector</td></tr>
<tr><td colspan="4">Urgent Priority Impact: Health and Cognitive Effects from Extreme Heat</td></tr>
<tr><td colspan="4">Action Topic 1: Assess heat vulnerabilities, develop an outreach strategy, and address heat related human health risks</td></tr>
<tr><td colspan="4">Description: This action topic focuses on addressing the priority impact of Health and Cognitive Effects from Extreme Heat to populations across the Commonwealth. Together, the following actions will mitigate risk associated with extreme heat through identifying populations vulnerable to heat stress, providing education and outreach to communities about heat risk, inventorying state assets and making improvements to increase resilience against extreme heat. The action topic aligns with the cross-government actions regarding the development and implementation of a new heat flag system and identifying regulatory opportunities to improve cooling standards in buildings.
Partners: LWD, DCR, DCAMM, MassDEP, DPH, AGO
Other Priority Impacts Addressed by Action Topic: Increase in Mental Health Stressors; Reduced Ability to Work; Health Effects from Degraded Air Quality; and Reduction in State and Municipal Revenues; Loss of life or injury due to high vulnerability dams, hurricanes, wildfires, extreme flooding, or extreme temperatures; and Disproportionate impacts on unhoused populations from extreme temperatures or extreme flooding.</td></tr>
<tr><td colspan="4">ACTION 1a. Develop and provide annual outreach information to employers and employees on the dangers of exposure to environmental heat</td></tr>
<tr><td rowspan="4">Develop and provide annual outreach information to employers and employees on the dangers of exposure to environmental heat, and strategies for minimizing the risks posed by such exposures. Outreach to be done by email, and in-person and virtual presentations. Collaborate with internal and external stakeholders on the efforts.</td><td>Scale</td><td>Lead(s) & Partner(s)</td><td>Hazard(s) Addressed</td></tr>
<tr><td>Statewide, Workforce</td><td>Lead: LWD
Partners: DPH, AGO</td><td>Extreme heat</td></tr>
<tr><td colspan="2">Goal(s) Addressed</td><td>Timeframe</td></tr>
<tr><td colspan="2">1, 3, and 6</td><td>Less than 3 years</td></tr>
<tr><td colspan="4">ACTION 1b. Address risk of extreme heat to building occupants</td></tr>
<tr><td rowspan="4">Identify buildings in areas designated by RMAT-supported climate data sets as being at high risk of extreme heat and track these vulnerabilities in an asset management system (CAMIS). Refer to this information with client agencies during capital planning and at the outset of new projects to address risks of extreme heat to occupants, especially at buildings that house vulnerable populations within the DCAMM portfolio, when feasible.</td><td>Scale</td><td>Lead(s) & Partner(s)</td><td>Hazard(s) Addressed</td></tr>
<tr><td>Statewide, Buildings</td><td>DCAMM</td><td>Extreme heat</td></tr>
<tr><td colspan="2">Goal(s) Addressed</td><td>Timeframe</td></tr>
<tr><td colspan="2">2, 4, and 6</td><td>5+ years</td></tr>
</table>

Human Sector – State Agency Actions

Action Topic: Assess heat vulnerabilities, develop an outreach strategy, and address heat related human health risks

Description: This action topic focuses on addressing the priority impact of Health and Cognitive Effects from Extreme Heat to populations across the Commonwealth. Together, the following actions will mitigate risk associated with extreme heat through identifying populations vulnerable to heat stress, providing education and outreach to communities about heat risk, inventorying state assets and making improvements to increase resilience against extreme heat. The action topic aligns with the cross-government actions regarding the development and implementation of a new heat flag system and identifying regulatory opportunities to improve cooling standards in buildings.

Partners: LWD, DCR, DCAMM, MassDEP, DPH, AGO

Actions:

- Develop and provide annual outreach information to employers and employees on the dangers of exposure to environmental health.
- Address risk of extreme heat to building occupants.
- Inventory and categorize shade shelters on DCR sites, and strategically improve shading and cooling structures in parks, prioritizing those located in Environmental Justice communities.

Human Sector – Cross-government Actions

Cross-government actions aligning with state agency actions to address the health and cognitive effects from extreme heat priority impact (and others)

Cross-government Actions aligning with Goal 4 (Implementation of Adaptation Actions for Communities and Ecosystems)

Cross-government Action: Develop and implement a new Heat Flag System

Description: Identify methods to obtain additional data on heat and ways to effectively communicate heat risk to the public across agencies. Develop and implement new Heat Flag system in alignment with NOAA's Heat Advisory Criteria for New England, to identify days of extreme heat to urge preparedness and caution to people outdoors, particularly children, elderly.

Photo: MVP Image Warehouse, MassECAN

Human Sector – Cross-government Actions

Cross-government actions aligning with state agency actions to address the health and cognitive effects from extreme heat priority impact (and others)

Cross-government Actions aligning with Goal 4 (Implementation of Adaptation Actions for Communities and Ecosystems)

Cross-government Action: Identify regulatory opportunities to improve cooling standards in buildings to address extreme heat impacts, through review of the State Sanitary Code

Description: Assess the State Sanitary Code for opportunities to promote cooling in residential buildings and mitigate extreme-heat risks to renters and remote workers.

Other Priority Impacts addressed by Action: Increase in Need for State and Municipal Policy Review and Adaptation Coordination; Health Effects from Aeroallergens and Mold; Reduced Ability to Work

Photo: MVP Image Warehouse

Infrastructure Sector – State Agency Actions

Action Topic: Reducing flood risk and supporting equitable restoration projects with communities.

Description: The action topic focuses on reducing flooding risk to communities in an equitable manner for Environmental Justice and Other Priority Populations. The actions address the Damage to Inland Buildings priority impact but are more broadly applicable to the hazards of inland and coastal flooding, coastal flooding and storm surge, coastal erosion, in addition to drought and enhancing stormwater management. Together, the collection of actions focuses on moving communities, structures, and assets from the floodplain to reduce risks and vulnerabilities and increasing equitable community access to grants for resilience projects and improving water quality.

Partners: MEMA, DCR, CZM, EEA, DER, State and local floodplain managers and communities

Actions:

- Acquisition/Buy-out Program Study
- Address flooding through better understanding of changes due to climate change; impacts of flooding to infrastructure, natural resources and groundwater; better planning and management; decrease in flood vulnerability
- Develop and implement recommendations to increase community access and equity for grants targeting coastal water quality and habitat
- Update DER's Environmental Justice Strategy
- Increase funding, eligibility, and focus on environmental justice to and within municipal and agency resilience action

Infrastructure Sector – Cross-government Actions

Cross-government actions aligning with state agency actions to reduce damage to inland buildings priority impact (and others)

Cross-government Actions aligning with Goal 4 (Implementation of Adaptation Actions for Communities and Ecosystems)

Cross-government Action: Floodplain Regulatory and Coordination Framework

Description: Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts. Identify best practices for municipalities to adopt to increase resilience standards for residential and/or non-residential construction in their communities. Advance opportunities within the building code to enhance resilience. Develop a Floodplain Management Plan that addresses and prioritizes actions that can be taken statewide to address and mitigate floods and their impacts.

Natural Environment Sector – State Agency Actions

Action Topic: Improve Coastal Wetland Mapping, Resilience Planning, and Restoration Efforts

Description: This action aims to address the Coastal Wetland Degradation priority impact and will help to address coastal flooding hazards and improve habitats, among other benefits. The action topic focuses on developing tools and utilizing geospatial datasets to identify opportunities to prioritize resilient efforts for coastal wetland and salt marsh restoration project to improve habitat, accommodate marsh migration, manage stormwater, and mitigate impacts from sea level rise. These efforts will be shared with CZM in consideration of their salt marsh migration land acquisition strategy.

Partners: DER, DCR, DEP, CZM, MassWildlife

Actions:

- Develop a GIS mapping tool for climate coastal and inland wetlands to identify resource area vulnerability corridors
- Identify and prioritize tidal restoration projects using the DER tidal crossing geodatabase
- Conduct coastal wetland modeling and restoration assessments for DCR's coastal wetlands to support planning and restoration efforts
- Advance salt marsh conservation and restoration
- Great Marsh Ecosystem Recovery Project
- Develop updated Wetlands restoration guidance and regulations to improve climate resilience
- Support adaptation of roads in salt marshes

Natural Environment Sector – Cross-government Actions

Cross-government actions aligning with state agency actions to address the coastal wetland degradation priority impact (and others)

Cross-government Actions aligning with Goal 4 (Implementation of Adaptation Actions for Communities and Ecosystems)

Cross-government Action 12: Develop a coastal resilience strategy

Description: Develop a coastal resilience strategy that considers climate resilient development and standards in vulnerable areas, develops best practices for coastal adaptation, and explores managed retreat.

Other Priority Impacts addressed by Action: Coastal Erosion; Inability to carry out mission and services due to damage, disruption, or loss of state assets and services; Damage, disruption, or loss of coastal infrastructure such as seaports, airports, and maritime industries; Emergency Service Response Delays and Evacuation Disruptions

Photo: MVP Warehouse

Governance Sector – State Agency Actions

Action Topic: Develop a strategy to identify resilience funding needs and leverage federal funding to support adaptation projects.

Description: This action topic aims to address the Increase in Demand for State and Municipal Government Services priority impact and has the potential to address elements of all priority impacts, as many proposed actions and adaptation projects identified lack of funding as a barrier to project implementation. Together, the actions focus on collaboratively identifying funding needs for resilience projects and obtaining federal funding sources to support CIP Investments, including adaptation projects.

Partners: A&F EO and DCAMM, MEMA, EEA, OCIR, Gov Office Director of Federal Funds and Infrastructure, and HED/DHCD

Actions:
- Develop a standardize approach to identifying resilience needs for capital planning purposes.
- Develop a standardized approach to aggressively leverage federal resources.
- Increase access to state resilience funding.

Governance Sector – Cross-government Actions

Cross-government actions aligning with state agency actions to address the Increase in Demand for State and Municipal Government Services priority impact (and others)

Cross-government Actions aligning with Goal 3 (Resilient State Assets and Services)

Cross-government Action 9: Expand evaluation of climate resilience for state capital investments

Description: Expand utilization of the RMAT Resilience Design Standards Tool to ensure climate vulnerability and resilient design is an evaluation criterion in determining state capital planning processes.

Other Priority Impacts addressed by Action: Damage to Inland Buildings; Damage to Coastal Buildings and Ports; Reduced Ability to Work; Damage, disruption, or loss of coastal infrastructure such as seaports, airports, and maritime industries; Damage to Inland State and Municipal Buildings and Land; Damage to Coastal State and Municipal Buildings and Land


Photo: MVP Warehouse

Economy Sector – State Agency Actions

Action Topic: Establishing Grant Programs to Support Farmers and Agricultural Productivity

Description: This action topic addresses the Decrease in Agricultural Productivity; Reduction in Food Safety and Security; and Soil Erosion priority impacts due to the inter-related nature of soil health, agricultural sustainability, and food production. This group of actions also address additional priority impacts, as highlighted below. Together, these actions aim to implement grant funding programs to support sustainable approaches to soil management, agriculture, and provide various ecosystem services. The grants will also assist farmers will evaluating their vulnerability to climate change and implementing practices to increase resilience. Similarly, DEP's proposed grant program can assist farmers with incorporate energy efficient and clean energy conservation into food production activities.

Partners: MDAR and DEP

Actions:
- Climate Smart Ag Program, Sustainable Soil Management and Grant Programs
- Grants for Private Agriculture Preservation Restrictions (APRs)
- Farm Climate Resiliency Program
- Grant opportunities for food/agriculture sectors to improve energy efficiency, adopt renewable energy and reduce GHG emissions (CERP)

Economy Sector – Cross-government Actions

Cross-government actions aligning with state agency actions to address the Reduced Ability to Work priority impact (and others)

Cross-government Actions aligning with Goal 6 (Resilient and Equitable Infrastructure, Ecosystems, and Communities)

Cross-government Action 15: Update school curriculum to include climate science and green workforce development.

Description: To engage youth in climate and hazard mitigation more directly, implement pilot clean energy innovation pathway for high school students focused on helping students get applied learning experience in the renewal energy sector. Initial clean energy innovation pathway pilot will provide data to inform growth to additional schools. Clean energy projects will reduce greenhouse gas emissions and could also provide redundant energy supply in case of power outages due to disaster events.

Other Priority Impacts addressed by Action: Damage to Electric Transmission and Utility Distribution Infrastructure; Damage to Rails and Loss of Rail/Transit Service; Loss of Energy Production and Resources; Health Effects of Extreme Storms and Power Outages; Reduction in State and Municipal Revenues; Increase in Demand for State and Municipal Government Services; Economic Losses from Commercial Structure Damage and Business Interruptions

2023 SHMCAP Implementation

Photo: Amanda McNeill

Implementation Roles and Responsibilities

- **Led by MEMA and EEA**
- **RMAT Roles and Responsibilities:**
  - Develop and implement cross-government and state agency actions.
  - Participate and provide implementation updates in quarterly RMAT meetings.
  - Update SHMCAP Action Tracker.
  - Identify needed changes based on new information and data, changed state or federal policies, or new opportunities.
  - Participate in post-disaster reviews of the SHMCAP, as needed.
  - Participate in scheduled five-year plan reviews and updates.
  - Serve as an advocate and liaison between the SHMCAP, actions, and the agency and Executive Office each member represents.
  - Ensure robust engagement throughout all phases of the SHMCAP.
  - Incorporate SHMCAP into state agency plans and programs and use it to inform updates to codes, regulations, policies, and guidance.

Discussion

Question for RMAT:

Where do you see the need and opportunity to engage through RMAT moving forward?

Photo: I. Draksic

Considerations for Future Opportunities

Future Opportunities (by priority impact/high consequence vulnerability)**:**

- Disproportionate Impacts on Unhoused Populations from Extreme Temperatures or Extreme Flooding
- Health Effects from Degraded Air Quality
- Health Effects of Extreme Storms and Power Outages
- Damage to Infrastructure, Utilities, and Buildings in Liquefaction Zones due to Earthquakes
- Damage or Loss to Homes and Critical Facilities in the Wildland Urban Interface
- Reduction in the Availability of Affordably Priced Housing
- Reduction in State and Municipal Revenues
- Economic Losses from Commercial Structure Damage and Business Interruptions

Considerations for Action Implementation

- **Closely collaborate and partner** with other state agencies and municipalities when implementing similar actions or when designing policy or technical assistance.
- **Engage Local, Regional, Community, and Tribal Representatives** early and throughout the implementation of actions.
- **Implement actions** to be consistent with 2023 SHMCAP Goals.
- **Consider prioritizing disproportionate impacts** on environmental justice and other priority populations during implementation.
- **Focus on critical assets** (e.g., nursing homes, hospitals, affordable housing), lifelines, and high consequence geographic areas when prioritizing locations for action implementation.
- **Use the RMAT meetings** to collaborate, problem-solve, identify opportunities, and coordinate grant and other funding opportunities.


Photo: I. Draksic

Considering Input: Local and Regional Meetings

- **Two workshops (April 4 and 6)**
  - Hour 1: Introduction to 2023 SHMCAP and status
  - Hour 2: Interactive session to gather feedback on cross-government actions
- **Interactive Session**
- **Presented the following categories of actions:**
    - Assessment & Research
    - Collaboration, Engagement & Education
    - Funding & Finance
    - Strategy, Planning & Codes
  - Asked the following questions:
    - *Does this action address the types of risks that your community is concerned about?*
    - *Are there ways to improve the action to better assist your community?*
    - *Are there other actions you'd like to see the Commonwealth take to reduce risk and increase resilience in your community?*

Photo: MVP Warehouse

Feedback from Stakeholder Meetings

High level feedback to consider during action implementation

- Respondents were largely in favor of proposed actions.
- Interest in performance metrics and timelines for actions.
- Interest in greater stakeholder engagement.
- Prioritize addressing vulnerabilities for EJ and other priority populations.
- Would like to have additional tools, templates, and training available applicable to the actions.
- Codes and regulations should be revised to increase flexibility to support resilience projects and strategies.
- Improve process for regulatory review and permitting for pilot climate adaptation and ecological restoration projects (ex. cranberry bog or saltmarsh restoration).
- Support for pilot projects to test various ideas (e.g., school curriculum, mobile solar energy systems).

Considering Input: Community Focus Groups

- **LydRev Communications and Marcos Luna**
- **Met with nine NGO/Community Organizations during April**
  - A Better City
  - Commonwealth Green Low-Income Housing Coalition
  - Change is Simple
  - Boston Climate Action Network
  - Mystic River Watershed Association
  - Public Health Institute of Western Massachusetts
  - Mothers Out Front
  - Neighbor to Neighbor
  - Quincy Climate Action Network

Photo: Stoss

- Questions regarding: "What actions can the commonwealth take to address your community's concerns?"

Feedback from Community Focus Groups to consider during action implementation

- Support more **education on climate change and hazard preparedness**; utilize more creative avenues for that education (e.g., schools, community liaisons, community-based organizations); reframe communication in ways that are relevant and understandable to **non-experts**.
- **Schools and education to schoolchildren are underutilized resources** for effective community education on climate and other hazards.
- **Language interpretation/translation is critical** and needs to be integrated into all state outreach and communication.
- State should **utilize NGOs** or consultants with **legitimate expertise in community outreach and education**; take expertise of outreach more seriously.
- State needs to **improve equitable access to energy efficiency and renewable energy program incentives** for lower income/renters/non-English speaking residents, and employment in clean energy transition for smaller businesses and contractors in historically underserved communities.
- State needs **regional planning entity** that can complement municipal vulnerability planning and coordinate decision making across multiple municipalities in a region with common concerns.
- State should prioritize **climate solutions with multiple co-benefits**, especially for vulnerable communities.

FY24 SHMCAP Implementation Funding

EEA awarding capital funding to projects implementing 2018 or 2023 SHMCAP actions

- In FY23, $5.8M allocated to 12 agencies to advance 23 projects
  - Average funding = $279k/project
- Projects must be implemented within FY24 (by June 30, 2024)

Applications due by EOD June 23, 2023 via Microsoft Forms

- Submit one form per project, multiple submissions by an agency are ok
  - Prioritization question if there are multiple projects
- Questions focus on project eligibility and project overview
  - Scope, timeline, and budget
  - Use of RMAT Tool; Climate 101 Training; ResilientMA.mass.gov climate data
- Reach out to mia.mansfield@mass.gov and marybeth.groff@mass.gov with any questions
- Agency review committee will meet in early July
  - Funding notifications in July for projects to begin August 1

Maintenance Process and Schedule

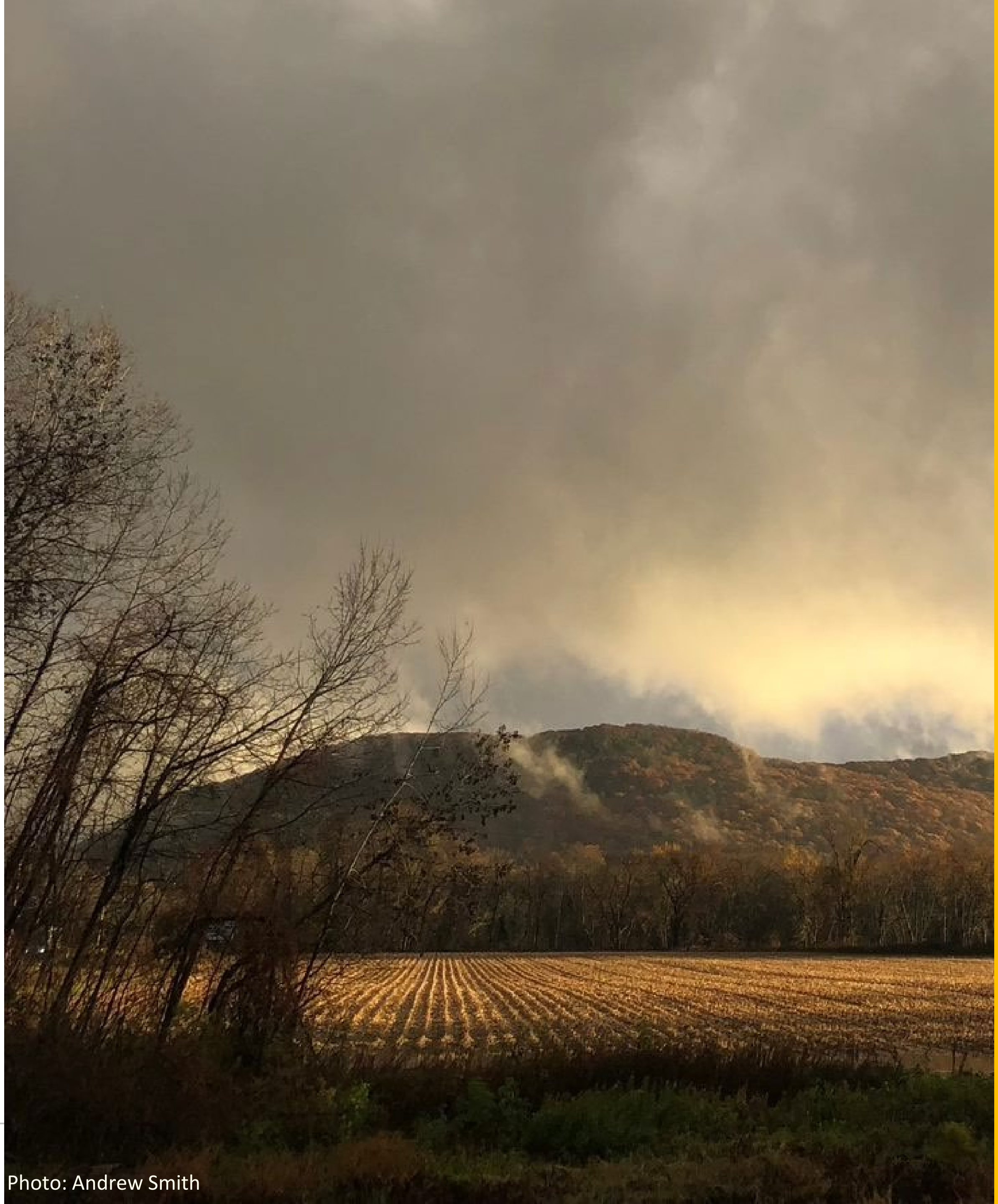
Photo: Andrew Smith

Action Tracker

- The Action Tracker is in the process of being updated, to be released in late 2023. Will include the following fields:
  - **Status of the action** (e.g., initiated, in-progress, percent completed, complete, deferred, delayed, or request for cancellation).
  - **Requests for deferral or cancellation**, as well as progress made, and any other relevant details of action implementation.
  - **Performance metrics**
- **Reminder:** It is the responsibility of RMAT members to update the tracker on a regular basis (at least annually, recommend quarterly)

Photo: I Draksic

Annual Plan Review

Objective: evaluate progress on state agency and cross-government actions and strategy.

- **Update the SHMCAP Action Tracker** in advance of the meeting.
- **Assess success of implementation**, determine trends, and identify emerging issues.
- **Determine the opportunities and challenges**, including barriers to implementation and approaches to overcoming them.
- **Identify changes to the Commonwealth's hazard and climate risks** and evaluate whether changes to actions are needed based on new information and understanding of risks.
- **Evaluate changes to federal or state policies, laws**, regulations, guidance, or funding opportunities that result in the need to revise the SHMCAP.
- **Prepare a summary document** of the annual review process.

Post-Disaster Review (as needed)

Objective: Identify opportunities to leverage or focus resources to address the needs that have emerged due to the disaster, as well as to better understand the impacts resulting from the disaster.

- Occurs if a Presidential Disaster Declaration is made for the Commonwealth.
- After the declaration, RMAT will conduct a plan review to determine:
  - Did the disaster result in needs or opportunities that could be addressed by the current actions in the SHMCAP?
  - Do actions need to be revised or added to better address these risks and vulnerabilities?
- RMAT may consider whether the Post-Disaster Review will replace the regularly scheduled Annual Review for the year.

Five Year Plan Review and Update

Objective: Review, plan, and identify the process for making updates in accordance with FEMA requirements.

- **Comprehensive review, update, and adoption (2028).**
- **Managed by MEMA and EEA with input from RMAT.**
- **Minimum qualifications for the update:**
  - Changes in development in the Commonwealth that may have increased or decreased risk exposure to populations, lifelines, and critical assets.
  - Progress on hazard mitigation and climate adaptation actions and efforts that may have reduced risks.
  - Changes in state and federal priorities since the last SHMCAP update.
  - Information and data developed since the last SHMCAP update based on new research, recent hazard events, or other experiences at the state, local, or regional scales, including any plans that were in progress but not completed in time to be incorporated into last SHMCAP update.

Annual Consultation with FEMA (Spring - 4th Quarter fiscal year)

<u>Objective</u>: Meet with FEMA annually to coordinate on the maintenance and implementation of the SHMCAP and any updates needed to the plan.

- Meet with FEMA's State Mitigation Program to review activities, plans, and programs to assist in the effective implementation of mitigation and adaptation planning and implementation.
- Coordinate with FEMA on the annual review of the SHMCAP.
- FEMA will provide a State Mitigation Program Consultation summary that describes the Commonwealth's program's strengths, opportunities for improving capabilities, and challenges in advancing mitigation.


Photo: MVP Warehouse

Overall Maintenance Schedule

Date	Activity
September 2023	2023 SHMCAP approved by FEMA
October 2023	Quarterly RMAT Meeting
January 2024	Quarterly RMAT Meeting
April 2024	Annual Implementation Update (using Action Tracker) And Annual Meeting with FEMA (4th Quarter Fiscal)
July 2024	Quarterly RMAT Meeting
August 2024	Annual Plan Review
September 2024	Summary of Progress Quarterly RMAT Meeting

Questions and Discussion

Discussion Question

Question for RMAT:

What type of support is needed from EEA/MEMA to assist agencies in collaborating among each other and with other groups and communities while implementing actions?

Wrap Up and Next Steps

Photo: Wikimedia Commons

Wrap Up and Next Steps

- Compile final 2023 SHMCAP document
- Governor's Office briefing
- Submit to FEMA for review (6/15/23)
- **Plan roll out in September 2023**
  - Including Executive Summary, updated resilient.mass.gov with Action Tracker
- Next RMAT meeting in summer 2023

Photo: MVP Warehouse

RMAT Meeting 6 – Summary Notes

May 31, 2023

Agenda

- Welcome and recap since last RMAT Meeting
- 2023 Final Actions
- Presentation of Action Strategy
- FY 24 SHMCAP Implementation Funding
- Plan Implementation and Maintenance
- Wrap Up and Next Steps

Meeting Objectives

- Review and present high-level summary of actions
- Present the strategy
- Discuss next steps for plan implementation, maintenance, and report submittal

Recap Since 3/14/23 Meeting (RMAT Meeting 5)

- Reviewed Vulnerability Assessment Chapter
- Revised, prioritized, and finalized state agency and cross-government actions
- Developed strategy based on input from actions
- Held local and regional agency meetings and community focus groups
- Briefed EEA Secretary and Office of Climate Innovation
- Next Steps:
    - Compile final 2023 SHMCAP document
    - Hold Governor's Office Briefing
    - Submit to FEMA for review on 6/15
    - Release plan in September 2023
    - Conduct RMAT engagements, action tracking, and SHMCAP updates

2023 SHMCAP Cross-government and State Agency Actions

- Recap on three rounds of action development
    - Round 1: reviewing 2018 actions, making status updates, and developing new actions to address priority impacts and high-consequence vulnerabilities
    - Round 2: reviewed and revised cross-government actions based on feedback from municipalities, NGOs, regional planning associations, and others. Continued to refine state agency actions based on feedback from PMT.
    - Round 3: Refined and revised actions, as needed. Organized cross-government actions by 2023 SHMCAP goal and state agency actions by priority impact.
- Summary of Cross-government Actions by Goal
- Action Development Outcomes
    - 157 total actions proposed (15 cross-government and 142 agency actions)
    - Evaluated actions for completeness, resolved, or consolidated actions, as needed.

  - Organized actions by action topic to show partners and collaboration among similar actions

Strategy

- 2023 SHMCAP Types of Actions
  - Infrastructure and development
  - Assessment and evaluation
  - Partnerships and collaboration
- State Agency Action Topics
  - Action topics are organized by priority impact and high-consequence vulnerability, focus on the highest consequence hazards, and identify what issues will be addressed by the agency actions.
- Significant partnerships and collaboration
  - Identify various agencies and other entities that worked together to develop actions.
- State Agency Topic Example
  - Walked through how the action topics and descriptions are used to tie actions together.
- Detailed examples of action topics (organized by sector) – State Agency Actions
  - Human Sector
    - Action topic example: assess heat vulnerabilities, develop an outreach strategy, and address heat related human health risks
    - Description of action topic, partners, and actions that are combined under the action topics
    - Connection to cross-government actions: develop and implement a new heat flag system; identify regulatory opportunities to improve cooling standards in buildings to address extreme heat impacts, through review of the State Sanitary Code
  - Infrastructure Sector
    - Action Topic: Reducing flood risk and supporting equitable restoration projects with communities
    - Description of action topic, partners, and actions that are combined under the action topics
    - Connection to cross-government actions: floodplain regulatory and coordination framework
  - Natural Environment Sector
    - Action Topic: Improve Coastal Wetland Mapping, Resilience Planning, and Restoration Efforts
    - Description of action topic, partners, and actions that are combined under the action topics
    - Connection to cross-government actions: develop a coastal resilience strategy
  - Governance Sector
    - Action Topic: Develop a strategy to identify resilience funding needs and leverage federal funding to support adaptation projects.
    - Description of action topic, partners, and actions that are combined under the action topics

        - Connection to cross-government actions: expand evaluation of climate resilience for state capital investments
    - Economy Sector
        - Action Topic: Establishing Grant Programs to Support Farmers and Agricultural Productivity
        - Description of action topic, partners, and actions that are combined under the action topics
        - Connection to cross-government actions: Update school curriculum to include climate science and green workforce development
- Pause for questions
    - MassWildlife indicated that they want to be partners for some of the actions but weren't listed (extreme heat, urban flooding, urban forestry). There will be an opportunity to identify additional partners, this doesn't have to be complete by the 6/15/23 deadline for FEMA.
    - MassAudubon was wondering if there are specific actions that speak to LID/Green Infrastructure? We'll need to follow up on specific actions that speak to this.
    - Charles River Watershed Association had questions about how community engagement was conducted, what type of feedback is collected, and how that feedback was incorporated into the actions. We provide a highlight of this later in the presentation.
- 2023 SHMCAP Implementation
    - Implementation Roles and Responsibilities
        - Lead by MEMA and EEA
        - RMAT roles and responsibilities
            - Develop and implement cross-government and state agency actions.
            - Participate and provide implementation updates in quarterly RMAT meetings.
            - Update SHMCAP Action Tracker.
            - Identify needed changes based on new information and data, changed state or federal policies, or new opportunities.
            - Participate in post-disaster reviews of the SHMCAP, as needed.
            - Participate in scheduled five-year plan reviews and updates.
            - Serve as an advocate and liaison between the SHMCAP, actions, and the agency and Executive Office each member represents.
            - Ensure robust engagement throughout all phases of the SHMCAP.
            - Incorporate SHMCAP into state agency plans and programs and use it to inform updates to codes, regulations, policies, and guidance.
    - Question for RMAT: "Where do you see the need and opportunity to engage through RMAT moving forward?"
        - Responses:
            - In the past we used the meetings to keep track of actions/ progress.
            - I would appreciate a chance to meet in person because these meetings were great for networking and collaborating.
            - Working together on the statewide floodplain management framework will also provide a time to get together.

        - Develop and engage in a process to modify action items based on changing conditions - allowing them to be "living" actions.
        - I attended a conference during the pandemic that included "speed dating" type of break-out rooms for networking, which was pretty fun. We only had time for 3 or four rounds, but if we saved a little time at each meeting, maybe we'd all get to know who's in the room a little better over time.
        - More connections and collaboration between existing efforts too. Municipalities are challenged with meeting goals and applying for funding across secretariats -- here's a note from just one MVP community in response to what they would like help with over the next year: "We would be interested in working more closely with the regional representative to fulfill goals and stay updated on recent data releases from ResilientMA, as well as ways to coordinate implementation with other state programs such as Green Communities, Housing Choice, and Complete Streets (all of which the Town is an active participant)."
- Consideration for Future Opportunities: priority impacts/vulnerabilities that have some but not a lot of actions and should be considered during implementation:
    - Disproportionate Impacts on Unhoused Populations from Extreme Temperatures or Extreme Flooding
    - Health Effects from Degraded Air Quality
    - Health Effects of Extreme Storms and Power Outages
    - Damage to Infrastructure, Utilities, and Buildings in Liquefaction Zones due to Earthquakes
    - Damage or Loss to Homes and Critical Facilities in the Wildland Urban Interface
    - Reduction in the Availability of Affordably Priced Housing
    - Reduction in State and Municipal Revenues
    - Economic Losses from Commercial Structure Damage and Business Interruptions
- Other considerations for action implementation:
    - Closely collaborate and partner
    - Engage local, regional, community, and tribal representatives
    - Consider prioritizing disproportionate impacts
    - Focus on critical assets
    - Use RMAT meetings to collaborate
- Summary of feedback from local and regional meetings
    - Two meetings for municipalities, regional planning agencies, and others
    - Collected feedback on cross-government actions
        - *Does this action address the types of risks that your community is concerned about?*
        - *Are there ways to improve the action to better assist your community?*
        - *Are there other actions you'd like to see the Commonwealth take to reduce risk and increase resilience in your community?*

- Feedback from Stakeholder Meetings (to consider during implementation)
    - Respondents were largely in favor of proposed actions.
    - Interest in performance metrics and timelines for actions.
    - Interest in greater stakeholder engagement.
    - Prioritize addressing vulnerabilities for EJ and other priority populations.
    - Would like to have additional tools, templates, and training available applicable to the actions.
    - Codes and regulations should be revised to increase flexibility to support resilience projects and strategies.
    - Improve process for regulatory review and permitting for pilot climate adaptation and ecological restoration projects (ex. cranberry bog or saltmarsh restoration).
    - Support for pilot projects to test various ideas (e.g., school curriculum, mobile solar energy systems).
- Community Focus Groups
    - Met with 9 NGOs and community organizations
    - Asked: "What actions can the commonwealth take to address your community's concerns?"
    - Summary of feedback:
        - Support more education on climate change and hazard preparedness; utilize more creative avenues for that education (e.g., schools, community liaisons, community-based organizations); reframe communication in ways that are relevant and understandable to non-experts.
        - Schools and education to schoolchildren are underutilized resources for effective community education on climate and other hazards.
        - Language interpretation/translation is critical and needs to be integrated into all state outreach and communication.
        - State should utilize NGOs or consultants with legitimate expertise in community outreach and education; take expertise of outreach more seriously.
        - State needs to improve equitable access to energy efficiency and renewable energy program incentives for lower income/renters/non-English speaking residents, and employment in clean energy transition for smaller businesses and contractors in historically underserved communities.
        - State needs regional planning entity that can complement municipal vulnerability planning and coordinate decision making across multiple municipalities in a region with common concerns.
        - State should prioritize climate solutions with multiple co-benefits, especially for vulnerable communities.
- Fiscal Year 24 SHMCAP Implementation Funding
    - Applications due by 6/23/23

- Maintenance Process and Schedule

  - Action Tracker
    - Will be released in late 2023
    - Will be used as the primary method to track action progress
  - The following activities will be conducted as part of plan maintenance:
    - Annual Plan Review
    - Post-Disaster Review (as needed)
    - Five Year Plan Review and Update
    - Annual Consultation with FEMA
- Final discussion question: "What type of support is needed from EEA/MEMA to assist agencies in collaborating among each other and with other groups and communities while implementing actions?"
  - Responses:
    - one central grant / program database for all state/regional efforts.
    - I wonder if an easier processes for ISAs would be helpful for cross-agency projects?
    - A spreadsheet containing all of the contacts that have been involved in this great effort, especially entities outside of state agencies.
    - Presentations from different agencies on available grant programs and regulatory processes to help other agencies understand where overlap or ripple effects exists.
    - Is there a comprehensive list of groups and communities and their points of contact organized by municipality or region with whom we can collaborate?
    - MassWildlife does a lot of landscape level work - it would be great to see the projects taking place in a map to be able to leverage at larger scales.
    - Guidance on new sources of funding to support these types of cross-govt actions would be helpful, to include on the thought about ISAs.

Wrap Up and Next Steps

- Compile the final 2023 SHMCAP document
- Governor's office briefing
- Submit plan to FEMA to review on 6/15/23
- Roll out the final plan during September 2023
- Next RMAT meeting will occur during the summer of 2023

Series 2 Stakeholder Meetings with Municipalities, Regional Planning Agencies, and Non-governmental Organizations

2023 SHMCAP Update

Series 2 – External Meetings
Meeting 1

April 4, 2023

Photo: Marblehead Harbor, Wikimedia Commons

Agenda

Welcome and Introductions
Hazard Mitigation Planning Overview
SHMCAP Overview and Status
Risk Assessment Summary
Framework and Process for Action Development
Action Development Discussion (Breakout Groups)
Wrap Up and Next Steps

Photo: Kevin Gill/Flickr

Welcome and Introductions

Let us know you are here!

Please place your name and affiliation in the chat


Photo: Amanda McNeill

Hazard Mitigation Planning Overview

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What sector are you affiliated with? (please select 1 option)

ⓘ Start presenting to display the poll results on this slide.

slido

Have you been involved in hazard mitigation and climate adaptation planning processes (at any level) before? (please select 1 option)

ⓘ Start presenting to display the poll results on this slide.


Photo: Andrew Smith

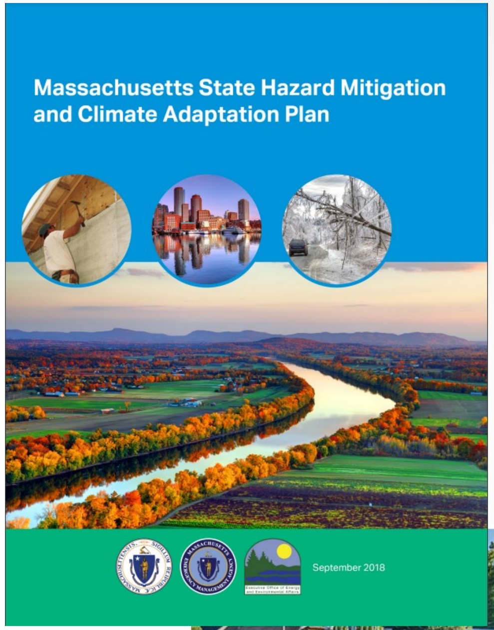
SHMCAP Overview

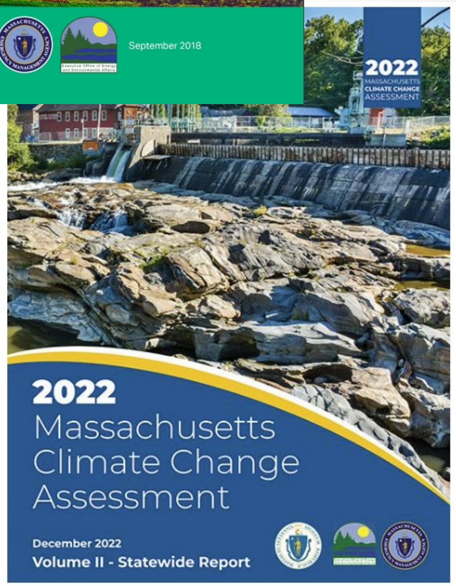
What is the 2023 SHMCAP?

Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP)

<u>Overview</u>

1. **Update to the 2018 SHMCAP**
2. **Informed by the 2022 MA Climate Change Assessment**
3. **Includes hazard mitigation and climate adaptation**
   - Hazards with impacts across the state
   - Priority impacts and vulnerabilities
   - Disadvantaged communities and disproportionate impacts
   - New actions to reduce most significant risks
4. **FEMA released a new Planning Policy Guide that will take effect for 2023 SHMCAPs, which includes:**
   - New priorities related to climate adaptation, equity, resilience, and building codes.
   - Includes mitigation requirements for High Hazard Dam grants and for the Fire Management Assistance Grants Program





What is Hazard Mitigation and Climate Adaptation?

Definitions

"Hazard mitigation" is **any sustainable action that reduces or eliminates long-term risk to people and property from future disasters**. Mitigation planning breaks the cycle of disaster damage, reconstruction, and repeated loss and damage.

“Climate change adaptation” is the **process of adjusting to current or expected effects of climate change**.” For humans, adaptation aims to moderate or avoid harm, and exploit opportunities; for natural systems, humans may intervene to help the adjustment. **Adaptation actions can be either incremental or transformative**.”

Benefits of Hazard Mitigation Planning and Climate Adaptation Plans

- **Limits damage, disruption**, and loss and reduces the amount of resources needed to recover
- **Reduces risk**
- Increases ability to **bounce back** after disasters
- Provides a **shared understanding** across the Commonwealth of the risks and climate impacts
- Helps Massachusetts and its communities obtain **funding** for hazard mitigation and climate adaptation projects

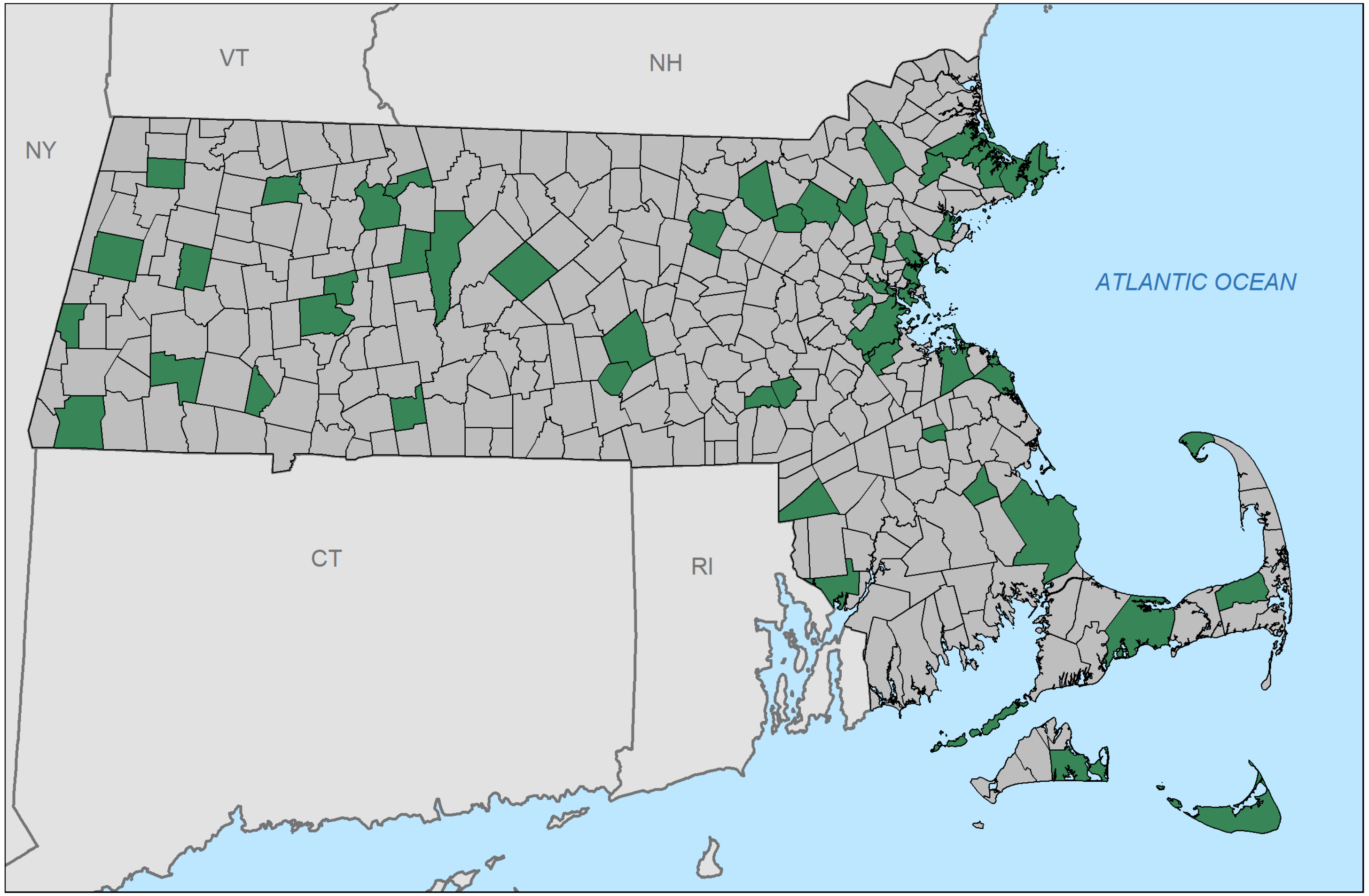
How is the SHMCAP used by the State?

- **Identifies critical assets** and services
- **Identifies hazards** that pose the greatest threat to Massachusetts
- **Includes a decision-making tool** to guide priority actions to mitigate hazards (mitigation strategy)
- **Sets statewide priorities**, develops program to implement priorities at statewide, regional, and local scales
- **Assists local municipalities** with hazard mitigation and climate adaptation planning
- **Implements projects** to reduce risks

Photo: MVP Image Warehouse

Photo: Amanda McNeill

Input from Local Hazard Mitigation Plans



Local HMPs. 2023 SHMCAP considers 37 Hazard Mitigation Plans from Communities across the Commonwealth.

The 2023 SHMCAP includes a review **37 Local Hazard Mitigation Plans** to inform local conditions, local experience with hazards, local damage from past events, and identify programs, projects, and other actions within each municipality to reduce risks.

Who are the partners?

FEMA

- Federal agency responsible for SHMCAP requirements, reviews, and approvals
- Provides pre-disaster planning, infrastructure funding and technical assistance to states, territories, tribal lands, and local jurisdictions

State Agencies

- **Led by the Resilient MA Action Team (RMAT)**; interagency team that provides information and develops the SHMCAP
- Responsible for identifying and implementing actions to reduce risks identified in the SHMCAP
- Provides support to local municipalities to develop HMPs and implement risk reduction actions

Localities, Communities, and others

- Adopts and updates local HMPs and climate plans
- Implements projects consistent with state priorities
- Works with Commonwealth agencies to coordinate projects

Photo: Dean Calma / IAEA

Hazard Mitigation Planning Process Steps

Collect data on hazards and regional climate projections, assets, populations

Coordinate and Collect Data

(Past sources to late 2022)

Evaluate current and future capacities for the state to increase resilience

Analyze Capabilities and Capacities

(fall/winter 2022)

Evaluate vulnerabilities and risk informed by 2022 Climate Assessment, HAZUS, SMEs, RMAT

Assess Risks

(fall/winter 2022)

Identify actions to develop a statewide hazard mitigation strategy

Mitigation Strategy

(winter/ spring 2023)

Refine and prioritize actions, obtain partner feedback

Identify Implementation Procedures

(April 2023)

Plan approved by FEMA, continuously track progress

Review & Adopt the Plan

(June – Sept. 2023)

We are here

Planning and Engagement Process

- **2022 meeting series for the MA Climate Change Assessment**
- **Monthly meetings with Resilience Massachusetts Action Team (RMAT)**
- **Coordinated with agency and external subject matter experts:**
  - Reviewed risk assessment
  - Identify and address gaps in hazard data, assets, infrastructure, and other considerations
- **Conducted a survey of state agency capabilities and vulnerabilities; review of best available data and information**
  - Identify strengths, needs, and opportunities to expand capacity
  - Conduct risk assessment and incorporate 2022 Climate Assessment
- **Developed actions to address priority impacts** identified in the 2022 Climate Assessment and Risk Assessment **vulnerabilities**
- **Stakeholder meetings held to obtain input and recommendations** on statewide actions (April 4th and 6th)
- **Internal state review and finalization**
- **FEMA review and comments (mid-June)**
- **Authorization by September 2023**

Key Documents Referenced

- **2022 Climate Change Assessment**
- **2018 SHMCAP**
- **Review of local HMPs statewide**
- **New hazards data**
  - Hazard and sector-specific data and information
- **Latest climate data and information**
  - Massachusetts Environmental Justice population data
  - 2020 census data
  - Downscaled GCM projections (temperature, precipitation)
  - Massachusetts Shoreline Change Project data
  - New seismic site class data for earthquake modeling
  - Massachusetts Coastal Flood Risk Model (MC-FRM)
- **State Agency Survey**
  - Capacity and Capabilities
  - Key Vulnerabilities

Photo: Ali Stevenson

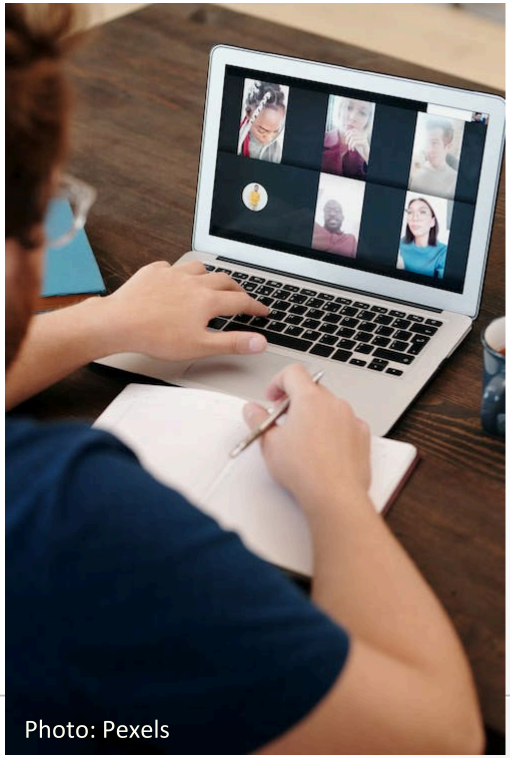


Photo: Pexels

SHMCAP 2023 Goals

- Collaboration, Communication, Funding, and Engagement
- Science-based and Informed Decision-Making
- Resilient State Assets and Services
- Implementation of Adaptation Actions for Communities and Ecosystems
- Consideration of Climate Mitigation (when designing hazard reduction actions)
- Resilient and Equitable Infrastructure, Ecosystems, and Communities

Photo: Kate Adams

Risk Assessment Summary

Overview: Risk Assessment

- **Risk:** "Potential for damage, disruption, or loss to assets and services from hazards and climate change. All likely hazards should be included in the risk assessment. "

- **Purpose** is to identify those hazards that are likely to pose risks to state based on current and future projections of the hazards and the changes to these hazards due to climate change.

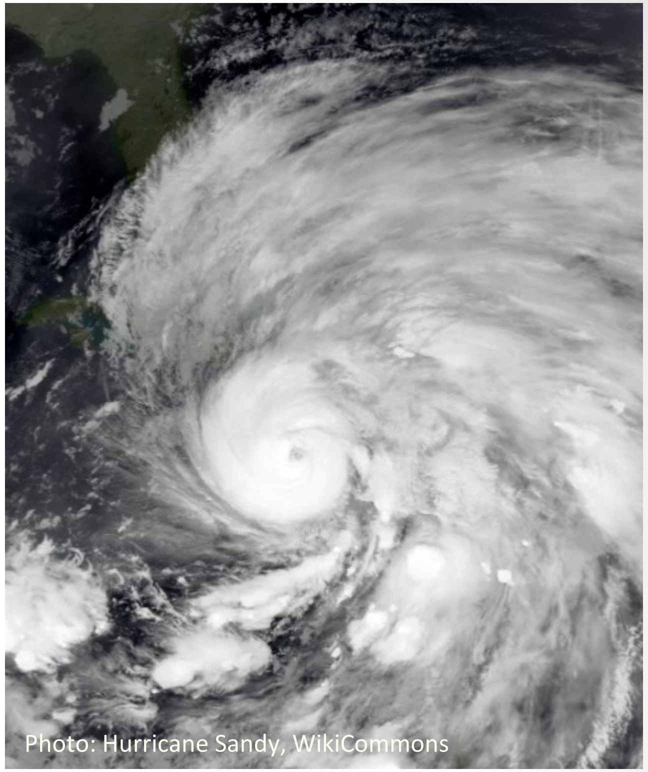


Photo: Hurricane Sandy, WikiCommons


Photo: Mario Tama/Getty Images

Risk Assessment: Hazard Snapshots

Summary information on hazards

Concepts covered:

- **Vulnerability:**
  - Informed by 2022 Climate Assessment
  - Assessed disproportionate impacts
  - Identified risk to state assets and critical facilities
  - Discussion on risk and impact to community lifelines
- **Location:**
  - Hazards were classified on local, county, regional, statewide, and multi-state scales
- **Changing conditions:**
  - Considered climate change effects for relevant hazards, with projections for mid and end of century

*Used the Climate Assessment (CA) rankings for *disproportionality* for hazards covered by the CA

Indicators used in Snapshot

Location: geospatial reach and geographic descriptions

Likelihood: likelihood of the hazard happening (considering a changing climate)

Magnitude of consequence: magnitude of impact and ability to respond (Warning time).

Qualitative: Discussion of adaptive capacity and disproportionate impacts*

Hazard Snapshot: Coastal Flooding

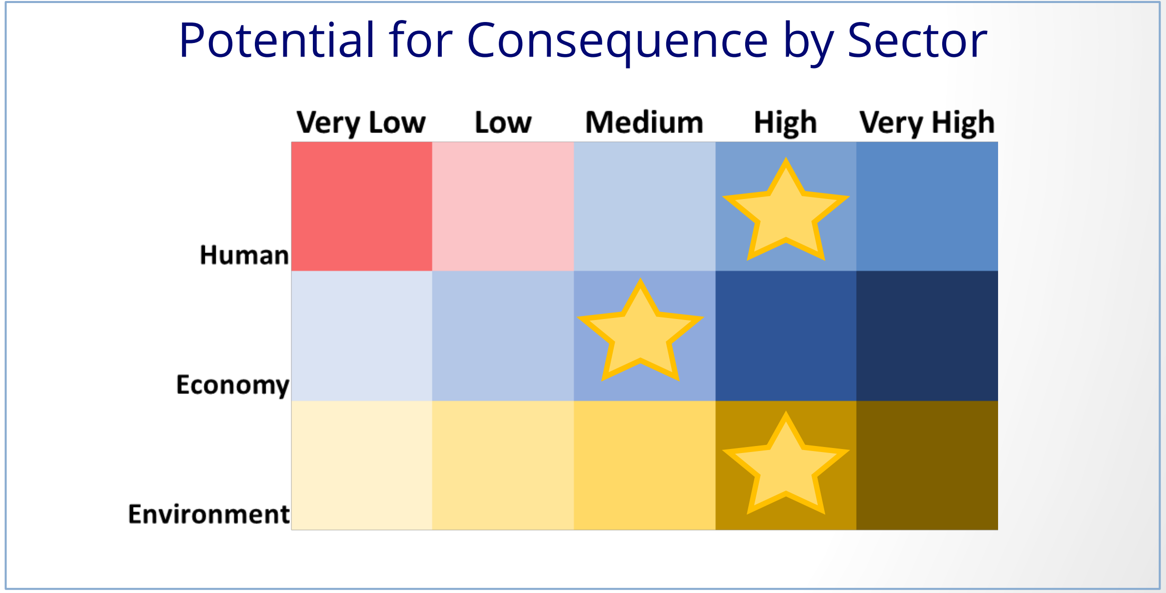
Data used in RA analysis

- Massachusetts Coastal Flood Risk Model (MC-FRM)
- FEMA flood zones
- FEMA Standard Digital Flood Insurance Rate Maps
- National Coastal Property model
- Traffic delay data (EMS response impacts)

Methods used in RA analysis

- MC-FRM outputs to calculate area flooded with SLR, annual expected flood damages to coastal properties, and emergency response service impacts from traffic delays
- FEMA flood maps to calculate number of people and infrastructure, in different flood zones in each county
- Analyzed economic vulnerability to coastal flooding using the National Coastal Property model

Snapshot components



Hazard Snapshot: Coastal Flooding

Additional information

Areas most at risk:

- State coastline, particularly Boston Harbor region

Distribution of impact and vulnerability

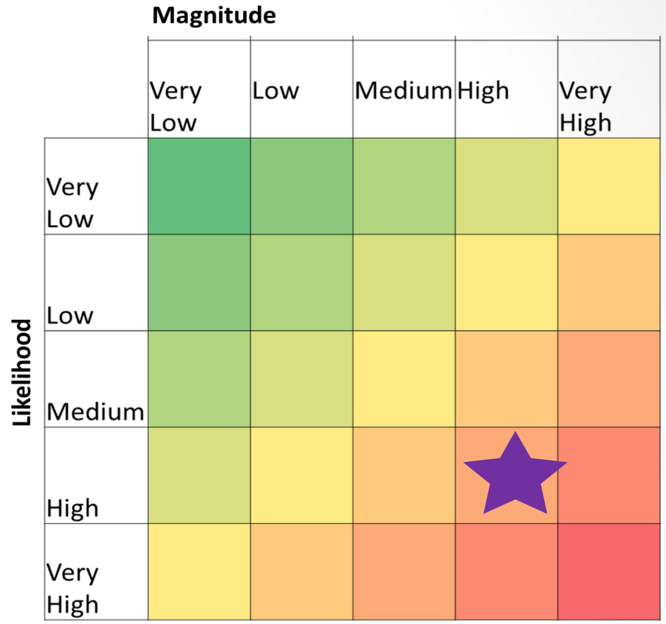
- Increased risk of injury and death for communities living near the coast with limited ability to evacuate (elderly, young, linguistic isolation, transit dependency)
- Flooding expected to impact affordable housing, especially in Boston, Chelsea, Quincy, and Revere

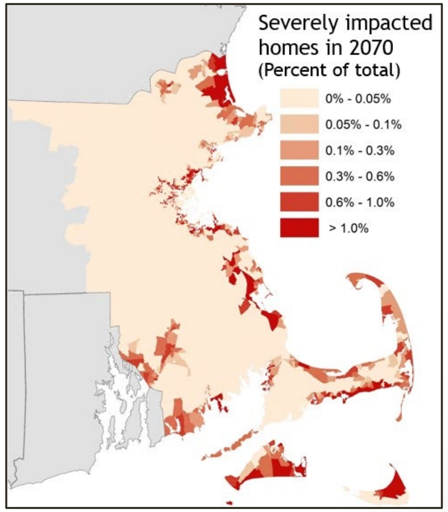
Priority Impacts Drawn from the Climate Assessment

- Damage to coastal buildings and ports
- Coastal erosion and coastal wetland degradation
- Marine ecosystem degradation
- Damage to coastal state and municipal buildings and land
- Damage to tourist attractions and recreation amenities
- Emergency service response delays and evacuation disruptions
- Health effects from aeroallergens and mold

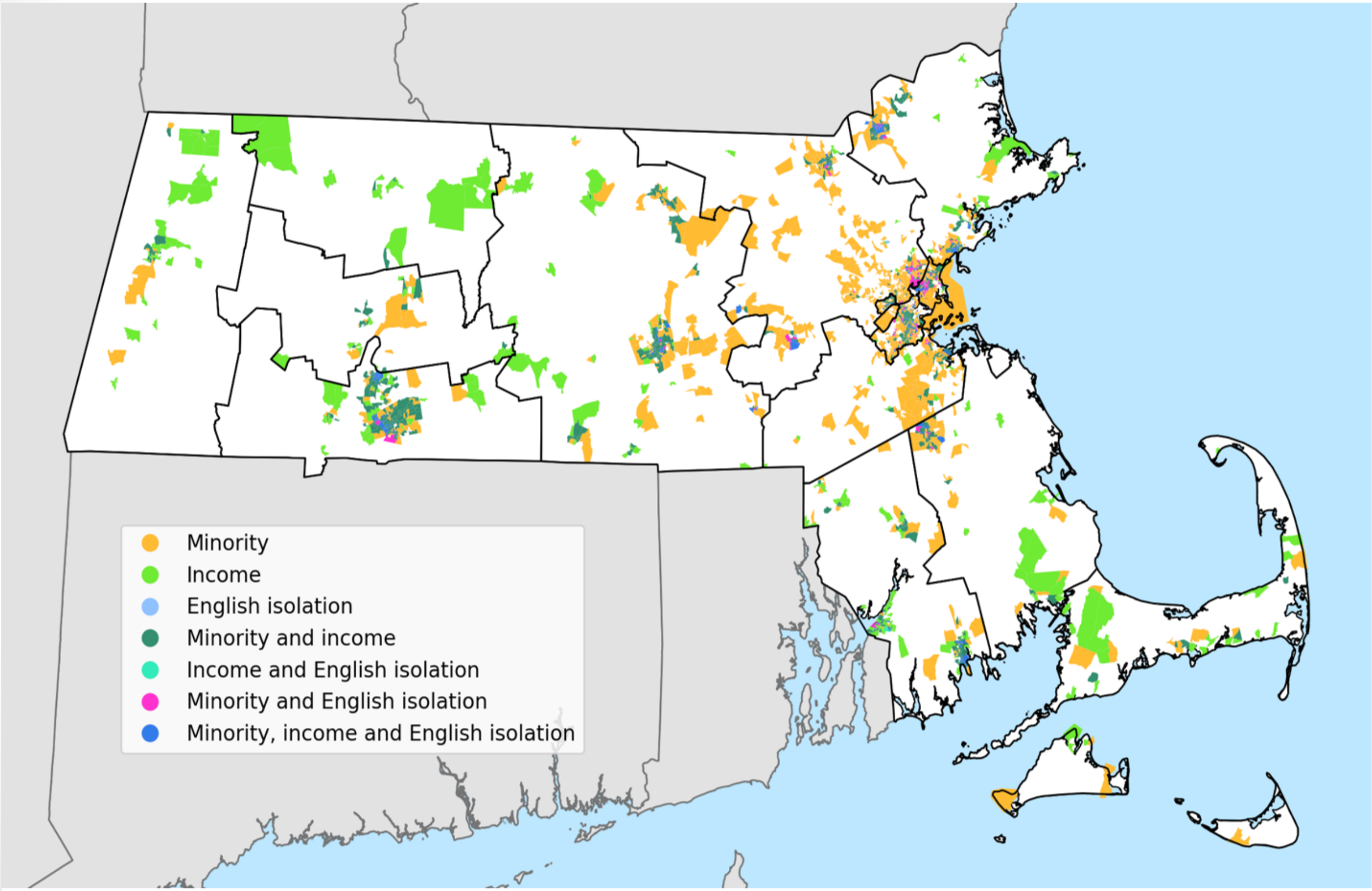
Snapshot components

Magnitude and Likelihood





Environmental Justice Populations in the Commonwealth



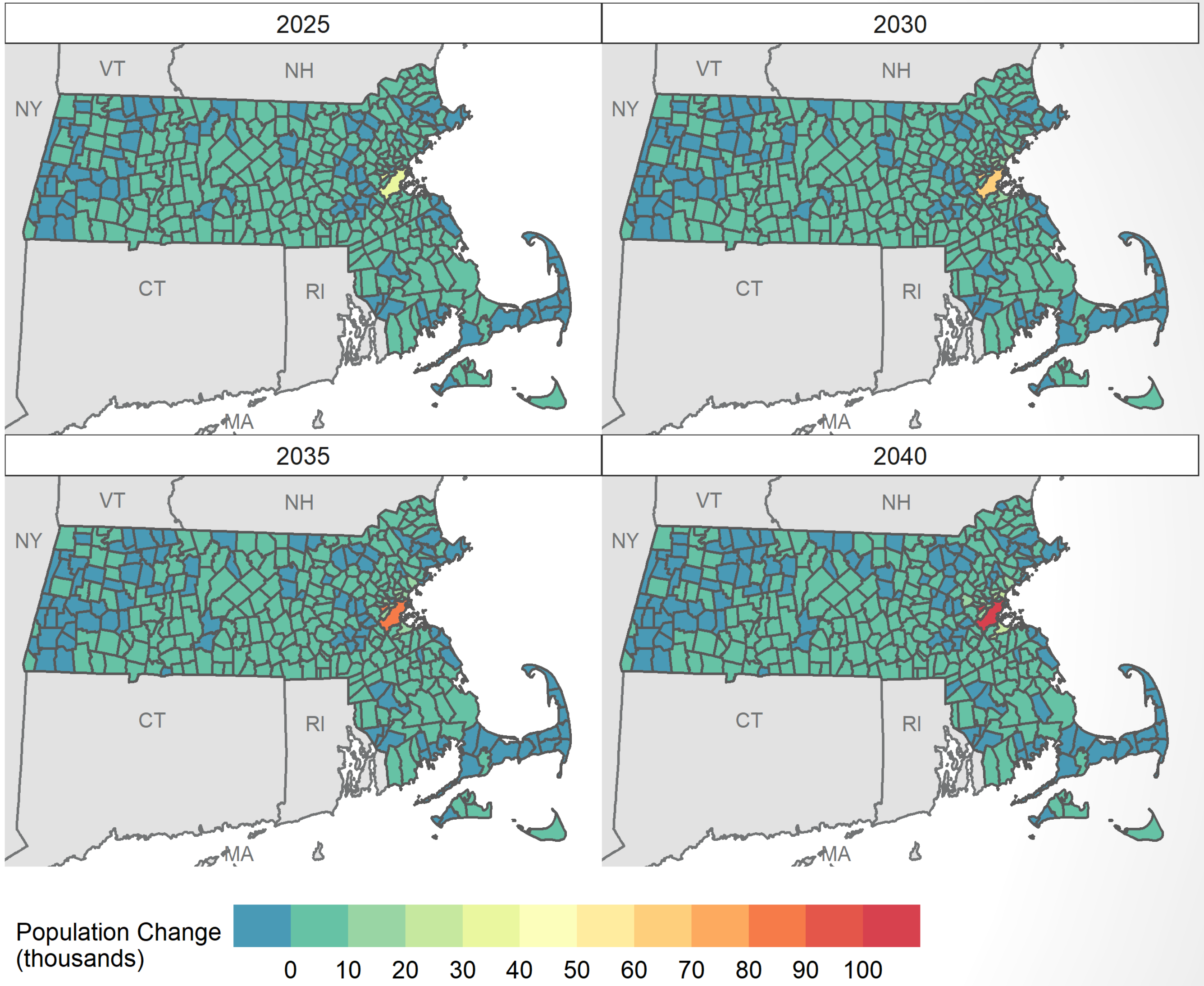
EJ Populations. Data from Massachusetts Bureau of Geographic Information (MassGIS 2021).

All hazards were assessed to determine if the **impacts affected disadvantaged communities disproportionately** using MA EJ Population data and 2020 Census information

Disproportionality is defined as impacted some populations more than others due to **characteristics that make them more vulnerable to risk**

Future Populations

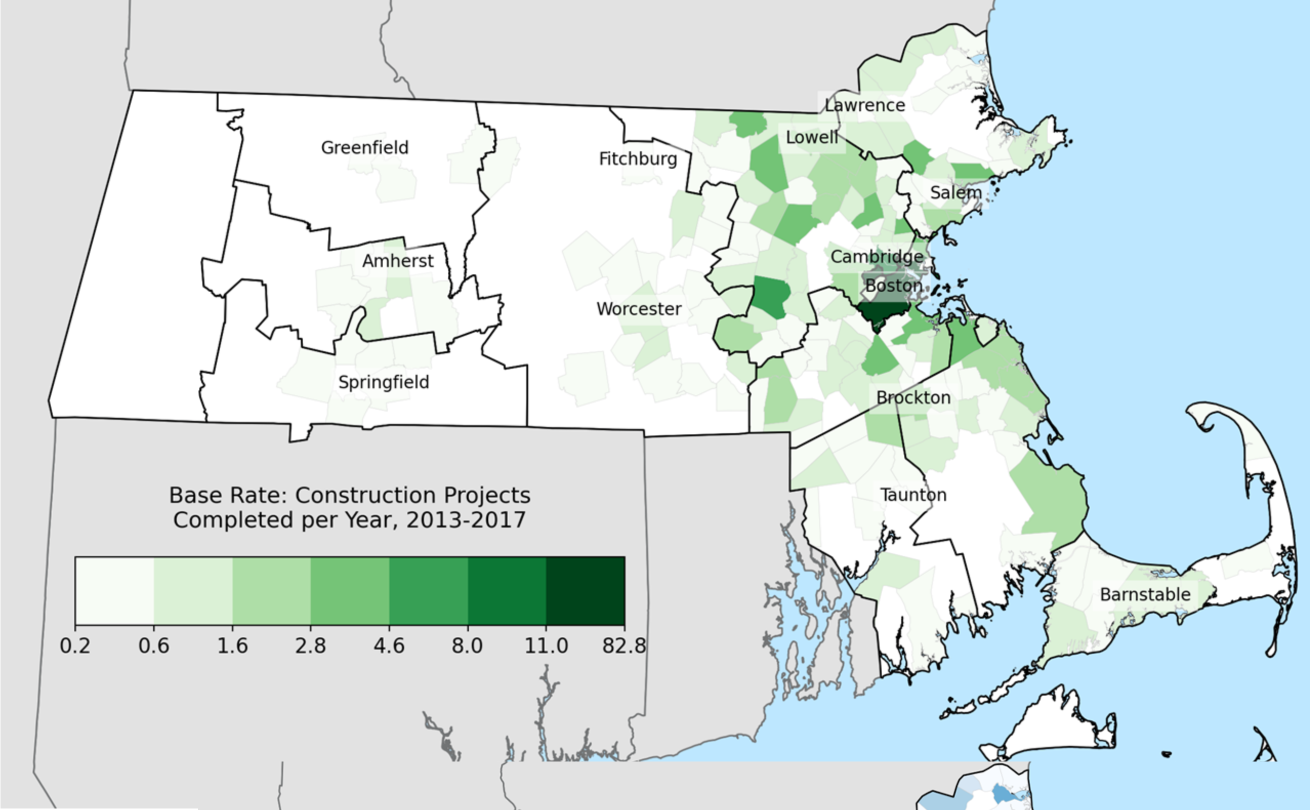
Each hazard was assessed to determine **exposure of future populations to impacts** over four timeframes. Population change in 2025, 2030, 2035, and 2040 was considered to determine where the population exposed is increasing and where it is decreasing

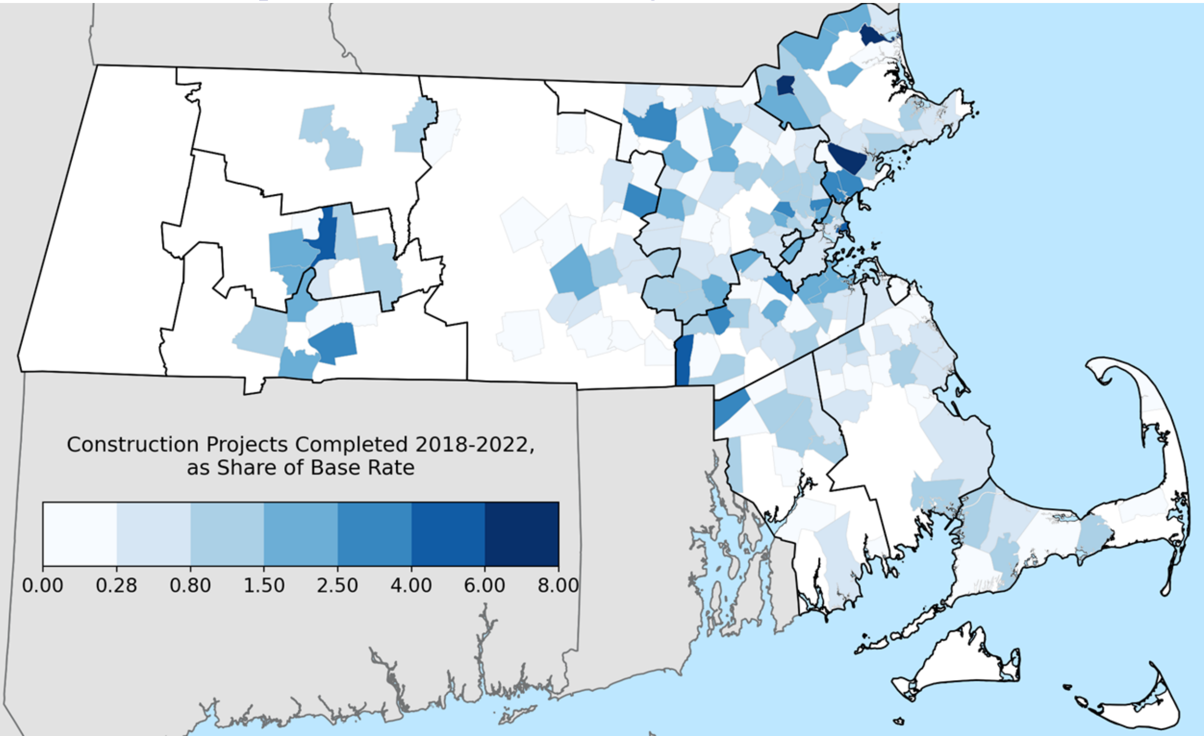


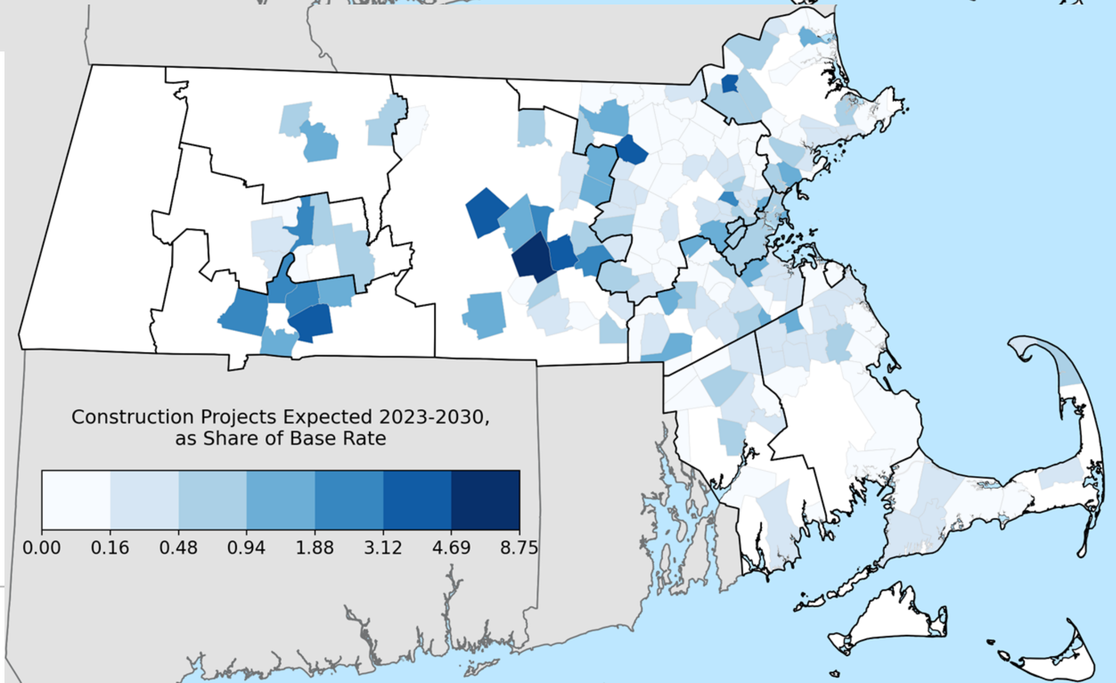
Projected population change. Estimated change in population from 2020, per MCD. MCDs in shaded blue are expected to decrease in population. From UMass Donahue Institute and MassDOT Vintage Population Projections (UMDI-DOT 2018).

Development Patterns

Each hazard was evaluated against data on development trends from three timeframes- 2013 to 2017, 2018 to 2022, and 2023 to 2030 to determine whether areas that are likely to be exposed to hazards **are increasing or decreasing in development density**







2023 SHMCAP Risk Assessment: Hazards

Coastal Erosion

Coastal Flooding and Storm Surge

Dam Overtopping

Drought

Earthquake

Extreme Temperatures

Groundwater Rise

Hurricane Tropical Cyclone

Inland Flooding

Invasive Species

Landslide

Other Severe Weather

Tornado

Tsunami

Wildfire

Winter storms / Nor'easter

Summary of Hazard Events since 2018 SHMCAP

Four Presidential Disaster Declarations

- 3 severe winter storm and flooding events (2 in 2018 and 1 in 2022)
- Covid-19 Pandemic

Between 2018 and 2022, the National Oceanographic and Atmospheric Association (NOAA) listed the following events in Massachusetts (NOAA, 2022):

- 20 coastal flooding events
- 19 tornadoes, with 8 in Worcester County alone
- 27 temperature warnings, with 10 for heat and 17 for cold

Priority Impacts and Vulnerabilities

How do we prioritize the hazards to mitigate?
Which are the most likely or have the highest consequences to MA?

2023 SHMCAP viewed hazards through a priority impact and consequence lens, which considers:

- **Risks with the most significant impacts** from current and future hazards based on climate change projections (magnitude of consequences)
  - *Focus on impacts to human life and health, economy, natural environment, assets, and lifelines*
- The **likelihood to which the hazard is to occur**
  - *How these hazards will have a **disproportional impact** to disadvantaged communities (including EJ populations)*

Priority Impacts and Vulnerabilities = highest consequence impacts from hazards

Coastal Flooding and Storm Surge | Drought | Extreme Temperatures | Inland Flooding | Invasive species | Hurricanes | Winter storms / Nor'easter

slido

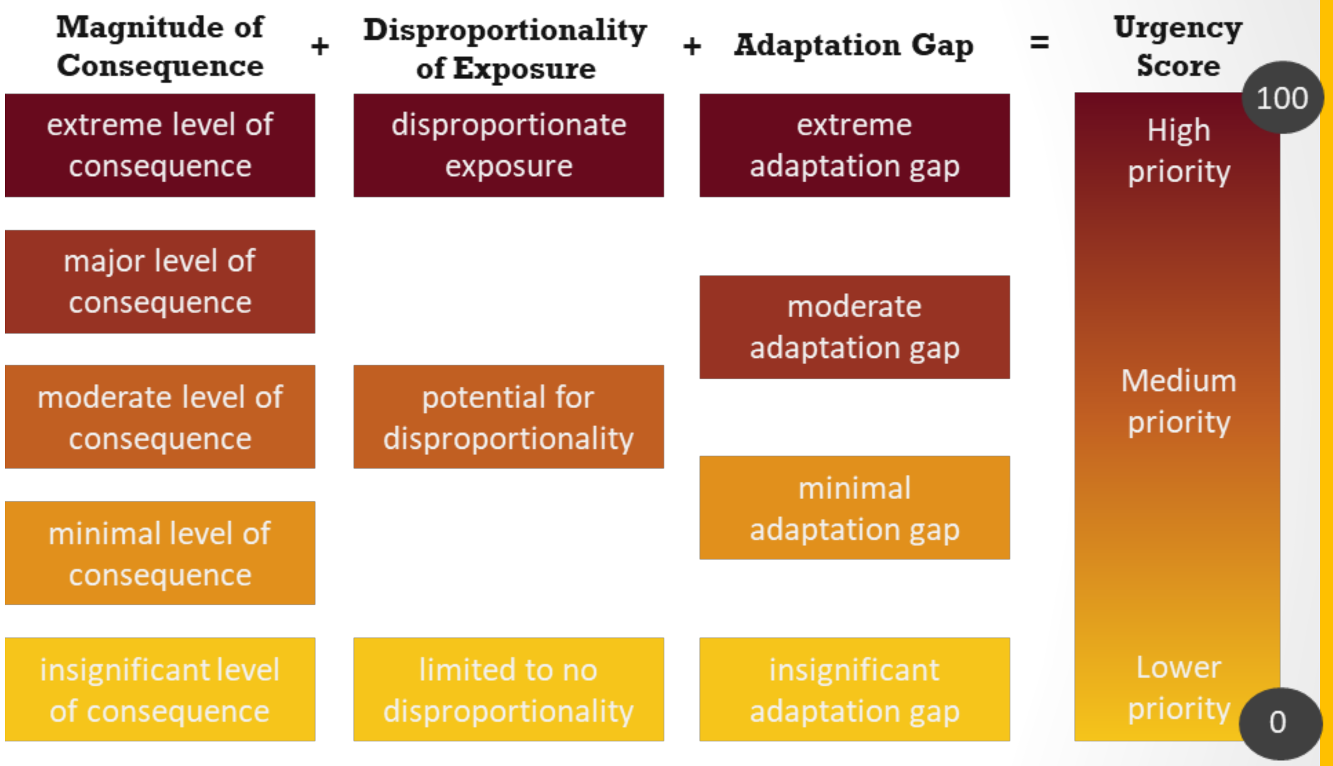
Which top three hazards pose the greatest threat to your community?

ⓘ Start presenting to display the poll results on this slide.

Urgency Assessment Methods

Each impact is assigned an urgency score based on:

- **Magnitude of Consequence:** *How large of a climate effect do we expect from this impact?*
- **Disproportionality of Exposure:** *Will populations living in environmental justice areas be disproportionally affected?*
- **Need for Effective Adaptation:** *Are we currently doing enough to adapt to this impact or are there gaps in effective adaptation actions? How soon is action needed?*
- Component scores are averaged to create Urgency Score



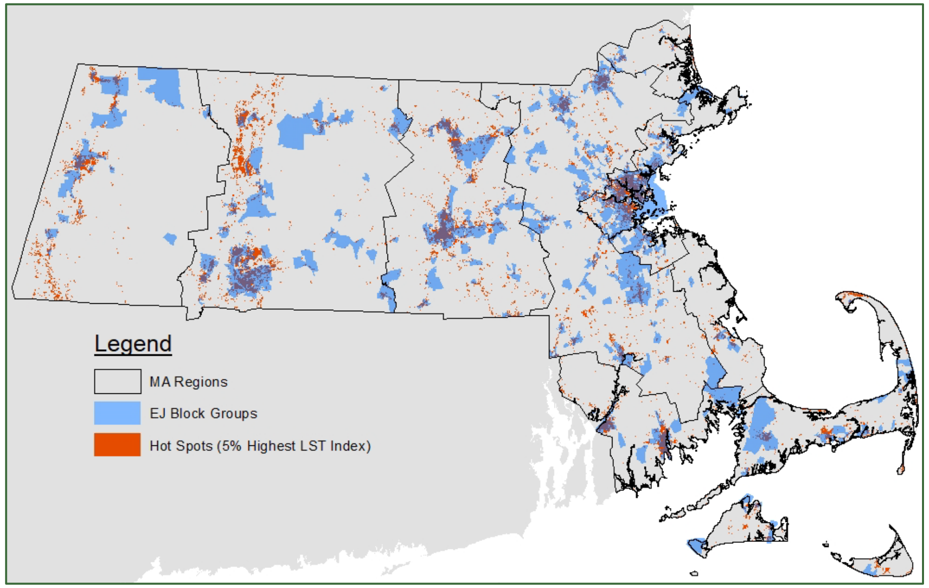
Human Sector

IMPACTS TO PEOPLE'S HEALTH, WELFARE, AND SAFETY

Health and Cognitive Effects from Extreme Heat

Extreme Level of Consequence	Disproportionate Exposure	Moderate Adaptation Gap

- Covers all health aspects of changes in frequency and severity of days with extreme temperatures
- Impacts of extreme heat episodes on:
  - Health
  - Learning
  - Workplace injuries



Health and Cognitive Effects from Extreme Heat

- **Health Effects from Degraded Air Quality**
- **Emergency Service Response Delays and Evacuation Disruptions**
- Reduction in Food Safety and Security
- Increase in Mental Health Stressors
- Health Effects from Aeroallergens and Mold
- Health Effects of Extreme Storms and Power Outages
- Damage to Cultural Resources
- Increase in Vector Borne Diseases Incidence and Bacterial Infections

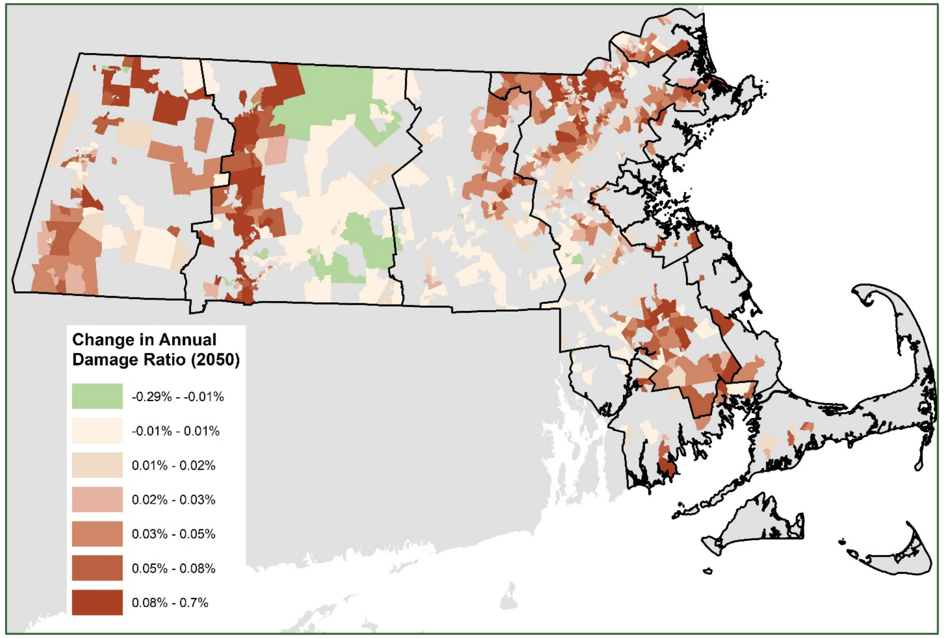
Infrastructure Sector

IMPACTS TO BUILDINGS AND TRANSPORTATION SYSTEMS, AND HOW WE GET OUR ELECTRICITY AND WATER

Damage to Inland Buildings

Major Level of Consequence	Disproportionate Exposure	Moderate Adaptation Gap

Addresses the risk of flooding to inland structures (residential and commercial) from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms, and by rivers affecting buildings in the floodplain (fluvial flooding)



Damage to Inland Buildings

- **Damage to Electric Transmission and Utility Distribution Infrastructure**
- **Damage to Rails and Loss of Rail/Transit Service**
- Loss of Urban Tree Cover
- Damage to Coastal Buildings and Ports
- Reduction in Clean Water Supply
- Damage to Roads and Loss of Road Service
- Loss of Energy Production and Resources

Natural Environment Sector

IMPACTS TO ECOSYSTEMS AND NATURAL RESOURCES, AND HOW PLANTS AND ANIMALS CAN THRIVE HERE

Freshwater Ecosystem Degradation

Extreme Level of Consequence	Potential for Disproportionality	Extreme Adaptation Gap

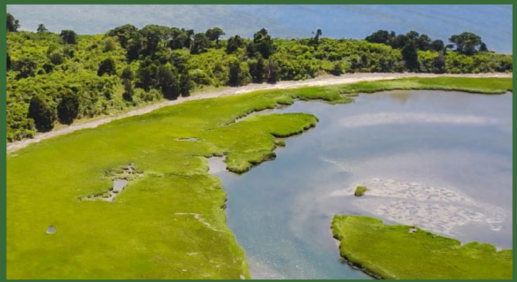
Rising temperature and changing precipitation patterns lead to a reduction in ambient water **quality** and changes in water **quantity**, resulting in changes to habitat quality in rivers, streams, ponds, lakes, and freshwater wetlands

Marine Ecosystem Degradation

Extreme Level of Consequence	Potential for Disproportionality	Extreme Adaptation Gap

Changing **sea surface temperatures**, **ocean acidification**, and **water quality issues** from increased runoff nearshore alter habitat conditions in marine environments leading to changing marine species distribution

- **Freshwater Ecosystem Degradation**
- **Marine Ecosystem Degradation**
- **Coastal Wetland Degradation**
- **Forest Health Degradation**
- Shifting Distribution of Native and Invasive Species
- Coastal Erosion
- Soil Erosion



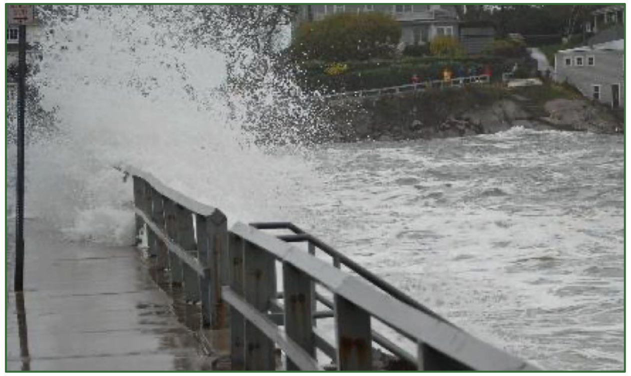
Governance Sector

IMPACTS TO STATE AND LOCAL GOVERNMENT OWNED FACILITIES, GOVERNMENT FINANCES, AND DEMAND ON GOVERNMENT SERVICES

Reduction in State and Municipal Revenues

Major Level of Consequence	Disproportionate Exposure	Moderate Adaptation Gap

- State and municipal revenue streams impacted through:
  - Property tax loss following structure damage of any type, from any hazard, and
  - Income and sales tax losses associated with business interruptions or effects on industrial activities



- **Reduction in State and Municipal Revenues**
- **Increase in Costs of Responding to Climate Migration**
- **Increase in Demand for State and Municipal Government Services**
- Damage to Coastal State and Municipal Buildings and Land
- Increase in Need for State and Municipal Policy Review and Adaptation Coordination
- Damage to Inland State and Municipal Buildings and Land

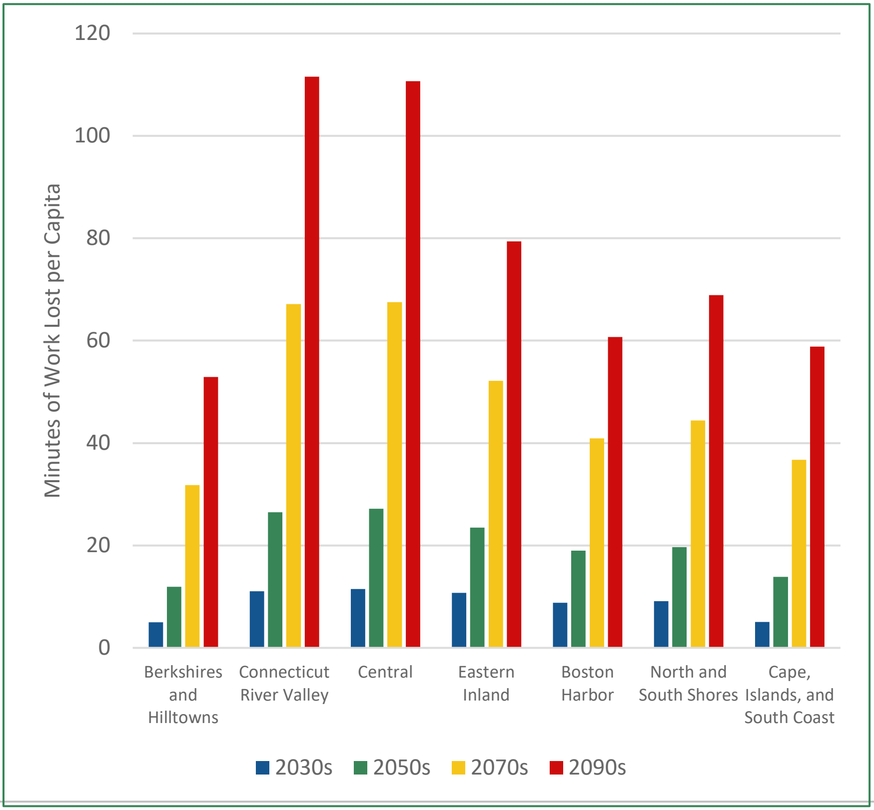
Economy Sector

IMPACTS TO PEOPLE'S ABILITY TO WORK AND MAKE A LIVING, DUE TO DAMAGES TO INFRASTRUCTURE, OUR NATURAL ENVIRONMENT, OR PEOPLE'S HEALTH, AND PEOPLE'S ABILITY TO FIND AFFORDABLY PRICED HOUSING

Reduced Ability to Work

Extreme Level of Consequence	Disproportionate Exposure	Moderate Adaptation Gap

- Workers could be impacted by:
  - More frequent extreme heat days and dangerous work conditions
  - Increasing incidence of climate-induced health effects and associated caretaking
  - Weather-induced disruptions to transportation
- Impacts are felt most by workers in outdoor industries, those who rely on public transportation, and those who care for others at home



Reduced Ability to Work

- **Decrease in Marine Fisheries and Aquaculture Productivity**
- **Reduction in the Availability of Affordably Priced Housing**
- Economic Losses from Commercial Structure Damage and Business Interruptions
- Damage to Tourist Attractions and Recreation Amenities
- Decrease in Agricultural Productivity

Questions and Discussion

Photo: Lance Cheung


Photo: Irena Draksic

Framework and Process for Action Development

2023 SHMCAP Action Approach

Key Information For Action Development

- **Use Priority Impacts and Vulnerabilities to begin action development**
- **Evaluate consistency with 2023 SHMCAP Goals**
- **Design actions that consider or include the following:**
  - High consequence or urgent impacts/vulnerabilities
  - Disadvantaged communities (including EJ populations)
  - Critical assets and community lifelines
  - Preservation and enhancement of biodiversity and ecosystem health
  - Sustainability and climate mitigation
  - Climate change projections and adaptation
  - Effectiveness, feasibility, and environmental soundness
  - Specific assets, locations, and service populations

SHMCAP Action Categories

- Administrative support
- Assessment, research, analysis, science, and mapping
- Capital planning
- Changes to maintenance and operations, replacements
- Funding and financing
- Natural systems protections & enhancements (e.g., conservation, restoration, and management)
- Outreach and education
- Planning and policy
- Regulations, codes, and zoning
- Structure and infrastructure retrofits/new projects
- Technical support and assistance

slido

What types of actions is your community taking to address hazards in your community? (select all that apply)

ⓘ Start presenting to display the poll results on this slide.

SHMCAP Action Scales

Breakout Room Engagement

Actions are designed at different scales. The SHMCAP includes the following scales for actions:

Statewide (or Global) actions are designed to improve resilience across the Commonwealth and often provide support for more specific actions.

Regional and local actions are directed at a specific geographic location and focus on addressing risks within a specific location or set of locations.

Sector and system actions focus on reducing risks to a single sector or system such as transportation or energy or water assets and systems.

Agency specific actions increase resilience and reduce risk to agency assets and services, provide benefits to service populations, and/or build internal capacity.

Focus on Statewide (or Global) Actions

Breakout Room Engagement

Statewide actions, which are also known as global or cross-cutting actions, are actions that include the following attributes:

- ✓ **Multi-agency and/or multi-sector**, including state, municipal and other partners
- ✓ **Addresses risk at a multi-region**, coastwide, and/or statewide scale
- ✓ **Often unlock other actions** and provide capacity or capability for others to take further actions
- ✓ **Can leverage or be leveraged** to enhance local, region, or federal actions and programs
- ✓ **Can be organized around a specific issue**, geographic hotspot, specific assets, or disproportionately affected communities or populations

Why focus on statewide actions?

Statewide actions provide a critical opportunity for state and municipal collaboration, as well as state support for regional, municipal and local agencies and organizations

Statewide Actions Breakout Engagement

Organization and Details

Details of breakout rooms based on action type:

- Four rooms with the following action categories: Funding & Finance; Collaboration, Engagement & Education; Assessment & Research; and Strategy, Planning & Codes
- Participants will review proposed 2023 SHMCAP statewide actions and respond to these questions:
  - ✓ **Does the action address the types of risks that your community is concerned about?**
  - ✓ **Are there ways to improve the action to better assist your community?**
  - ✓ **Are there other actions you'd like to see the Commonwealth take to reduce risks and increase resilience in your community?**

2023 SHMCAP Statewide Action Breakout Group Sharing

Breakout Room Facilitators Share Take-aways from their Breakout Sessions


Photo: Matt Moloney

After today, feedback can be shared by:

- Jamboards will remain open until **April 13th**
- Emailing lindy.lowe@erg.com **by April 13th**

Breakout Group 1

Breakout 1: Funding & Finance

Action Title	Action Description	Lead Agency	Support Agency
Increase funding to support municipal and agency resilience actions	Increase funding to municipal and agency resilience actions. For example, launch revamped Municipal Vulnerability Preparedness Planning Grant program ("MVP 2.0") to build community capacity around social resilience and equity, reset priorities with input from those most impacted by climate change, and facilitate the transition from planning to action. Increase funding to agency SHMCAP implementation.	EOEEA	MEMA
Create a grant funding score card	Build out climate resilience metrics that the Commonwealth can use to track progress statewide. Develop a score card to be completed by localities when looking at grant funding. The state can use this information to identify which areas are applying for funding and identify priorities.	EOA&F	EEA, MEMA, DCR, A&F, DPU, HED, and DPH
Develop new revenue stream for climate action implementation	Develop a long term and sustainable new revenue stream to support climate resilience state and local implementation.	EOA&F	EEA, MEMA, DCR, A&F, DPU, HED, and DPH
Develop a searchable list of state funding opportunities	Develop an updated and searchable list of available state grant programs to align funding sources and leverage multiple benefits in resilience and community health.	EOEEA	EEA, MEMA, DCR, A&F, DPU, HED, and DPH
Mobile solar energy systems	Shift from generators to investments in mobile solar energy storage systems that can be used during emergencies.	EOEEA	DOER, MassDEP, and MEMA

Breakout 1: Funding & Finance [internal slide for PMT awareness]

Action Review

Share Jamboard:

- Actions will be listed on the jamboard, with a slide for each action. The slide will present three questions, including:
  - Does the action address the types of risks that your community is concerned about?
  - Are there ways to improve the action to better assist your community?
  - Are there other actions you'd like to see the Commonwealth take to reduce risks and increase resilience in your community?

Breakout Group 2

Breakout 2: Collaboration, Engagement & Education

Action Title	Action Description	Lead Agency	Supporting Agencies
Launch an Office of Climate Science	Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on statewide climate data and models and supports consistent application across agencies. Incorporate data for environmental justice, equity, and vulnerable populations. Identify opportunities to partner with universities on climate science.	EOEEA	EOE, DCR, MEMA, CZM, DEP, MassWildlife, DPU, DPH, A&F, and DCAMM
Convene a climate resilience stakeholder working group	Increase stakeholder engagement and partnership for resilience programs: Convene a climate resilience stakeholder working group to inform and guide resilience action and priorities.	EOEEA	DCR, MEMA, CZM, DEP, MassWildlife, DPU, DPH, and A&F
Update school curriculum to include climate science and workforce	Update the school curriculum to assist the next generation in understanding and developing skills needed to enter the workforce doing climate work.	EOE	
Regional Climate Task Force	Consider regional context when discussing state efforts, as some of these actions may result in effects across state boundaries.	EOEEA	DCR, MEMA, CZM, DEP, MassWildlife, DPU, DPH, and A&F
Identify a statewide adaptation framework	Develop a statewide adaptation framework and associated metrics to help guide actions with concrete deadlines and quantities, use this approach to also track progress toward resilience goals. By focusing on the metrics and outcomes, targets and goals can be developed, accordingly.	EOEEA	MEMA, DCR, DEP, HED, CZM, DCAMM, A&F, DPU, and OPSI
Promote more watershed-based efforts	Promote more watershed-based efforts.	EOEEA	DCR, DEP, MassWildlife, DPH, DPU, and MDAR

Breakout 2: Collaboration, Engagement & Education [internal slide for PMT awareness]

Action Review

Share Jamboard:

- Actions will be listed on the jamboard, with a slide for each action. The slide will present three questions, including:
    - Does the action address the types of risks that your community is concerned about?
    - Are there ways to improve the action to better assist your community?
    - Are there other actions you'd like to see the Commonwealth take to reduce risks and increase resilience in your community?

Breakout Group 3

Breakout 3: Assessment & Research

Action Title	Action Description	Lead Agency	Support Agencies
Conduct a statewide loss avoidance study	Conduct a statewide loss avoidance study to help quantify the losses avoided (e.g., damage prevented or benefits) and ecosystem service benefits due to the implementation of the Commonwealth's hazard mitigation and climate adaptation projects and run scenarios of the different risks and vulnerabilities associated with varying implementation strategies. Develop a strategy for coordinating property acquisition and structure elevation based on the loss avoidance study.	EOEEA	DCR, MEMA, CZM, DEP, MassWildlife, DPH, DPU, DCAMM, MDAR, OPSI, and A&F
Conduct groundwater vulnerability assessment	Assess vulnerability of groundwater resources to drought across Massachusetts.	EOHHS	MassDEP, MDA, DPH, MDAR, and DEP
Develop a framework for evaluating impacts of agency actions on socially vulnerable populations and affordable housing	Develop a framework for evaluating impacts of agency actions on socially vulnerable populations and affordable housing. Obtain guidance and training (potentially from social scientists) on how to incorporate recommendations for socially vulnerable populations. Consult with the state's new EJ office on resources. Develop guidance for assessments (e.g., how Environmental Justice is being addressed in MEPA permitting), data resources, and community engagement policies. Incorporate existing resources like DPH's Environmental Justice Tool. Clearly define and use common terminology when referring to "disadvantaged communities".	EOEEA (or EOHHS)?	HED, A&F, all other agencies
Develop a statewide floodplain management framework	Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts. Identify a method for communication across multiple agencies: who is doing what in the floodplain and where? What regulations, policies, and building codes exist among agencies that could be leveraged for multiple benefits and enhance floodplain restoration across the state? Identify collaborative efforts to fund and increase the inventory of floodplain easements. Ensure the most current data for floodplain boundaries are used across entities. Based on this framework and improved floodplain management approach, identify flood-vulnerable communities and identify the best mitigation measures for flood loss reduction.	EOEEA	DCR, MEMA, CZM, DEP, MassWildlife, DPH, DPU, MDAR, OPSI, and A&F
Develop and implement a new Heat Flag System	Identify methods to obtain additional data on heat and ways to effectively communicate heat risk to the public across agencies. Develop and implement new Heat Flag system in alignment with NOAA's Heat Advisory Criteria for New England, to identify days of extreme heat to urge preparedness and caution to people outdoors, particularly children, elderly.	EOHHS	DPH, DCR, DCAMM, DLS, and HED

Breakout 3: Assessment & Research [internal slide for PMT awareness]

Action Review

Share Jamboard:

- Actions will be listed on the jamboard, with a slide for each action. The slide will present three questions, including:
    - Does the action address the types of risks that your community is concerned about?
    - Are there ways to improve the action to better assist your community?
    - Are there other actions you'd like to see the Commonwealth take to reduce risks and increase resilience in your community?

Breakout Group 4

Breakout 4: Strategy, Planning & Codes

Action Title	Action Description	Lead Agency	Support Agencies
Protect 30 percent of land and ocean by 2023 (to align with the global 30x30 goal)	Implement EEA's Resilient Lands Initiative and incorporate the Healthy Soils Action Plan. Develop a statewide approach and collaborative efforts to preserve and enhance forest health and conservation to enhance resilience and provide carbon sinks for GHG mitigation. Also incorporate coastal vegetation, like seagrasses. Ultimately strive to have 30 percent of land and ocean protected by 2023 (to align with the global 30x30 goal). Evaluate the role of the private sector and the ability to support work on private land. Specifically, develop an approach to combine public/private initiatives for intersecting projects that are constrained by private property ownership.	EOEEA	DCR, MEMA, CZM, DEP, MassWildlife, DPH, DPU, MDAR, and A&F
Amend building codes for resilience	Develop a strategy to amend building codes to enhance resilience.	EOHED	DCAMM, HED, and OPSI
Develop a coastal resilience strategy	Develop a coastal resilience strategy that considers climate adaptation and climate migration, including managed retreat. Prioritize retreat from vulnerable coastal areas. Consider shoreline migration and other areas migration inland for both people and habitats.	EOEEA	CZM, DCR, MEMA, MassDEP, and MassWildlife
Develop a local-option floodplain building stretch code	Develop an above-code appendix, or "stretch code," for floodplain construction under the MA state building code that municipalities may adopt to produce buildings that are more resilient to climate risks than those constructed to the "base" MA state building code.	EOEEA	HED
Incorporate resilience to extreme heat into the Sanitary Code	Review the State Sanitary Code for opportunities to incorporate resilience to extreme heat in residential buildings to reduce risks for remote workers, especially the shortening of the annual time period during which minimum temperatures must be maintained (e.g., "heating season").	HHS	HED, DHCD
Develop a Post Disaster Redevelopment Plan	Develop a Post Disaster Redevelopment Plan.	EOEEA	MEMA, DCR, DEP, HED, CZM, DCAMM, A&F, DPU, and OPSI
Coastal building codes, regulations, and solutions	Mitigate damage to coastal buildings and ports via building codes, regulations, and structural solutions.	EOHED	DCAMM, HED, and CZM

Breakout 4: Strategy, Planning & Codes [internal slide for PMT awareness]

Action Review

Share Jamboard:

- Actions will be listed on the jamboard, with a slide for each action. The slide will present three questions, including:
  - Does the action address the types of risks that your community is concerned about?
  - Are there ways to improve the action to better assist your community?
  - Are there other actions you'd like to see the Commonwealth take to reduce risks and increase resilience in your community?


Photo: Wikimedia Commons

Wrap Up and Next Steps

Next Steps

Gathered input and recommendations during today's meeting (THANK YOU!)

- Will gather additional input and recommendations at second stakeholder meeting on April 6th

Work with Commonwealth agencies to incorporate input and recommendations into statewide actions

Jamboards will be available until April 13, 2023 for additional feedback.

- Funding & Finance Jamboard
- Collaboration, Engagement & Education Jamboard
- Assessment & Research Jamboard
- Strategy, Planning & Codes Jamboard

2023 SHMCAP Process and Timeline

1. State agencies obtain approval of final list of proposed actions by end of **April 2023**
2. Finalize 2023 SHMCAP actions and strategy by **early May**, Governors' Office review completed by **June 2023**
3. Draft to FEMA for review in **June 2023**
4. Final approved 2023 SHMCAP released in **Fall 2023**

For any additional questions or feedback, please contact:

- **Marybeth Groff**, MA Emergency Management Agency
  - 508-820-1435 or marybeth.groff@state.ma.us
- **Mia Mansfield**, MA Executive Office of Energy and Environmental Affairs
  - 857-338-4392 or mia.mansfield@state.ma.us
- **Lindy Lowe**, ERG
  - 510-290-9885 or lindy.lowe@erg.com

Feedback from Municipalities, Regional Planning Agencies, Non-government Organizations, Communities, and Others on Proposed Draft Cross-government Actions obtained during Stakeholder Meetings on April 4 and 6, 2023.

Proposed Cross-government Action	Feedback from Municipalities, Regional Planning Agencies, Non-government Organizations, Communities, and Others
Category: Assessment and Research	
Conduct a statewide loss avoidance study to help quantify the losses avoided (e.g., damage prevented or benefits) and ecosystem service benefits due to the implementation of the Commonwealth's hazard mitigation and climate adaptation projects and run scenarios of the different risks and vulnerabilities associated with varying implementation strategies. Develop a strategy for coordinating property acquisition and structure elevation based on the loss avoidance study.	• This action should account for infrastructure losses. • Suggest making all steps and data involved in this analysis available for municipalities to use for their own planning processes that can be tailored to their local needs. • Suggest incorporating public engagement in small communities as part of this analysis. It is important to learn about what their costs have been thus far and what they anticipate future damages to be. • Quantifying benefits will help communities in developing benefit-cost analyses for FEMA projects. • Suggest incorporating saltmarsh working group research priorities • We need better inland (non-coastal) flood modelling, not only on major rivers but also smaller, flashier systems in the western part of the state. • This action should prioritize equity for vulnerable populations.
Conduct groundwater vulnerability assessment to assess drought across Massachusetts.	• My organization is interested in improving metrics of vulnerability associated with this action. • Dartmouth has experienced aquifer protection issues. • My organization is concerned about water resource availability. • Non-metered customers need assistance. • This action is very needed. We are interested in metrics, as water supply issues are acute (Ipswich). Need help identifying impacts to water supply for customers that are not metered.
Develop a framework for evaluating impacts of agency actions on socially vulnerable populations and affordable housing. Obtain guidance and training (potentially from social scientists) on how to incorporate recommendations for socially vulnerable populations. Consult with the state's new EJ office on resources. Develop guidance for	• Cape Cod has a climate equity plan, we could use training and would benefit from partnering with the state. • My organization is excited to see this action here. We don't seem to have a lot of demonstrative actions surrounding this. • State should be able to step in if a project is having adverse climate impact or impact on EJ communities.

assessments (e.g., how Environmental Justice is being addressed in MEPA permitting), data resources, and community engagement policies. Incorporate existing resources like DPH's Environmental Justice Tool. Clearly define and use common terminology when referring to "disadvantaged communities".	• Suggest including guidance, training, and state partnership about how to do this. • Suggest using or developing communications frameworks to help with messaging. Partner with regional planning agency. • Create a communications framework - add language and the messaging to support this from equity perspective.
Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth that considers climate change data and impacts. Identify a method for communication across multiple agencies: who is doing what in the floodplain and where? What regulations, policies, and building codes exist among agencies that could be leveraged for multiple benefits and enhance floodplain restoration across the state? Identify collaborative efforts to fund and increase the inventory of floodplain easements. Ensure the most current data for floodplain boundaries are used across entities. Based on this framework and improved floodplain management approach, identify flood-vulnerable communities and identify the best mitigation measures for flood loss reduction.	• The current approach is archaic, top down, federal level decision and local communities need to adapt change. • Developing model floodplain regulations is of interest to many communities. This would be helpful for the Cape. • For floodplain studies, the FEMA Flood Maps should be updated more frequently than every 40 years. More focus on mapping floodplains would be helpful. • The FIRM still has so many A Zones without elevations. Municipalities hiring engineers to update the FIRM is expensive and FEMA doesn't always accept their approaches. • Include floodplain managers as a support agency. • Provide funding to update our FIRMs or sections of the FIRM without elevations. • Suggest this action include working with conservation commission, who routinely administer wetland protection act and floodplain regulations.
Develop and implement a new Heat Flag System. Identify methods to obtain additional data on heat and ways to effectively communicate heat risk to the public across agencies. Develop and implement new Heat Flag system in alignment with NOAA's Heat Advisory Criteria for New England, to identify days of extreme heat to urge preparedness and caution to people outdoors, particularly children, elderly.	• This is lower priority - communities already have heat warnings in effect
Category: Funding and Financing	
Increase funding to support municipal and agency resilience actions. Increase funding to municipal and agency	• Yes, there is a high need for increased funding for municipalities AND DCR, MassDOT, and DCAMM.

resilience actions. For example, launch revamped Municipal Vulnerability Preparedness Planning Grant program (“MVP 2.0”) to build community capacity around social resilience and equity, reset priorities with input from those most impacted by climate change, and facilitate the transition from planning to action. Increase funding to agency SHMCAP implementation.	• Expand the type of funding the Municipal Vulnerability Preparedness (MVP) program offers. Suggest providing funding for a broader range of approvable projects. • Increase the amount of money available to any one project. • Provide funding for implementation (monetary needs usually greater). • The 10% match is prohibitive. MVP match has non state funding requirements. • Increase the total amount of funding to the MVP program to be able to fund more projects. • Foster innovative thinking through permitting and funding support. • The application and management of MVP prevents small communities with limited staff from participating. • Our organization lacks the technical staff to help complete MVP applications. • Need to fill gap where many communities that need funding don't have resources to apply. How to get them the resources to be able to apply. Need to also have resources to manage a grant. • Suggest creating a list or matrix that helps communities identify funding sources. • Would be helpful to have more resources at the state level. • Suggest government agency or municipality partnering with community-based organizations. • Importance of cultivating a greater awareness of flooding potential in communities. • The new options for non-profits to initiate/run projects is great (CZM/MVP). However, municipal support creates potential for competition for limited resources. • Consider adjusting match requirements to account for smaller communities. • CT has a program to help communities get FEMA ready. A separate grant window should be created for this purpose in MA with support for BCAs, EHP, etc. • Create a separate grant window for non-profits that does not compete with municipalities for the same pot of money.

Create a grant funding score card. Build out climate resilience metrics that the Commonwealth can use to track progress statewide. Develop a score card to be completed by localities when looking at grant funding. The state can use this information to identify which areas are applying for funding and identify priorities.	• This action is much needed to address the risks my community is facing. • This action should include a comprehensive list of available grants. • This does not seem like a priority to my organization. It is unclear what the benefit would be for communities. • Suggest using MassWorks approach to look at cost of inaction. Could look at protection of evacuation routes and critical infrastructure. • Create dashboard application to easily organize and pull out actions. • Scorecard that is simple for participants to use. • Having to go through COMMBUYS can be difficult at times. • Tying so many resiliency implementation efforts to competitive grants prevents the smallest communities from participating, they need regional resources. • Suggest providing direct funding to planning commissions and council of governments to distribute regionally. • Consider making awarded grant applications available for better public review.
Develop new revenue stream for climate action implementation. Develop a long term and sustainable new revenue stream to support climate resilience state and local implementation.	• In MA the Towns must have the full funding for the grant upfront because they are usually reimbursable, but this is hard for Towns to do when we're talking about millions of dollars. • Suggest that this action make funding clear and easily obtainable. • Yes, coastal resilience projects are not cheap and hard to fund. • Yes, this is definitely needed. Governor Baker's proposal was a good start. • Yes, DCR is underfunded to do what it needs to do on its property to provide regional resilience, too much of its time/money spent on roads - give them to MassDOT. • Suggest incorporating planning assistance efforts to provide funding for studies of what local storm water utility enterprise funds might look like for individual communities. • Half of Hawley is DCR state owned lands. PILOT is insufficient. Payment in lieu of taxes PILOT.

	• Make it easy to use the new revenue stream without having to jump through hurdles. • Resources for culverts are needed to make community wide improvements in a short time. Otherwise, it takes years to replace a few problematic culverts and decades for all. • Suggest that a percentage of funds generated by a community is earmarked for that community. • Hawley has 350 people and 430 culverts. 100 year upgrade of culverts to meet climate goals. • Create similar opportunities to the state revolving fund that may provided zero interest loans to communities. • A new agency/authority with the ability to raise revenue and bond is needed for coastal resilience, see Boston Globe article.
Develop a searchable list of state funding opportunities. Develop an updated and searchable list of available state grant programs to align funding sources and leverage multiple benefits in resilience and community health.	• Ensure the searchable list is easy to access and understand. • Full-time staff are necessary for successful grant work. • Yes, seems like an easy win, not sure it warrants being an action in a 2030 target year plan given the other pressing issues. • Regional planning organizations should be included as a potential partner. • This would be a big help. We have many opportunities but limited people to apply for the grants. • Allow state agencies to take a broader look at innovative solutions that don't perfectly align with their agency goals. • Offer workshops, free consulting, targeted technical assistance for municipal officials to better understand and access the large federal funds, they won’t last forever.
Mobile solar energy systems. Shift from generators to investments in mobile solar energy storage systems that can be used during emergencies.	• Yes. Would be helpful to have funding to help shelters and schools transition to solar panels, etc. • Utility providers in MA have control over implementation of microgrids, that creates challenges. • Consider microgrids at community areas that could be potential shelters.

	• Ensure that emergency generators can function as intended. Have solar first, but also back up.
Category: Collaboration, Engagement, and Education	
Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on statewide climate data and models and supports consistent application across agencies. Incorporate data for environmental justice, equity, and vulnerable populations. Identify opportunities to partner with universities on climate science.	• My organization feels there is an overwhelming amount of information. Consider how this office would help us narrow down cull information to inform decisions. • I think resilience is a very important and useful framework to take because it considers important adaptations. • Question: Do you feel like there is a sufficient understanding of why resilience is an important system of thinking verses other concepts of sustainability? • Incorporate clearinghouse consolidating and accessibility into this action. • Make the information concise. Sometimes there is too much information. • Translate what is important to know from the data sources. For example, regarding weather, there was a state weather person that helped explain the data. • Suggest that the Office of Climate Science be a one stop shop for cities and towns to access the information they need (ex. everyone has indexes CDC, EJ, cross referencing). • Look at piloting programs so that towns have a sample climate solution that has actually been permitted in the state.
Convene a climate resilience stakeholder working group. Increase stakeholder engagement and partnership for resilience programs: Convene a climate resilience stakeholder working group to inform and guide resilience action and priorities.	• This action should include EJ and consider many things, like aging. • Should ensure the working group is expanded so its not the same people who feel they already have a voice (ipswich). • I appreciate the resilience theory as opposed to other ideas like climate science. ex- resilience theory- adaptation, regime shift, sustainability. • There is a lot of potential for a working group to help coordinate stakeholder engagement. • The framing is important to consider, starting same page about framework and goals.

	• Engage a diverse group of stakeholders - don't just get the same seven people who are already heard by the system. • Recommend annual (or more frequent) priority-setting and tracking, this can help keep these groups on track to meet their goals. • Boston already has experience - challenge for scope creep. • Ensure climate justice is aligned and integrated into this structure.
Update school curriculum to include climate science and workforce to assist the next generation in understanding and developing skills needed to enter the workforce doing climate work.	• Needs to advocate at a very high level, pilot programs with controls around them (not limited by situations where regulations have not kept pace). • I like the support for vulnerable populations. EJ can be challenging, what to do if you are not a designated EJ but have justice issues? How can we advance that even if we don’t have enough of those? • Need to be able to act before the process and regulations catch up.
Regional Climate Task Force. Consider regional context when discussing state efforts, as some of these actions may result in effects across state boundaries.	• Regional task force to coordinate across state boundaries would be helpful.
Develop a statewide adaptation framework and associated metrics to help guide actions with concrete deadlines and quantities, use this approach to also track progress toward resilience goals. By focusing on the metrics and outcomes, targets and goals can be developed, accordingly.	• In particular, it would be extremely useful to have shared resources across the state in regard to agriculture on a local level.
Promote more watershed-based efforts.	• Maybe expand on what is meant by "efforts"? watershed collaborative groups only? • This approach has worked in Essex. • Yes, this has shown to be successful in the Mystic watershed. Support should be scaled up and replicated. • Suggest providing outreach to and uplifting watershed-level activities that are already happening through local watershed groups. • Have watershed restoration plans with climate change in mind. • Suggest funding /empowering watershed groups to work with municipalities.

	• Suggest empowering/facilitating watershed organizations building relationships and partnerships with planners/planning boards, DPW directors, con coms, etc.
Category: Strategy, Planning, and Codes	
Protect 30 percent of land and ocean by 2030 (to align with the global 30x30 goal). Implement EEA's Resilient Lands Initiative and incorporate the Healthy Soils Action Plan. Develop a statewide approach and collaborative efforts to preserve and enhance forest health and conservation to enhance resilience and provide carbon sinks for GHG mitigation. Also incorporate coastal vegetation, like seagrasses. Ultimately strive to have 30 percent of land and ocean protected by 2030 (to align with the global 30x30 goal). Evaluate the role of the private sector and the ability to support work on private land. Specifically, develop an approach to combine public/private initiatives for intersecting projects that are constrained by private property ownership.	• Yes, seagrass! Like interagency approach to include perspectives on ecological value, fishing industry, permitting new development, water quality issues. • Some plan needs to be made to connect the preserved lands. A checkerboard of 30% will not allow necessary wildlife movement to benefit from preserved land. • It's a good start to addressing risks my community is concerned about. • Yes, land protection and ocean resource protection are important actions in the Cape Cod Regional Policy Plan. • Seagrasses are important to include - could be better coordinated at a state level. • May be useful to split this into inland and coastal, with discrete examples for each. • Protection in excess of 30% is appropriate for some areas. • Tie this to the land acquisition goals identified by Biomap. • Communities that are already at 30% should be encouraged to achieve 50%. • It is broad and a narrower focus or breaking it into smaller goals might be helpful. • Ease the OSRP requirements so that we only have to spend time addressing the items that actually go into preserving land, instead of all the extras. The OSRP is required for state fund. • Work with the CCC to identify priority land & ocean resources. • Having redundancy in staffing would be important to make sure the strategy is effective. • Could be more strategic coordination between state and local agencies. • I think that "protected" land means protected from development, but what isn't clear is who owns the land and who has rights to enjoy it. It should be public or free access.

	• Consistent minimum protections for all communities and targeted enhanced protection on high quality habitats. • Improve process for regulatory review and permitting for pilot climate adaptation and ecological restoration projects (ex. cranberry bog or saltmarsh restoration). • Clarify that Article 97 land CAN be used for public resiliency needs (green infrastructure, flood protection) as one acceptable open space use/function. • Protected DCR land must be understood to have a role in building coastal and inland flood and heat resilience. DCR needs to embrace it proactively as a resource management goal.
Amend building codes to enhance resilience.	• Yes, given some flexibility to deal with historic resources. • Yes, communities (and regulatory agencies) are having to work around BBRS' failure of leadership on this, and the result is an emerging zoning patchwork and convoluted regs. • Yes, CRS discounts are limited because of the state's low building code rating. • Amend building codes to enhance resilience... and then giving examples might make it more action oriented. • This action needs greater specificity. • There should be upfront coordination between state agencies to provide consistency. • Continue to promote sustainable energy efficiency rebate/incentive programs like MassSave and similar state programs. • Maybe term it “resiliency stretch code”. • This action should consider resilient incentives. • Develop training for local building inspectors on floodplain codes. • Need for policy/set of best practices for businesses to have climate resilience or preparedness plan. Many facilities have hazardous materials stored. • Boston buildings are required to be LEED Gold level - should we adopt that at the state level? Regional priority credits.

	• Urban vs. rural areas in MA have different priorities and issues. If there are incentives built into the code to address housing vertically that might help. • Just amend the building code, don't develop a strategy to amend it. A floodplain stretch code is one example of an amendment, not a separate strategy. • Expand culvert replacement grant programs and Division of Ecological Restoration funding programs. • Getting local public input to try to better understand the challenges that individual communities face. • Introduce a statewide buyout program or funding program with specific guidelines and requirements.
Develop a coastal resilience strategy. Develop a coastal resilience strategy that considers climate adaptation and climate migration, including managed retreat. Prioritize retreat from vulnerable coastal areas. Consider shoreline migration and other areas migrating inland for both people and habitats.	• Yes, absolutely on Nantucket. • My community is concerned about how to remain accessible when the single access causeway through a marsh to our neighbourhood becomes inaccessible, not retreat. • Tie this to a strategic timeline - by when does it make sense to start retreating in some areas vs others? • Managed retreat might need to be considered for urban interphase area re: wildfire-prone areas. • The state needs to update their laws/bylaws so that projects can happen at the Town level and not be shot down at the state level. • These adaptation strategies can be costly, financial support at a state level would be great. • Coastal resilience strategy should be integrated with 30 x 30 goal – opportunity to preserve places that might be vulnerable to flooding or serve as saltmarsh migration pathways. • Prioritizing retreat should be led locally by residents, based on equity/best practices, not a top down plan. Elected officials should lead state retreat policy not agency staff. • Instead consider providing a specific grant window and technical assistance (mediators, etc.) for communities that want to start looking at retreat.

	• Create structures that allow communities and residents to choose retreat. SLR already provides enough pressure to retreat, government just needs to make it a viable option. • Make more state funding available for smaller communities. • Update regulations to allow for coastal resilience projects. • State agencies goals can be in conflict at times ways to prioritize resiliency to overcome these conflicts are needed. • Reform legislation and regulations to enable implementation of nature-based and hybrid coastal resilience strategies.
Develop a local-option floodplain building stretch code for floodplain construction under the MA state building code that municipalities may adopt to produce buildings that are more resilient to climate risks than those constructed to the "base" MA state building code.	• Yes, inland flooding is a real concern for most of our towns and their residents. • Our community is asking many questions about stretch codes. More specificity is needed. • This is excellent! More specific than, but a bit redundant with, the previous update building code action. • elaborate to include benefits to communities with adoption • Need to add revisions to adequately address mold and chronic dampness in the state sanitary code (it already exists in housing code but needs to be strengthened). • Would be helpful to have a local option floodplain stretch code. • Would be helpful to have a template - communities that are FEMA adopted that have flood maps have a floodplain ordinance. • There is a risk that this furthers inequities in adaptation between wealthier and poorer communities. A statewide strengthened code would reduce this risk
Incorporate resilience to extreme heat into the Sanitary Code. Review the State Sanitary Code for opportunities to incorporate resilience to extreme heat in residential buildings to reduce risks for remote workers, especially the shortening of the annual time period during which minimum temperatures must be maintained (e.g., “heating season”).	• Sanitary code refers to the housing code - clarify this so that folks have more context. • Need to add revisions to adequately address mold and dampness and stipulations to prevent moisture intrusion in the state sanitary code. • This action is unclear - which part of the sanitary code is being referenced?

	• Sanitary Code relationship with septic systems - how does this work with residential buildings? Clarify the language. What section of the code is this referring to? • MA gets a lot of heat and cold - if we're looking at extreme heat, what measures or countermeasures are we taking? • Clarify how we plan to increase resilience to extreme heat. Through increasing electricity costs or a more sustainable approach?
Develop a Post Disaster Redevelopment Plan.	• Yes this is great. Communities need to be ready to wisely invest federal disaster dollars strategically and not make those decisions on the fly during/right after a disaster • focus on reducing potential for flooding by promoting properly sized culverts for future scenarios, rethink and relocate development away from floodzones, and reconnect wetlands • Grant support for communities wanting to develop these plans locally, not just HMPs and MVP plans. Integrate with CDBG. CT helps municipalities get FEMA-ready. • Collaborate with large private land conservation organizations to set the stage for land swaps after disaster
Mitigate damage to coastal buildings and ports via building codes, regulations, and structural solutions.	• Yes, communities up and down the coast are pursuing structural solutions for vulnerable coastal areas and ports, but many stuck on funding/financing/permitting. • Involve land/homeowners to take more of the load to reduce pressures and incentivize landowners to address issues rather than reliance on infrastructure. • Expand seawall funds. • Create or make clear the legal pathway in which public money can be spent on private property (e.g., marine industrial/DPA) for public resilience purposes. • Make DPA regulations more flexible to allow flood protection (water-dependent use) infrastructure improvements acceptable. Limited by "ease of deconstruction" criteria. • Create more predictable cross-agency permitting pathways for seawall raising projects on already developed waterfronts (i.e., not fronting beaches).

	• Encourage relocation even if flood insurance is not involved.

Appendix 4.A:
State Capabilities and Approaches Supporting Document

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Planning and Regulatory				
Massachusetts State Building Code (780 Code of Massachusetts Regulations (CMR))	BBRS	Massachusetts State Building Code (MSBC) covers the entire state, applies to both public and private construction, and is administered through the local building inspectors with state oversight. The Code addresses multiple natural hazards including wind, seismic, snow, and flood hazards. Section 1612 of the MSBC contains most of the NFIP construction requirements related to buildings or structures.	NFIP standards are an integral section of the MSBC, ensuring that all new construction and substantial improvements meet national flood resistant standards. Many communities have enacted stricter standards under their local floodplain ordinances. Allows for the application of NFIP standards on all new construction of buildings and structures throughout the Commonwealth.	MA is in the process of adopting the 2021 edition of the ICC model codes, which have further improvements for design and construction requirements for buildings and structures in flood hazard areas. The process of promulgating these code changes is intended to be complete in early 2023.
Chapter 589 of the Acts of 1983—An Act Relative to the Protection of the Massachusetts Coastline	CZM	Defines the role of the state's coastal program and its policies in state government, including the formal establishment of CZM within EOEEA and a directive that all departments and divisions within EOEEA assist in the implementation of the coastal program. Under this authority CZM undertakes comprehensive coastal education and protection programs and ensures that projects located in or affecting the coastal zone are in compliance with CZM enforceable program and policies.	Very effective. CZM has developed and continues to expand on numerous coastal risk and vulnerability reduction initiatives as part of its coastal program as described elsewhere in this section. New and innovative enhancements to these initiatives have made the agency more adaptable and more flexible to better serve the municipalities in coastal areas.	Unchanged.
The National Flood Insurance Program Community Assistance Program—State Support Services Element (CAP-SSSE)	Department of Conservation and Recreation's Flood Hazard Management Program	Executive order designates the Massachusetts Water Resources Commission as the state coordinating office for the NFIP. Under MGL Chapter 21, the Department of Environmental Management (now DCR) Division of Water Resources serves as support staff for the Water Resources Commission. In 1979, the Flood Hazard Management Program was created within the Division of Water Resources to be the NFIP coordinating office. The Department of Environmental Management is now the Department of Conservation and Recreation.	FEMA's CAP-SSSE is a federally-supported opportunity for states to work closely with National Flood Insurance Program (NFIP) communities in their state. In Massachusetts, this allows staff in DCR's Flood Hazard Management Program to conduct outreach, training and general technical assistance to the 341 NFIP communities in the Commonwealth. Each	Unchanged. In the FY2022 year, this state office worked specifically with more than 259 communities, offered 11 training events, and gave an additional 597 individuals technical assistance regarding floodplain management. The office reviewed more than 87 MEPA filings for projects in the floodplain, worked with other state agencies to update and improve the state building code, and offered expert testimony at 8 building code appeals board hearings. Overall, the Massachusetts CAP-SSSE program is considered to be an extremely effective program in New England, helping to reduce flood losses and promote healthy
Clean Vessel Act	DMF	The Massachusetts Clean Vessel Act provides free and convenient pump out service to recreational boaters along the coastline. The program currently funds and maintains over 78 pump out stations and 65 pump out boats. As it is illegal to discharge waste into waters within 3 nautical miles of the MA coast, the pump out service helps recreational boaters dispose of their onboard waste conveniently and safely.	Reduces sewage discharges from recreational boaters into coastal waters, protecting public health and marine ecosystem health	New to plan (2023).
Statewide Disaster Behavioral Health Plan	DMH	Serves as behavioral health annex to the CEMP.	Increases collaboration between private and state partners to provide behavioral health supports to communities and individuals post disaster.	New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Massachusetts Executive Order No. 569: Establishing an Integrated Climate Change Strategy for the Commonwealth	EOEEA	Established the requirement for the Commonwealth to develop an integrated climate change strategy. It lays out a comprehensive approach to further reduce greenhouse gas emissions, safeguard residents, municipalities and businesses from the impacts of climate change, and build a more resilient Commonwealth. It also requires the designation of a "Climate Change Coordinator" within each Executive Office.	Provides the authority, direction, and funding mechanisms for the Commonwealth to prepare state agency vulnerability assessments and adaptation plans based on the best available data on existing and projected climate change impacts. Enhances collaboration across state government to build resilience to current and future hazard conditions.	2019 Launch of the Resilient MA Action Team, that instituted Climate Coordinators in each EO, as required by EO569.
Massachusetts Environmental Policy Act MGL Ch. 30, Sec. 61-62h; 301 CMR 11.00	EOEEA	The primary state environmental review process for state actions, projects with state funding, or projects requiring permits or licenses from state agencies. SHMT has representation on MEPA reviews.	Effective in ensuring that major development projects being contemplated have considered applicable flood protection laws and regulations.	Interim Protocol for Climate Adaptation and Resilience effective October 1, 2021 to require additional focus on a project's climate resilience through use of the RMAT Climate Resilience Design Standards Tool.
EOEEA: Community Preservation Act	EOEEA	Encourages cities and towns to undertake the purchase of open space to preserve natural resources.	Very good collaboration that allows for the preservation of open space that also serves as flood storage areas. Also, allows for the potential purchase of floodplains and wetlands to prevent future building of potential flood-prone structures.	EOEEA is working with the City of Holyoke Conservation Commission to ensure any of EEA new construction does not interfere or impact any of the wetlands on or near EEA property.
Massachusetts Executive Order 181, Barrier Beach Protection (1980)	EOEEA	This Executive Order discourages further development on barrier beaches by limiting state and federal funding for new support facilities, gives priority status for relocation assistance to storm-damaged barrier beach areas, and encourages public acquisition of barrier beaches for recreational purposes.	Recognizes that human-induced changes to barrier beaches decreases the storm damage prevention and flood control capacities of these dynamic coastal areas. Assists in reducing or limiting development in high risk areas for coastal flooding, erosion, and high winds.	Unchanged.
Massachusetts Climate Change Adaptation Report	EOEEA	This report provides a framework for assessing a suite of strategic, long-term solutions designed to enable neighborhoods and natural resources to adapt to climate change while striving to mitigate greenhouse gas emissions.	Provides a mechanism for addressing impacts of climate change (such as sea level rise) through identification, development, and implementation of actions enhancing adaptation to climate change issues.	Development of 2022 MA Climate Assessment to identify urgent climate risks across five sectors and seven regions in the Commonwealth.

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Clean Energy and Climate Plan	EOEEA	The Clean Energy and Climate Plan for 2025 and 2030 (2025/2030 CECP) provides details on the actions the Commonwealth will undertake through the next decade to ensure the 2025 and 2030 emissions limits are met. The 2025/2030 CECP development is informed by the 2050 Decarbonization Roadmap such that the strategies, policies, and actions outlined in the 2025/2030 CECP will put the Commonwealth on a pathway to achieve net zero greenhouse gas emissions by 2050.	The 2025/2030 CECP is rooted in the understanding that climate change poses a unique and potentially irreversible threat to the well-being of society. It expresses the Commonwealth's plans for 2025 and 2030 that maximize the ability to realize a 2050 future in which the heat in homes, power in vehicles, and electric grid can all operate with a minimum reliance on fossil fuels, and natural and working lands can be protected from conversion and better managed and restored to enhance carbon sequestration. The 2025/2030 CECP exhibits the confidence that Massachusetts can help lead the clean energy transition and that doing so will mean more well-paying jobs, improved public health, reduced consumer costs, and better quality of life for all residents.	New to plan (2023).
Drought Management Plan	EOEEA	The Massachusetts Drought Plan was updated in 2019 and was developed to maximize the state's ability to effectively prepare for and respond to drought conditions. The plan aims to minimize drought impacts to the Commonwealth by improving agency coordination; enhancing monitoring and early drought warning capabilities; and outlining preparedness, response, and recovery activities for state agencies, local communities, and other entities affected by drought. The plan lays out an integrated, multi-agency approach to managing drought, with an emphasis on state-led preparedness and response actions as drought conditions change.	Using updated science and a systemic approach to assessing droughts, the Secretary of EEA makes drought declarations that in turn set actions in motion for better coordination among agencies, more timely responses to drought impacts, and reduces use of water throughout the Commonwealth.	New to plan (2023).
2021 and 2022 Climate Law	EOEEA	On March 26, 2021, Governor Baker signed into law An Act Creating A Next-Generation Roadmap for Massachusetts Climate Policy, which requires the EEA Secretary to set interim emissions limit and sector-specific sublimit every 5 years. The 2030 emissions limit shall be at least 50% below the 1990 baseline, the 2040 emissions limit shall be at least 75% below the 1990 level, and a 2050 emissions limit that achieves at least net zero statewide greenhouse gas emissions, provided that in no event shall the level of emissions in 2050 be higher than a level 85% below the 1990 level. It also specifies July 1, 2022 as the deadline for the adoption of the 2025 and 2030 emissions limits and sublimit, as well as the release of a comprehensive plan to achieve those limits. In compliance with the new law, EEA will develop and finalize the 2025/2030 CECP by the deadline. At the same time, the Administration is continuing implementation of the strategies, policies, and actions outlined in the Interim 2030 CECP. **https: //malegislature.gov/bills/192/S9**	The Act establishes the Clean Heat Commission, and also requires the MEPA Office to develop new regulations by the end of 2021 that would require: Submission of an environmental impact report (EIR) for any project that is likely to cause damage to the environment and is located near an environmental justice (EJ) population; Assessment of potential existing unfair or inequitable environmental burden and related public health consequences for the EJ population; and Analysis of how the proposed project might result in a disproportionate adverse effect on the EJ population.	New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Resilient Lands Initiative	EOEEA	Plan for future land conservation and stewardship, drafted with a focus on climate change mitigation and adaptation	The RLI was drafted with potential climate adaptation benefits of land conservation and stewardship in mind.	New to plan (2023).
Healthy Soils Plan	EOEEA	Plan to manage soils, with climate change a strong focus	The HSP was drafted with potential climate adaptation benefits of land conservation and stewardship in mind.	New to plan (2023).
Natural Resource Damages Restoration Projects	EOEEA and MassDEP	The Secretary of EOEEA is the Trustee for Mass. NRD program, including the Trust where collected NRD damages are held. Funding can be used to restoration projects. Funded projects include dam removals and culvert repair / restoration.		New to plan (2023). See NRD restoration funds website here: https: //www.mass.gov/service-details/natural-resource-damages-program-restoration-funds-massdep
Massachusetts Executive Order No. 579: Establishing the Commission on the Future of Transportation in the Commonwealth	EOEEA and MassDOT	Establishes an 18-member commission tasked with laying out potential developments in the transportation field between 2020 and 2040, and to advise the Governor and Lieutenant Governor on how to ensure that transportation planning, forecasting, operations and investments for this period can best account for future conditions including disruptive technologies, climate change, land use and demographic trends.	Expected to result in effective approaches for determining the kinds of investments that will be needed to make transportation infrastructure more resilient to climate change. Climate and Resiliency is identified in the EO as a required topic for the commission to investigate.	Unchanged.
Metro Boston Coastal Resilience Study	EOEEA/ US Army Corps of Engineers	The Commonwealth of MA received an authorization through the 2020 Water Resources Development Act that allows for a funding agreement with the US Army Corps of Engineers (USACE)to conduct a planning study to address climate resiliency at a regional scale. The Study includes a regional vulnerability assessment and identification of recommended regional adaptation strategies and an implementation framework that builds on existing local plans and priorities, that will be completed by the USACE and potential subcontractors.	Framework for regional vulnerability assessment and identification of regional adaptation projects that benefit multiple municipalities and EJ communities.	New to plan (2023). Agreement signed in December 2021, Shared Visioning Milestone to be complete by April 2023 with Recommendations Milestone in October 2024.
Civil Defense Act of 1950	EOPSS and MEMA	Authorizes the creation of the Massachusetts Civil Defense Agency (predecessor to the Massachusetts Emergency Management Agency) and the development of a statewide civil defense program.	The Massachusetts hazard mitigation program is administered jointly by MEMA in coordination with DCR. Maintains its effectiveness for enabling all intended programs.	Unchanged.
Massachusetts Executive Order 144 and Massachusetts Executive Order 242	EOPSS and MEMA	Amends and updates the Civil Defense Act of 1950 by creating the position of Secretary of Public Safety, coordinating emergency preparedness activities and the promulgation of a Comprehensive Emergency Response Plan for the Commonwealth.	Very effective EO that allows for the CEMP to be reviewed and revised as needed each year.	Unchanged.
Massachusetts Zoning Enabling Act MGL Ch. 40A	Legislature	The Zoning Act was enacted in 1975 to facilitate, encourage, and foster the adoption and modernization of zoning ordinances and bylaws by municipal governments and to establish standardized procedures for the administration and promulgation of municipal zoning laws.	Effective at enabling municipalities across the Commonwealth to develop, update, and enforce local regulatory standards and development policies that include measures for increasing public safety and reducing risks to natural hazards. The act itself was amended in 2010 to improve the law.	In 2021 MGL c40A was amended to add Section 3A which requires 175 communities to zone for multi-family housing near transit where applicable. TOD zoning is a climate adaptation measure. New program is being implemented by DHCD now.

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Massachusetts Executive Order 149 and Chapter 21 of Massachusetts General Laws (MGL)—	MA Water Resources Commission through the Department of Conservation and Recreation's Flood Hazard Management Program	Executive order designates the Massachusetts Water Resources Commission as the state coordinating office for the NFIP. Under MGL Chapter 21, the Department of Environmental Management (now DCR) Division of Water Resources serves as support staff for the Water Resources Commission. In 1979, the Flood Hazard Management Program was created within the Division of Water Resources to be the NFIP coordinating office. The Department of Environmental Management is now the Department of Conservation and Recreation.	FHMP staff work with FEMA and officials from NFIP participating communities to implement the NFIP in Massachusetts. The FHMP is a technical assistance program and has no regulatory authority. Program staff is available to provide technical assistance to all interested parties on issues such as the NFIP, floodplain management, floodplain building requirements, floodplain mapping, flood mitigation, and flood insurance. In addition to floodplain management technical assistance (per NFIP regulations) offered to local governments, residents, other agencies, non-profit organizations, and industry professionals, staff also reviews floodplain development proposals that trigger MEPA review. Over the past several years the number of requested MEPA projects for review have more than tripled, with this work becoming a major component of the work of the FHMP staff. Staff in this program also work closely with CZM on a number of matters, as well as with the BBRS on updates to building code standards for floodplain construction. Effectiveness includes number of flood insurance policies in the state, number of successful flood mitigation projects, classification of CRS communities, and other metrics for reducing flood losses.	The FHMP plans to begin development of a statewide floodplain management plan in late 2023, seeking input from a multitude of stakeholders including state agencies, FEMA, local governments and no-profit organizations.
National Historic Preservation Act of 1966 (36 CFR Part 800 – Protection of Historic Properties)	Massachusetts Historic Commission (MHC)	The MHC administers the National Historic Preservation Act Section 106 review process for all proposed hazard mitigation projects submitted to the federal government under the HMGP, FMA, and PDM programs. Properties subject to Section 106 review include all properties listed on the National Register of Historic Places and all properties believed to be eligible for listing in the National Register.	Ensures that FEMA-funded mitigation projects achieve loss reduction while preserving the historic integrity of the listed properties. Promotes measures to reduce future losses of economic, cultural, and historical facilities that are vital to many Massachusetts communities. Also ensures that new risk reduction projects will not adversely affect cultural and historic sites.	Unchanged.
The Massachusetts Public Waterfront Act - Chapter 91 Program; (MGL Ch. 91)	MassDEP	Protects the coastal tidal area for public open space purposes and regulates new and expanded construction within this area.	Very effective tool for risk reduction by restricting development along coastal shores, which are high hazard areas.	Updated. "Chapter 101" should be "Chapter 91." MassDEP is the lead agency, not CZM. Although it includes language regarding sea level rise, Chapter 91 only requires sea level rise projections to be based on historical data and does not require specific actions for adaptation. MassDEP plans to propose resiliency focused amendments to the waterways (c.91) regulations and finalize them in 2023.

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Massachusetts Wetlands Protection Act MGL Ch. 131, Sec. 40; 310 CMR 10.00	MassDEP	Establishes state policy for protecting the Commonwealth's wetland resource areas by limiting development in wetland resource areas and within a 100-foot buffer zone. Wetland resource areas include the 100-year coastal and riparian flood hazard areas identified by FEMA.	Very effectively and appropriately limits new and expanded building in the Commonwealth's coastal and wetland resource areas including lands subject to flooding.	MassDEP will proposed amendments to establish performance standards for Land Subject to Coastal Zone Flowage in late 2022 and finalize them in 2023. Companion amendments will also be proposed in its section 401 Water quality certification regulations. The proposed changes will also adopt more current precipitation data (NOAA 14) for use in designing work in wetlands resource areas.
Massachusetts Rivers Protection Act; MGL Ch. 258-Acts of 1996; incorporated into 310 CMR 10.00	MassDEP	Establishes state policy for protecting the natural integrity of the Commonwealth's rivers and establishes open space along the rivers. The Act regulates activities within the Riverfront Resource Area extending 200 feet from the edge of each bank.	Very effective. This Act expands the area along the Commonwealth's rivers in which flood control aspects of a proposed project are considered. Effectively aligns with this plan because two of the eight interests promoted by this Act are providing flood control and preventing stormwater damage.	Unchanged.
Massachusetts Inlands and Coastal Wetlands Restriction Acts (MGL Ch. 130, Sec. 105) and inland areas (MGL Ch. 131, Sec. 40A)	MassDEP	Records at the Registry of Deeds restrictions on individual property deeds against future development of coastal wetlands on Cape Cod, some towns on the south coast, and in the Charles River basin. The program now focuses on restoring wetlands.	Further protects critical coastal wetlands and barrier beaches from development. Reduces the amount of new development in high risk coastal areas that could be affected by coastal flooding, erosion, and high winds.	These programs may present opportunities to explore protecting critical coastal and inland wetlands areas with restrictions following public procedures.
Massachusetts -Title 5/Septic System Management Title 5, (310 CMR 15):	MassDEP	Establishes minimum standards for the subsurface disposal of sanitary sewage. Enforced by MassDEP and local boards of health. Communities may adopt standards more restrictive than the state requirements.	Title 5 is very effective and administered to mitigate losses due to adverse effects of improper sewage treatment by strict requirements for placement and construction within high hazard flood areas. Helps to minimize property damage as well as environmental and health risks that could occur from improperly built septic systems in high hazard flood areas.	Title 5 / NSA and Watershed permitting regs planned to be proposed (draft regs) in 2022. The proposed changes will address nitrogen discharges from septic systems.
Massachusetts Oil Spill Prevention Act	MassDEP	Created by statute in 2004 MOSPRA established a fee on barrels of oil entering the state, to be deposited in the MOSPRA Trust.	MOSPA has provided funds for oil spill response trailers, equipment for responding, and training for first responders. The program has also supported Geographic Response Strategies for susceptible coastal areas	New to plan (2023). In 2022 the program sponsored a Integrated Threat and Climate Impact Assessment. Draft report should be available in December 2022. 83 trailers have been provided to 70 communities and over 2000 first responders have been trained.
Massachusetts Contingency Plan (C21E and 310 CMR 40)	MassDEP	The MCP governs the assessment and clean up of releases of oil and hazardous materials.	The program has been effective through implementation of a privatized cleanup program with Licensed Site Professionals in cleaning up thousands of contaminated sites.	New to plan (2023). In 2022 MassDEP is planning to finalize amendments to the MCP to require consideration of reasonably foreseeable site conditions, including the impacts of climate change, in assessing sites and choosing remedial options.
Transportation Reform Bill, Chapter 25 of the Acts of 2009 – An Act Modernizing the Transportation Systems of the Commonwealth	MassDOT	This Act amends MassDOT's enabling legislation to designate the Office of Transportation Planning (OTP) as the lead on adaptation planning at MassDOT. Per the language included in the Act, this planning will "ensure that the Commonwealth's transportation infrastructure is designed to tolerate increased environmental stress due to climate change, including, but not limited to increased temperatures, increased stormwater runoff, and extreme weather events."	Effective. While OTP has long been engaged on climate adaptation planning, this Act enhanced their efforts by establishing a team of senior managers from each MassDOT division to serve on an internal working group that OTP chairs. This body is responsible for identifying work done to date, additional needs, and next steps to advance resiliency, as well as serving as a point of contact with stakeholders.	Unchanged.

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Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Initial Transportation Asset Management Plan (TAMP)	MassDOT	The TAMP is a risk-based asset management plan prepared for the National Highway System (NHS) to improve or preserve the condition of the assets and the performance of the system. Section 5 of MassDOT's 2018 draft version of the TAMP outlines its approach to climate change and extreme weather risk. The final version of the MassDOT TAMP was published in September of 2019.	Effective. The risk management strategy in MassDOT's final TAMP will be in part founded upon current studies underway at MassDOT which consider vulnerability from climate change and extreme weather.	Unchanged.
Strategic Planning	MBTA	In early 2020, the MBTA released an organization-wide Strategic Plan, which documented the agency's Mission, Vision, and Values. Among the values set was a focus on Sustainability, stating that "we invest resources wisely in solutions for our team, our communities, and our environment." The MBTA continues to build on this value to align its sustainability work-- including a focus on climate resiliency--across all parts of the agency.	Set mission to incorporating climate resilience in agency efforts.	New to plan (2023).
Local Food Action Plan	MDAR	The plan was designed to increase production, sales and consumption of Massachusetts-grown food; create jobs and improve wages in food and farming; protect the land and water needed to produce food, while maximizing the environmental benefits of agriculture and fishing; ensure food safety; and reduce waste, hunger and food insecurity, while making available more fresh, healthy food to everyone who lives here. The plan offers recommendations for the public and private sectors to see these	The Plan is a discussion and a series of recommended actions. It has no authority to implement its recommendations, but some are climate oriented and include assistance to farmers around crop and livestock climate change adaptation strategies, explore carbon credits, asses current water used by the agricultural sector, resources to	New to plan (2023).
Farmland Action Plan	MDAR	The MA Farmland Action Plan is intended to address the farmland needs and goals of the Commonwealth including but not limited to increasing farmland conservation, addressing farmland access (including urban farmland), food security, and the long-term economic and environmental viability of farms across all regions of the Commonwealth of Massachusetts.	TBD pending rollout. Recent significant statewide planning efforts point to the need for a broader approach to farmland protection that increases the pace of farmland protection, focuses on priorities to ensure productive land stays in agriculture,	New to plan (2023). Farmland Action Plan currently under review pending approval for release.
Massachusetts Executive Order No. 604: Establishing the Office Of Climate Innovation and Resilience Within the Office Of the Governor	Office of Climate Innovation and Resilience	Establishes the position of Climate Chief and creating an Office of Climate Innovation and Resilience within the Governor's Office. The Office of Climate Innovation and Resilience is charged with harnessing all of the resources and authority available to the Governor and the executive department to advance the Commonwealth's climate innovation, mitigation, adaptation and resilience policies. The Office is led by the Climate Chief, who is	Among other provisions, the Executive Order directs the Climate Chief to begin a comprehensive review of current staffing, policymaking and resources of all Secretariats to support a whole-of-government approach to addressing climate change. The Climate Chief is required to	New to plan (2023).
Administrative and Technical				
Massachusetts State Rapid Response Coastal Storm Damage Assessment Team (Storm Team)	CZM	The Storm Team consists primarily of state and local officials with coastal planning, geology, and engineering expertise who are on call to conduct damage assessment surveys of coastal areas immediately following storm events. CZM partnered with the National Weather Service in 2009 to make the StormReporter tool operational for the Team, helping to promote rapid delivery and archival of coastal storm damage observations and photos.	Valuable assessments provide state and federal emergency managers with information of coastal storm damage within several hours of a storm event, allowing better targeted response and recovery assistance. This team continues to be used several times a year as coastal storm events occur.	Updated. Corrected the name of the team.
Bureau of the State House Hazards and Vulnerabilities Assessment *(in development)*	Bureau of the State House	The Hazards and Vulnerabilities Assessment (HVA) will detail the natural, technological, and human-made risks and hazards that may impact the State House. As of Fall 2022, the assessment was out for bid.		New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
MyCoast: Massachusetts	CZM	MyCoast: Massachusetts is an online portal for CZM to collect and analyze pictures and data relating to coastal storm events and King Tides as shared by Storm Team members and volunteers. Information collected is used to visualize the impact of coastal hazards in real-time and to enhance awareness among decision-makers and stakeholders.	MyCoast provides the Commonwealth with timely data and information to make better decisions, including but not limited to real-time disaster response via the StormReporter part of the tool, which has been made operational for the Storm Team.	Updated description of capability. CZM supports the annual license for the Massachusetts MyCoast platform, which includes development and maintenance of the website and mobile applications.
StormSmart Coasts Program	CZM	This is a technical assistance program that was designed to help communities address challenges arising from erosion, storms, floods, sea level rise, and other climate change impacts. The program operates on two levels: a website that provides a suite of tools for successful coastal floodplain management; and direct technical assistance to communities.	This program provides all 78 coastal communities with valuable information needed to improve their floodplain management strategies. It has helped communities enhance their regulatory language, planning, and outreach efforts to address coastal flooding.	Unchanged.
Coastal Erosion Commission	CZM	Established in 2014, this commission was charged with investigating and documenting the levels and impacts of coastal erosion in the Commonwealth and developing strategies and recommendations to reduce, minimize, or eliminate the magnitude and frequency of coastal erosion and its adverse impacts on property, infrastructure, public safety, and beaches and dunes.	The commission produced a final report in 2015, which provides eight overarching strategies with specific actions to mitigate the risks posed by coastal erosion in Massachusetts.	Unchanged.
Coastal Hazards Commission	CZM	Launched in 2006, this commission was charged with reviewing existing coastal hazards practices and policies, identifying data and information gaps, and drafting recommendations for administrative, regulatory, and statutory changes.	The commission produced a final report in 2007 with 29 recommendations to improve the management of risk from coastal hazards in Massachusetts.	Corrected the name of the commission.
Climate Resilience Checklist and the Asset Risk Ratings	DCAMM	The checklist is used to assess the climate resilience for buildings owned, leased, or operated by the Commonwealth. It focuses on hazards related to flooding, extreme heat, and extreme precipitation and includes questions on current site conditions and design strategies that will mitigate hazards.	DCAMM's Statewide Resilience Master Plan (SRMP) provides guidelines for planning and implementing resilient design strategies. This includes the use of the climate resilience checklist, asset risk ratings, and other tools and controls in DCAMM projects. As the agency is responsible for facilities management, major public building construction, and real estate services for the Commonwealth, the use of these tools will guide the implementation of resilient building strategies.	New to plan (2023).
Service Forestry Program	DCR	Service Forestry meets the needs of landowners and municipalities by providing technical expertise, services and programs. This program also acts as the oversight for the Massachusetts Forest Cutting Practices Act (FCPA; MGL Ch. 132)	This program provides landowner programs such as Working Forest Initiative, Foresters for the Birds, Forest Stewardship Program, Climate Forestry, as well as provides services such as woodland evaluations and wildlife habitat assessment.	New to plan (2023).
Standards for Trail Crossings *(in development)*	Department of Conservation and Recreation	Will set standards to replace damaged and structurally unsound crossings. Updated crossings will be low impact, made of sustainable materials, and anticipate future climate risks and impacts.	Will support trail crossing updates that are more stable and sustainable	New to plan (2023).

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Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Capital Investment Plan	Department of Conservation and Recreation	The FY22 Capital Improvement plan outlines FY21 capital accomplishments in the state and plans for how to use FY22 towards DCR's goals	DCR's FY22 Capital Improvement Plan includes specific goals for climate resiliency, clean energy, and environmental justice investments	New to plan (2023).
Dam Safety High Hazard Dam Assessment	Department of Conservation and Recreation	Maintains records of dams located state-wide ensuring compliance with acceptable practices pertaining to dam inspection, maintenance, operation, and repair.	Focus on best practices for inspection, maintenance, operation, and repair of dams.	New to plan (2023).
Historic Curatorship Program	Department of Conservation and Recreation	Considers recommendations from DCR's Net Zero Working Group in developing public/private partnerships to rehabilitate DCR's historic properties	Focus on rehabbing properties.	New to plan (2023).
Historic Properties Program	Department of Conservation and Recreation	Program is adding climate vulnerability to the criteria for prioritizing preservation projects.	Assessing climate vulnerability to projects.	New to plan (2023).
FireWISE	Department of Conservation and Recreation	Forest fire prevention program, community protection and education.	Focus on forest fire prevention.	New to plan (2023).
Forest Action Plan	Department of Conservation and Recreation	Contains assessments on the conditions of and threats to forests in Massachusetts. Outlines DCR's forestry goals and strategies for achieving them over the next 10 years. The most recent forest action plan was published in 2020.	The Forest Action Plan provides an analysis of forest conditions and trends in Massachusetts, identifies threats to forest land and resources, identifies priority areas where federally funded cooperative forestry program outreach and activity can be emphasized and coordinated, and outlines strategies to address the threats to forest resources and ensure healthy trees and forests into the future. Where, Goal 1 (of 10) is to increase resistance and resilience of trees and forests to mitigate and adapt to the effects of climate change.	New to plan (2023).
Continuous Forest Inventory Program	Department of Conservation and Recreation	Established in the late 1950s, this is a comprehensive data set of our forests. This tool allows us to gain a better understanding of our forested lands. Trends associated with forest health, carbon storage, growth, yield, and mortality, which helps identify threats and opportunities with respect to forest management and adequate responses to emerging threats.	The resulting trends from this long-term, accrued data helps to identify current and future threats, which can inform state foresters of the most appropriate forest management opportunities, given their current and predictive status. This data also provides the information needed to leverage other data and research, and to model stand and landscape responses to different forest management scenarios implemented across the state.	New to plan (2023).

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Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Urban and Community Forestry Program and the Greening the Gateway Cities Program	Department of Conservation and Recreation	The Urban and Community Forestry Program assists communities and nonprofit groups in protecting, growing, and managing community trees and forest ecosystems. The Greening the Gateway Cities Program, a subset of the Urban and Community Forestry Program, is designed to reduce household heating and cooling energy use by increasing tree canopy cover in urban residential areas. Through coordinated reforestation efforts, tree plantings in DCR parks, and technical assistance to municipal partners and groups, over 30,000 trees have been planted to date.	The Urban and Community Forestry Program improves the environment and enhances the livability of all Massachusetts communities. The Greening the Gateway Cities Program specifically focuses on reducing household heating and cooling energy use by lowering wind speeds, reducing summertime air temperature, and increasing direct shade by planting trees in urban communities. Additionally, this program aids in improving air and water quality.	New to plan (2023).
Forest Health Program	Department of Conservation and Recreation	Provides tree health care services for the DCR's state forests, parks, and reservations. The program works in cooperation with state, federal, and municipal agencies to detect, manage, and treat biotic and abiotic factors that negatively impact Massachusetts' state forests.	Monitors and treats state forests for forest health issues, including non-native pathogens and insects. Highly critical as climate change is expected to favor non-native species and negatively affect overall forest health.	New to plan (2023).
Forest Legacy Program	Department of Conservation and Recreation	Land acquisition program run by DCR in cooperation with the US Forest Service. It provides federal grant funding to protect environmentally important forestland from conversion to non-forest uses. Voluntary landowners who wish to protect their land with the program may sell the property in fee simple, or if they wish to retain ownership of the property, sell a conservation restriction.	This program protects lands from conversion to non-forest uses by facilitating legally binding agreements that prohibit certain uses such as development, but allows the property to be managed for forestry, recreation, and other conservation values.	New to plan (2023).
Land Protection Program	Department of Conservation and Recreation	DCR Land Protection Program: acquires land and conservation restrictions to protect important natural and cultural resources, provide public recreational opportunities, and protect the integrity of the State Parks. The program includes resiliency and vulnerability criteria in land acquisition planning and parcel evaluation, as well as targets lands that provide flood storage, protect biodiversity, conserve riparian zones, and other areas vulnerable to climate related hazards.	Permanent protection of key parcels prevents fragmentation and conversion of natural and working lands, provides greenspace for people, and connected habitats for plants and wildlife.	New to plan (2023).
Division of Water Supply Protection Land Acquisition Program	Department of Conservation and Recreation	DCR Division of Water Supply Protection land acquisition program: focuses on protecting the Quabbin Reservoir, Wachusett Reservoir, and Ware River watersheds - the source of drinking water for 3.1 million people that is treated and distributed by the Massachusetts Water Resources Authority. The internal Land Acquisition Panel that reviews proposals, has integrated climate change impacts to its review process.	Integrated climate change impacts to its review process.	New to plan (2023).
State Fire Assistance; the Cooperative Forestry Assistance Act (PL 95-313), Volunteer fire Assistance, and Federal Excess Property program	Department of Conservation and Recreation, Forest Fire Bureau	USDA Forest Service provides a wide range of grants to states for wildfire prevention, training, and education programs; federal excess firefighting materials; technical assistance and grants to communities with fewer than 10,000 population for forest fire related purposes.	A collaborative program that provides critical support to local wildfire prevention programs.	Unchanged.
Massachusetts Wildfire Program, MGL Chapter 48: Sections 8 through 28C	Department of Conservation and Recreation, Forest Fire Bureau	Carries out a comprehensive program of wildfire prevention, suppression, and education through the state fire bureau and municipal forest wardens.	This program is critical and reliable as it is the primary vehicle to reduce losses from wildfire.	Unchanged.

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Restoration Potential Model tool	DER	This tool displays a map of all known dams in the Commonwealth. Users can click on dams of interest and learn, for each dam, the relative ecological benefit of its removal compared to other dams in MA.	Publicly accessible information on the ecological benefits of dam removals. Can be used to evaluate and prioritize river restoration efforts, with potential benefits for habitat resilience.	New to plan (2023).
State Energy Security Plan	DOER	The 2022 State Energy Security Plan (SESP) details MA's energy profile, vulnerability and risks to the state's energy systems, and how MA responds to emergencies in the energy sector.	Guides government action on how to respond to various energy emergencies, as well as action for how to mitigate energy risks	New to plan (2023).
Massachusetts Climate Change Clearinghouse (resilient MA)	EOEEA	The Massachusetts Climate Change Clearinghouse is an online gateway for policymakers, local planners, and the public to identify and access climate data, maps, websites, tools, and documents relevant to climate change adaptation and mitigation across Massachusetts. The goal of the website is to support scientifically sound and cost-effective decision-making and to enable users to plan and prepare for climate change impacts. The vision is a dynamic site where users can find information in multiple ways, including through interactive tools that use data from different sources.	Very effective. The primary intended audiences for this website are local planners and decision-makers and those who support their work, as well as state agency staff. The site streamlines the decision- making process by helping to identify problems, investigate solutions, and take action. A decision- maker can use the site to identify vulnerable infrastructure, residential areas, and ecosystems; evaluate the risks posed by climate change; and develop strategies and implementation plans for their town or city.	Regularly updated to include best available climate data, new SHMCAP and MVP portal, Climate Resilience Design Standards Tool, Resilience Grant viewer.
Massachusetts Climate Change Projections	EOEEA	Released in December 2017, this report provides downscaled projections for changes in temperature, precipitation, and sea level rise for the Commonwealth as developed by researchers from the Northeast Climate Science Center at the University of Massachusetts Amherst. EOEEA provided support for these projections to enable municipalities, industry, organizations, state government and others to utilize a standard, peer-reviewed set of climate change projections that show how the climate is likely to change in Massachusetts through the end of this century. More recently, EEA, in partnership with Cornell University, U.S. Geological Survey and Tufts University, led the Massachusetts Climate and Hydrologic Risk Project (Phase 1) and has developed new climate change projections for the Commonwealth. These projections are accessible on the Resilient MA Climate Change Projections Dashboard.	These climate projections help municipal officials, state agency staff, land managers, and others to identify future hazards related to, or exacerbated by changing climatic conditions. The information is particularly useful in the development of local multi-hazard mitigation plans and for communities participating in EOEEA's Municipal Vulnerability Preparedness (MVP) program. The projections can help communities to think through how future hazards in their community may change, given projected changes in future climate conditions.	New best available climate data developed include the MC-FRM for sea level rise and coastal storm modelling, Climate Hydro-Risk study for precipitation and temperature projections, MAPC Land Surface Temperature on statewide urban heat hotspots. Resilient MA Climate Hub contains an interactive Climate Change Projections Dashboard.
Climate and Hydrologic Risk Project	EOEEA (manager) / MassDEP (funding source)	Collaboration with USGS, Tufts, and Cornell University. Development of model and visualization tool that will project the impacts of climate on water systems at a local scale in MA. Model will provide statistics on flood and drought risks and projected future average conditions.	Planners can use tool to better understand how climate and hydrologic systems may change in the future and the impacts that could have on infrastructure.	New to plan (2023).
Massachusetts Executive Order 484 Leading by Example –Clean Energy and Efficient Buildings,	EOEEA and A&F	Established the requirement for state agencies to prioritize practices and programs that address resource use at state facilities, including a reduction in energy consumption derived from fossil fuels and emission associated with such consumption. It also requires development of a Leading by Example Program to coordinate efforts at state agencies to reduce their environmental impacts.	By sustaining the environment and by implementing long-range planning for clean energy resource use, more hazard mitigation measures may be implemented by state agencies.	Unchanged.

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Statewide Stream/River Hydraulic Model	MassDEP	Collaboration with USGS, UMass Amherst, and MassDEP. Multi-phase and multi-year ongoing project with end goal of developing a GIS-based hydraulic modeling tool for the entire state of MA. Will include all ~25k stream crossings in the state, and preliminary culvert designs for all.	Will support the evaluation of existing culverts and provide information for projects that will upgrade culverts to meet goals for aquatic habitat connectivity and resiliency in the event of river/stream flooding	New to plan (2023).
Land Subject to Coastal Storm Flowage Advisory Group	MassDEP	Beginning in 2014, MassDEP's Wetlands and Waterways Program commenced an Advisory Group to develop and adopt regulations for performance standards for Land Subject to Coastal Storm Flowage (LSCSF). This area is defined as the "land subject to any inundation caused by coastal storms up to and including that caused by the 100-year storm, surge of record or storm of record, whichever is greater" (310 CMR 10.04). To date the Wetlands Protection Act (WPA) regulations have lacked performance standards within this coastal resource area, leading to confusion about how to adequately protect this area.	Significant progress has been made on the development of new standards to preserve the characteristics of the landforms of the floodplain (e.g. slope, vegetative cover, permeability etc.) to protect the interests of storm damage prevention and flood control. Although the new performance standards have not yet been approved for public release, it is anticipated that they will be very effective for reducing risk and vulnerability in LSCSF areas. The current understanding of an increase in the rate of sea-level rise and the effects of climate change has expanded the need for the development and adoption of these standards.	Proposed regulatory changes are expected to be available for public comment in late 2022 and finalized in 2023.
Clean Energy Results Program	MassDEP and DOER	Advancing energy efficiency and clean energy generation at sites regulated by MassDEP including water utilities, brownfields, and landfills among others. Gap energy grants to jump-start energy efficiency and renewable energy projects at water utilities have been provided in three separate grant rounds.	Effectiveness of the Gap energy grant program has been evaluated and results are summarized in the storybook on the website here: https://www.mass.gov/info-details/massachusetts-gap-energy-grant-program	New to plan (2023). Expansion of Gap Funding Model to Multifamily Affordable Housing and Food-Producing Nonprofits and Small Businesses engaged in food distribution - $ 8.1 million of grant awards (https://www.mass.gov/news/baker-polito-administration-awards-81-million-in-gap-energy-grants-to-62-organizations-and-municipal-facilities) https://www.mass.gov/clean-energy-results-program; https://www.mass.gov/info-details/massachusetts-gap-energy-grant-program
Massachusetts Coast Flood Risk Model	MassDOT	The Massachusetts Coast Flood Risk Model (MC-FRM) provides a high-resolution and probabilistic model of coastal flood risk. It projects present and future flood risks and takes into account climate-related hazards such as sea level rise and coastal storms.	The model was developed for MassDOT to be able to better assess potential flooding vulnerabilities to highways and other transportation infrastructure near the Massachusetts coastline.	New to plan (2023).
Fluvial Geomorphology Training Program	MassDOT	The Massachusetts Rivers & Roads Training, offered by MassDOT Highway Division, is a training program on the fundamentals of fluvial geomorphology and its applications to the transportation network. There are online, classroom, and field components to the training, which is presented in three tiers.	Increases education on river processes and the risks they may pose to roads, bridges, and other transportation infrastructure.	New to plan (2023).

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Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
HDR's report on hatchery infrastruc	MassWildlife	The study evaluates climate vulnerabilities at MDFW-owned hatcheries.		New to plan (2023).
BIoMap 2023	MassWildlife	The framework uses ecological principles to identify lands most resilient to climate change.		New to plan (2023).
Coldwater Climate Change Refugia	MassWildlife	The study uses temperature models and land cover to identify watersheds with the potential of having cold water refugia.		New to plan (2023).
Flood Risk and System Wide Resiliency	MBTA	The MBTA has taken full advantage of the Massachusetts Coastal Flood Risk Model, developed by MassDOT and the Woods Hole Group, which examines coastal flood risk using a dynamic model to understand how flood risk changes with rising sea levels. Using a GIS map of its facilities in conjunction with this flood model, the MBTA developed flood risk screening reports to use when scoping capital improvement projects and siting future facilities. The MBTA has also partnered with researchers at the Massachusetts	Will utilize the findings from these vulnerability assessments to bolster systemwide resiliency	New to plan (2023).
Emergency Management	MBTA	The CCVA findings also inform emergency management activities, such as updates to the severe weather operations plan. The findings are also shared with the MBTA's Insurance Provider's Loss Control Engineers to coordinate climate resiliency efforts with other risk mitigation activities. In the case of a predicted severe weather event, the MBTA determines operational safety status. If the MBTA is unable to safely operate its vehicles/assets at their current capacity, the MBTA either runs a reduced level of service (e.g., during a winter storm event) or cease operations until they can be safely resumed. The MBTA coordinates closely with MEMA, and MBTA security and management staff sit with its state agency partners	The CCVA findings also inform emergency management activities, such as updates to the severe weather operations plan. The findings are also shared with the MBTA's Insurance Provider's Loss Control Engineers to coordinate climate resiliency efforts with other risk mitigation activities.	New to plan (2023).
Comprehensive Emergency Management Plan	MEMA	The CEMP is an all-hazards plan developed to address the natural and human-caused hazards that threaten MA. It describes the state's system to prevent, prepare for, respond to, and recover from disasters and emergencies. It also assigns specific areas of responsibility for coordinating resources to support emergency and/or disaster responses.	This is a coordinated plan that addresses hazards, emergencies/disasters, and preparation and response actions across sectors in the state. It can be used to provide timely, strategic, and targeted disaster and/or emergency services.	New to plan (2023).
Massachusetts Threat and Hazard Identification and Risk Assessment	MEMA	The Threat and Hazard Identification and Risk Assessment (THIRA) is a 4-step risk assessment process developed by FEMA. The MA THIRA helps the Commonwealth identify hazards and threats of concern, describe them in context, establish capability targets to address the threats/hazards, and estimate the resources required to meet these targets. The THIRA may include technological, human-caused, or natural hazards. The THIRA is updated annually	The THIRA provides a guide to relevant threats and hazards and outlines the Commonwealth's goals for addressing them, along with how resources would be mobilized to do that	Unchanged.
MEMA Local Hazard Mitigation Pla	MEMA	Guided by FEMA policies, this process involves local governments who develop and maintain their own mitigation plans. Local plans must be reviewed and approved of by MEMA and FEMA Region 1.	Updated FEMA policies, effective in April 2023, require local governments to include climate change effects in their risk assessments. They include other provisions that prioritize community resilience and equity considerations in the hazard mitigation planning process.	New to plan (2023).

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Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Floodplain Management Services and Section 22 Planning Assistance to States Program	MEMA and Department of Conservation and Recreation	U.S. Army Corps of Engineers provides floodplain management and water resources technical assistance to states. This program provides a continuing source of technical assistance for flood loss reduction plans and projects. In MA, the program is administered through the state's Silver Jackets Team in coordination with the US Army Corps of Engineers.	Technical assistance to communities helps to identify potential projects and supports resilience planning at the local or regional level.	This US Army Corps service program is most effectively presented and utilized through the state's Silver Jackets Team, which is co-hosted by MEMA & DCR. If the Corps has a greater volume of funding, more can be done in MA to bring about flood loss reduction.
State Hazard Mitigation Team	MEMA and other state agencies	The state hazard mitigation team is composed of numerous state agencies who work together to bring a broad understanding of mitigation needs to MEMA's administration of the federal mitigation grant programs as well as local hazard mitigation planning efforts.	Very effective. All agencies work cooperatively to provide support for hazard mitigation grants and project management, especially ongoing technical assistance to communities, regional planning agencies, and other state and federal agencies participating in mitigation programs statewide, especially under the HMGP, BRIC and FMA programs.	
Climate Adaptation for DoD Natural Resource Managers Guide	National Wildlife Federation, DoD	The guide was developed to help Department of Defense (DoD) installation managers address climate considerations in their Integrated Natural Resource Management Plans (INRMPs). The guide provides an introduction to climate adaptation concepts and a flexible INRMP adaptation planning process consisting of the following steps: 1. set context for adaptation planning, 2. assess climate vulnerabilities and risks, 3. evaluate implications for INRMP goals and objectives, 4. develop strategies and actions to reduce climate risks, 5. implement adaptation actions and projects, and 6. monitor and adjust adaptation actions.	As per the DoD INRMP Implementation Manual (DoDM 4715.03), DoD installations must address climate considerations when updating or revising their INRMPs. Accordingly, climate adaptation will be taken into account when planning the management of the ~25 million acres of DoD land. This will also help DoD installations mitigate climate risks and sustain their national security functions.	New to plan (2023).
Mutual Aid Agreements for Forest Fires	Northeastern Forest Fire Protection Commission (NFFPC)	The mandate of the NFFPC is to provide the means for its member states and provinces to cope with fires that might be beyond the capabilities of a single member through information, technology and resource sharing (mutual aid) activities.	Enables Massachusetts to call upon additional out-of-state resources to combat extreme conflagrations in Massachusetts.	Stafford Act Master Coop Fire Agreement: Provides for State and Federal Fire agencies to exchange resources on national incidents. Enables Massachusetts to send or receive resources for large incidents where capacity limits have been reached.
Massachusetts Ocean Acidification Panel / Report	Special Legislative Commission on Ocean Acidification	The 2021 Massachusetts Ocean Acidification Report, produced by the Special Legislative Commission on Ocean Acidification, provides an overview of ocean acidification in MA and its effects on the state's shell fishing and other marine industries. It also assesses Massachusetts' current ocean stewardship practices and relevant organizations and funding sources for this type of work. The report also contains recommendations for how the Commonwealth can better study, monitor, and mitigate the threats of ocean acidification	The 2021 report contains the commission's strategic recommendations across nine action areas with the goal of mitigating and adapting to ocean acidification.	New to plan (2023).
Coordinated State and Federal Review of Floodplain Development	The Water Resources Commission's Flood Hazard Management Program at Department of Conservation and Recreation in cooperation/coordination with CZM, DEP, MEPA, and others	WRC's FHMP staff at DCR coordinates with MEPA, CZM, DEP, MEMA and other agencies (often USACE, EPA, and MADOT) to review proposed floodplain development projects/ construction that trigger MEPA review for environmental issues. Comments are provided to the proponent regarding resilient development practices and regulations.	This is not a DCR initiative but rather an example of how WRC staff at DCR participates with other agencies in overall statewide review of floodplain development proposals.	In recent years this activity includes FEMA Region 1's involvement and deeper scrutiny on potential violations at the local level; the state meets at least quarterly (often weekly) with FEMA staff to develop solutions to local floodplain construction violations, which in turn often leads to more training on related floodplain management topics.
U.S. EPA Stormwater Management Program	U.S. Environmental Protection Agency (EPA)	Provides support for 255 of 351 Massachusetts municipalities to prepare Phase II Storm Water Management Plans.	These plans directly address the major cause of flood damage loss in non-coastal communities in the Commonwealth.	Unchanged.

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Stream Gauge Monitoring	Water Resources Commission staff at Department of Conservation and Recreation, and U.S. Geological Survey (USGS)	USGS researches processes that trigger natural hazards and manages real-time river flood stage monitoring and warning systems. Through a cooperative program with the state (DCR), USGS maintains 108 real-time stream-gauging stations as well as many groundwater monitoring wells in cooperation with state agencies. Real time river flood stage monitoring is essential for the operation of flood response plans.	Effective for areas with gauges and monitoring/warning systems in place.	Unchanged.
Capital Projects and Asset Management				
PL 566 flood control dams, under state and local control and maintenance	DCR / Dam for 6 non DCR Dams	32 small flood control dams that provide flood control to small watersheds in the central and western sections of the Commonwealth. 26 or 32 are owned and operated by DCR.	Very effective. The Commonwealth continues to inspect state-owned PL 566 dams and provides flood protection to watersheds susceptible to high flood flow.	Updated/clarified dams operated by DCR. With funding from U.S. Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), DCR owns and manages 26 of the 32 Small Flood control Dams. $580,000 awarded to DCR for risk assessment study. The "Rawson Hill Brook Dam" in Shrewsbury, is one out of 26 that is fully rehabilitated to the latest dam safety standards to withstand a 500-yr flood event. It is also the first in Massachusetts to be built with the new roller compacted concrete technique, making it durable and resilient for the next 100 years.
Massachusetts Dam Safety Program, Ch. 330, Acts of 2002; 302 CMR 10	Department of Conservation and Recreation, Office of Dam Safety	Inspects and registers the 2,900 dams in the Commonwealth. These structures require continual maintenance, which is a challenge to state and local governments. Dams need continual inspection and maintenance schedules.	Helps ensure the structural integrity of dams, thus preventing downstream flood loss.	Unchanged.
Transmission and Distribution Resiliency	Department of Public Utilities (DPU)	To prepare for vulnerabilities associated with climate change, the DPU opened a proceeding in an effort to ensure that electric distribution companies adopt grid modernization technology and practices that will enhance electric service reliability and resiliency in the face of extreme weather and allow for more efficient daily utility operations.	DPU will prioritize resiliency during grid modernization proceedings in an effort to responsibly accelerate storm hardening, deployment micrograms and resiliency projects at vulnerable critical sites for transmission and distribution.	Unchanged.
Statewide Resilience Master Plan	Division of Capital Asset Management and Maintenance (DCAMM)	DCAMM developed the Statewide Resilience Master Plan (SRMP) to identify and address potential climate impacts to the State's portfolio of over 8,300 assets. As described earlier in this section the purpose of the SRMP was to develop a process to identify potential climate exposures, evaluate risks/vulnerabilities, and implement adaptation strategies to achieve resilience against climate impacts.	The SRMP supports the Commonwealth's desire for a comprehensive, multi-year strategy to mitigate the risks posed to existing State-owned buildings and other assets by natural hazards and projected impacts caused by a changing climate.	Unchanged.
DCAMM Continuity of Operation Plan (COOP)	Division of Capital Asset Management and Maintenance (DCAMM)	In 2019, DCAMM completed a Continuity of Operation (COOP) plan, consistent with FEMA requirements and Massachusetts Executive Order 490; "The purpose of this DCAMM Continuity of Operations Plan (COOP) is to provide a framework to ensure continued operation of mission essential functions for up to 30 days when an internal or external emergency impacts the Agency's facilities, systems, personnel, and/or operations."		New to plan (2023).
The DCAMM Climate Resilience Checklist	Division of Capital Asset Management and Maintenance (DCAMM)	DCAMM developed a climate resilience assessment checklist for building-level evaluation of the resilience of Commonwealth assets, in keeping with the goals of the SRMP's goals of identifying existing climate exposures, risks and vulnerabilities, as well as the tasks assigned to DCAMM by the 2018 SHMCAP.	The climate resilience assessment checklist, used in conjunction with the Climate Resilience Design Standards tool, allows DCAMM to gather information about each site in order to better target resilience projects at Commonwealth sites.	New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
RMAT Climate Resilience Design Standards Tool	EOEEA	Development of interactive web-based tool that provides resilience standards, guidelines, and a project risk screening tool using the best available climate science data and projections for Massachusetts in three critical areas: sea level rise/storm surge, extreme precipitation (urban or riverine flooding), and extreme heat.	Piloted and utilized across capital planning process, MEPA, municipal infrastructure grant programs such as MVP, Massworks.	New to plan (2023). Launched in April 2021, updated version released in July 2022.
Energy Generation Resiliency Survey	EOEEA, in coordination with New England Power Generators Association (NEPGA)	EOEEA, in partnership with NEPGA will distribute a survey identifying resiliency efforts taken or planned to date at our generating facilities and soliciting feedback on recommended steps to take to improve the preparedness of generation facilities in the Commonwealth. As part of this effort, EOEEA will make time to meet with generators interested in advancing their resiliency efforts in partnership with the state.	The ability to generate power during natural disasters and under new environmental stress predicted is essential to the public safety, public health, and economic vitality in the Commonwealth. The New England Power Generators Association (NEPGA) represents 92% of all the generating capacity in the Commonwealth, with facilities located in twenty-five cities and towns across the state.	Part of EOEEA's new building design and construction.
IT Capital Plan	EOTSS	The EOTSS Capital plan establishes new IT capital priorities and advances IT policy objectives. It invests in a portfolio of projects that modernize the Commonwealth's operations while prioritizing security.	Through continued planning and investment in IT, the Commonwealth maintains a technological foundation that is standardized, resilient, and secure, while supporting the delivery of government services	New to plan (2023).
The Central Artery/ Tunnel Vulnerability and Adaptation Assessment	MassDOT	The Central Artery/ Tunnel (CA/T) Vulnerability and Adaptation Assessment, completed in June 2015, created the hydrodynamic Boston Harbor Flood Risk Model (BH-FRM) to identify risk and depth of water resulting from storm surge-induced coastal flooding in the City of Boston under current and future sea level rise and storm surge. Based on the CA/T system's high sensitivity to flooding and little redundancy built into it, the CA/T study report recommended conceptual level adaptation strategies for current and future time horizons.	Very effective. MassDOT continues to consider the recommendations presented in the report. However, in order to supply adaptation measures sooner, MassDOT is developing an alternate strategy to provide protection to 2030. This pilot project also resulted in the creation of various mapping products available to the public for discussion and research, including Coastal Flood Exceedance Probability Maps and Estimated Flood Depth Maps for areas within the BH-FRM domain.	Unchanged.
State-wide Transportation Asset Vulnerability Assessment (inland flooding)	MassDOT	The study aims to provide a better understanding of which MassDOT's assets (infrastructure) are most likely to be at risk due to future inland flooding by utilizing the latest climate model results, suitable hydrologic and hydraulic tools, geospatial analysis and scenario planning methods. The potential impact of extreme heat on transportation assets and operations is also investigated qualitatively. The study has delivered a prototype methodology for mapping out future climate-related inland floodplains at a watershed level and for assessing assets' vulnerability to extreme flood events. The study will eventually generate a prioritized list of assets for resilience actions.	Effective. The study results will build a scientific foundation for MassDOT state-wide adaptation strategies and programs.	Unchanged.

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Deerfield River Watershed Vulnerability Assessment	MassDOT	This assessment evaluated the vulnerability of road-stream crossings within the Deerfield River Watershed to climate change. The assessment included analyses of hydraulic and geomorphic failure risks under current and future climate conditions, including potential impacts to emergency services. Through this innovative and multi-disciplinary approach, the team created a prioritization and decision-making tool that can be used during MassDOT's project planning and development process.	Effective. This tool helps to facilitate a proactive approach to upgrading vulnerable structures, in place of the previous reactive (event-driven) approach.	Unchanged.
Coastal Transportation Vulnerability Assessment	MassDOT	This assessment refined the state-of-the-art Boston Harbor Flood Risk Model (BH-FRM) and extended it to the entire Massachusetts coastline to identify transportation assets vulnerable to sea level rise and storm surge. It evaluated impacts associated with the current year, 2030, 2050, and 2070/2100 climate scenarios and recommend conceptual-level adaptation strategies.	Effective. Using this model extension to the BH-FRM, MassDOT will be assessing the vulnerability of Massachusetts coastal transportation systems including primarily roads, bridges, and railways. This project also helps in the evaluation and development of protection strategies over time and by location, considering both built and natural protection strategies. Data will be made available for coastal communities to inform them for their resiliency efforts.	Unchanged.
Cape Main Line (Drone Pilot Project)	MassDOT Rail Division	The project identifies hot spots in the Cape Main Line susceptible to embankment failures due to climate change-induced drought conditions.	This project has identified some hotspots in the Cape Main Line and shared information with key stakeholders to monitor slopes and modify harvesting procedures.	New to plan (2023).
New water source at McLaughlin hatchery	MassWildlife	Replaces water source located within the floodplain.	Effective. Precludes the need for operating equipment in the floodplain but still vulnerable to changes in reservoir water temperatures and wind patterns..	New to plan (2023).
Additional online services	MassWildlife	Enables continued asset management and services in the event of power outages and disease outbreaks.	Very. Operation such as online teleworking, classes, license sales, and MESA filings provided continued services to customers during pandemic. Important records are also being stored on a cloud-based server.	New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Climate Vulnerability Assessments	MBTA	The MBTA has completed a series of climate change vulnerability assessments that detail exactly where, how, and why we are vulnerable. These assessments cover all rapid transit lines in detail and offer an overview of all modes, especially with respect to flood risk, the climate hazard that presents the biggest challenge to the MBTA. Along with these assessments, the MBTA has been able to geo-locate many of its critical assets and key facilities and overlay these with flood risk information from the Massachusetts Coastal Flood Risk Model. These tools are all available to MBTA staff in GeoDOT (the GIS platform owned by MassDOT). The MBTA Environmental Department is now processing and preparing this information so that it may be implemented in the MBTA's various programs. The MBTA is positioned to act upon the findings whenever possible. Having completed high-level assessments for all MBTA rapid transit lines, we are now conducting more detailed assessments at the asset or location level. We will begin detailed assessments of the maintenance facilities for our bus fleet and Commuter Rail in FY 23, contingent upon the availability of additional capital funding to do this work.	The MBTA has been able to identify and pin point the most vulnerable portions of our system and there are lists of recommended actions from these assessments that the MBTA can now weave into its plans, policies, programs, procedures.	New to plan (2023).
Capital Needs Assessment (CNA)	MBTA	Every three to four years, the MBTA carries out an assessment of our capital needs. This process, the Capital Needs Assessment (CNA), seeks to: • better understand the condition and age of our capital assets, and the approximate costs to replace or repair them, and • leverage this information to support smarter capital investment decision-making. This year's CNA, which is currently in development, includes climate vulnerability information and will help to prioritize projects with resiliency benefits. This is in addition to the ongoing screening of Capital Investment Plan projects for climate resiliency to ensure these projects address this issue where possible.	Climate vulnerability information from the climate vulnerability assessments will help to prioritize projects with resiliency benefits. The CNA attempts to address vulnerability even earlier in the project origination process, well before a project ends up in the Capital Investment Plan (CIP). [Note: The MBTA publishes its own CIP now, that is separate from MassDOT's CIP.]	New to plan (2023).
U.S. Army Corps of Engineers Dam Safety Program	U.S. Army Corps of Engineers (USACE)	With many flood control structures originally built by the USACE (dams, dikes, seawalls, and protection barriers), this program aims to help protect many cities in Massachusetts from riverine and tidal flooding. The USACE assists the Commonwealth and local governments in conducting annual inspections and provides other technical and financial resources.	Effective. Since completion, these structures have prevented flood damage in major Massachusetts urban areas estimated at millions of dollars.	Unchanged.
Financial				

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Coastal Resilience Grant Program	CZM	Since 2014, CZM has administered the Coastal Resilience Grant Program to provide financial and technical support for local efforts to increase awareness and understanding of climate impacts, identify and map vulnerabilities, conduct adaptation planning, redesign vulnerable public facilities and infrastructure, and implement non-structural (or green infrastructure) approaches that enhance natural resources and provide storm damage protection.	Very effective. Since 2014, CZM has made 201 grant awards to local communities and other eligible applicants for a broad range of successful coastal resilience projects. In total, this includes allocating more than $37 million in state capital funds for risk reduction projects, and per CZM staff, there has been a tremendous improvement in the understanding and awareness of coastal and climate risks by local officials and other participating stakeholders. The grant program has effectively increased the dialogue for risk reduction at the local community level.	Updated the grant award information.
Fire Management Assistance Grant Program	Department of Conservation and Recreation	The Commonwealth annually signs an agreement with FEMA for this program under Section 420 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act.	The Commonwealth must have a signed and up-to-date FEMA-State Agreement and a Wildfire Management Plan before receiving federal funding under approved requests for Fire Management Assistance declarations.	Unchanged.
Community Clean Energy Resiliency Initiative	Department of Energy Resources (DOER)	Launched in 2014, this $40 million initiative provides grant awards that are focused on municipal resilience projects that use clean energy technology solutions to protect communities from interruptions in energy services due to severe climate events made worse by the effects of climate change.	Early rounds of the grants in 2014 focused on project implementation in critical infrastructure and technical assistance. More recent grant awards have supported resiliency improvements for hospitals, feasibility studies for state-owned medical facilities, and resiliency tool development.	Unchanged.
Culvert Replacement Municipal Assistance Grant Program	Department of Fish and Game, Division of Ecological Restoration (DER)	The Culvert Replacement Municipal Assistance Grant Program is for Massachusetts municipalities interested in replacing an undersized, perched, and/or degraded culverts located in an area of high ecological value. The purpose of this funding is to encourage municipalities to replace culverts with better designed crossings that meet improved structural and environmental design standards and flood resiliency criteria.	Effective at helping local communities reduce flood-related risks and vulnerabilities by providing funds to replace undersized or otherwise inadequate culverts that present hazards to public safety, including flooding, culvert failure, and road washout. The program encourages projects to reduce vulnerability and enhance resiliency to changing climatic conditions, including flood damage caused by more frequent, high intensity storms.	Unchanged.
DER Priority Restoration Projects	Department of Fish and Game, Division of Ecological Restoration (DER)	Each few years DER selects wetland (freshwater and coastal), cranberry bog, river and flow restoration Priority Projects through a state-wide, competitive process. DER chooses high-priority projects that bring significant ecological and community benefits to the Commonwealth, including those that reduce flood hazard risks and increase climate resilience.	All of DER's restoration projects and services improve the resilience of ecosystems by removing or upgrading critical infrastructure and reducing impairments to ecosystem health. These projects also benefit communities by improving public health and safety and increasing resilience to climate change and extreme weather.	Updated description.

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Public Housing General Fund	Department of Housing and Community Development (DHCD)	Division of Public Housing: Public Housing General funding (Bond Cap H012 - $90M) allows local housing authorities (LHAs) to undertake more high-priority projects to preserve their existing portfolios and pursue the redevelopment of obsolete units	Focus on high-priority projects to preserve their existing portfolios and pursue the redevelopment of obsolete units.	New to plan (2023).
Public Housing Sustainability and Resiliency Fund	Department of Housing and Community Development (DHCD)	Division of Public Housing: Public Housing Sustainability and Resiliency funding (Bond Cap H026 - $5M, of which 20% -30% is spent on resilience-related projects on average (also leverages Mass Save funding for energy efficiency, some of which also makes properties more resilient (i.e., weatherization ASHPs)) targets investments based on energy expenditure data in replacing and modernizing high-cost and emissions generating equipment, with the goal of reducing utility costs and emissions and improving the climate change preparedness of approximately 80,000 low-income, disabled, and elderly residents of public housing who are particularly vulnerable to flooding, storm surges, heatwaves, and extreme weather events.	Focus on resilience-related projects and leverages Mass Save funding for energy efficiency, some of which also makes properties more resilient.	New to plan (2023).
Public Housing Innovations (Mixed-Income Demonstration) Fund	Department of Housing and Community Development (DHCD)	Division of Public Housing: Public Housing Innovations (Mixed-Income Demonstration) funding (Bond Cap H024 - $8.5M, leverages tax credits, debt, and private funding) supports innovative approaches to redevelop public housing and create new market-rate or affordable housing developments through partnerships leveraging private resources and local housing authority land.	Focus on innovative approaches to redevelop public housing.	New to plan (2023).
Local Housing Authorities (subsidies)	Department of Housing and Community Development (DHCD)	Division of Public Housing: Local Housing Authorities (GAA 7004-9005 - $92M) receive operating subsidies from DHCD for operation of ~43,000 units of state-aided public housing.	Focus on operation of ~43,000 units of state-aided public housing.	New to plan (2023).
Emergency Assistance	Department of Housing and Community Development (DHCD)	Division of Housing Stabilization: Emergency Assistance (GAA 7004-0101 - $220M) family shelter system is available to eligible families with children and pregnant women who meet categorical eligibility requirements and have incomes below 115% of the federal poverty level.		New to plan (2023).
Individual Shelter System	Department of Housing and Community Development (DHCD)	Division of Housing Stabilization: Individual Shelter system (GAA 7004-0102 - $110M) network is supported by DHCD including 56 individual shelter providers as well as service agencies that address the needs of an unaccompanied adult population.		New to plan (2023).
Community Development Block Grant (CDBG)	Department of Housing and Community Development (DHCD)	Division of Community Services: Community Development Block Grant (CDBG) (Federal HUD - $30M) is a competitive grant program available to municipalities with fewer than 50,000 residents. CDBG funds a broad range of community development activities that assist low- and moderate-income residents, such as housing, microbusiness assistance, public services, targeted economic development, and revitalizing areas of slum or blight	Grants funds to cities and towns and allows for mitigation and adaptation within the regulatory parameters when undertaking eligible redevelopment projects or replacing infrastructure.	New to plan (2023).
Heating Emergency Assistance Retrofit Task Weatherization Assistance Program	Department of Housing and Community Development (DHCD)	Division of Community Services: Heating Emergency Assistance Retrofit Task Weatherization Assistance Program (HEARTWAP) (Federal HHS - $13M) provides emergency heating system repair, maintenance and replacement services to Low-Income Home Energy Assistance Program (LIHEAP) eligible households. DHCD decides how much of the LIHEAP grant to dedicate to this purpose	Provides emergency heating system repair, maintenance and replacement services	New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Low-Income Weatherization Assistance Program	Department of Housing and Community Development (DHCD)	Division of Community Services: Low-Income Weatherization Assistance Program (WAP) (Federal DOE - $9M) provides eligible households with full-scale home energy efficiency services	Provides eligible households with full-scale home energy efficiency services	New to plan (2023).
Community Planning Grant Program	Department of Housing and Community Development (DHCD)	Division of Community Services: Community Planning grant program (Bond Cap H035 - $2.5M) provides communities with funding for technical assistance to complete Community Planning projects such as the creation of housing production and land use plans, feasibility and parking studies, and zoning reviews and updates	Supports Community Planning projects such as the creation of housing production and land use plans, feasibility and parking studies, and zoning reviews and updates	New to plan (2023).
Housing Choice Grants	Department of Housing and Community Development (DHCD)	Division of Community Services: Housing Choice Grants (Bond Cap H025 - $4M) provides designated communities with capital grants for a wide range of activities, including compliance with multi-family zoning in MGL c.40A section 3A (MBTA Communities)	Ensures compliance with zoning laws.	New to plan (2023).
Rural and Small Town Development Fund	Department of Housing and Community Development (DHCD)	Division of Community Services: Rural and Small Town Development Fund (Bond Cap H036 - $5M) provides capital grants for a wide range of activities including infrastructure, new buildings and rehabilitation for 181 towns	Focus on infrastructure, new buildings and rehabilitation	New to plan (2023).
District Local Technical Assistance	Department of Housing and Community Development (DHCD)	Division of Community Services: District Local Technical Assistance (DLTA) (GAA 1599-0026 - $3M) provides funds to Regional Planning Authorities for municipal technical assistance.	Supports regional planning	New to plan (2023).
Climate Resilient Housing	Department of Housing and Community Development (DHCD)	Division of Housing Development: Climate Resilient Housing (Bond Cap H033 - $1.7M) allows developers of affordable housing to apply for competitive grants to equip homes to better respond to climate change and reduce greenhouse gas emissions through use of efficient, sustainable design practices in affordable, multi-family housing developments	Focus on equipping homes to better respond to climate change and reduce greenhouse gas emissions through use of efficient, sustainable design practices in affordable, multi-family housing developments	New to plan (2023).
Low-Income Housing Tax Credits	Department of Housing and Community Development (DHCD)	Division of Housing Development: Low-Income Housing Tax Credits (LIHTC) (Federal TRE - $18M tax credit authority) are made available through DHCD's annual rental funding competitions and translates into over $180M in equity for affordable rental projects		New to plan (2023).
State Low-Income Housing Tax Credits	Department of Housing and Community Development (DHCD)	Division of Housing Development: State Low-Income Housing Tax Credits (state LIHTC) (State Tax Credits - $30M tax credit authority) are made available during DHCD regularly scheduled rental funding competitions and can generate up to $120M annually in equity for tax credit projects		New to plan (2023).
State Subsidy Funds	Department of Housing and Community Development (DHCD)	Division of Housing Development: State subsidy funds (several programs ~ $100M annually) are made available during the rental funding competitions, using the same criteria as LIHTC		New to plan (2023).
HOME, Housing Trust Fund, and ARPA/ARP funds	Department of Housing and Community Development (DHCD)	Division of Housing Development: HOME, Housing Trust Fund, and ARPA/ARP funds (federal funding ~ $150M annually) are made available for housing development projects that are required to meet high standards of green, sustainable, and climate resilient design.	Focus on housing development projects that are required to meet high standards of green, sustainable, and climate resilient design.	New to plan (2023).
Boating Infrastructure Grants	DMF	Provides funding for new or upgraded recreational boater facilities		New to plan (2023).

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Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Municipal Vulnerability Preparedness Program	EOEAA	Launched in 2017, this program provides annual funding awards to communities to complete vulnerability assessments and develop action-oriented resiliency plans. Upon completion communities become certified as an MVP community and are eligible for follow-up grant funding and other opportunities.	This program supports and complements other community-based risk reduction efforts, including the integration of hazard mitigation and climate adaptation into local government plans, policies, and projects that are focused on building long-term community resilience.	7 FTEs hired to support program; currently 97% of municipalities are participating with $100M invested in local climate resilience through the program since its 2017 launch.
SHMCAP Implementation Agency Grants	EOEEA	Dedicated capital budget line to RMAT agency implementation of SHMCAP Actions.	Supports all Secretariats in annual funding to implement priority SHMCAP actions.	New to plan (2023). Funding initiated at $850k in 2020, increased to $3M in 2021 and $5.85M in 2022.
Dam and Seawall Repair or Removal Program	EOEEA	The Dam and Seawall Repair or Removal Program offers financial resources to qualified applicants for projects that share EOEEA's mission to enhance, preserve, and protect natural resources and the scenic, historic and aesthetic qualities of the Commonwealth. The program was established in 2013 by the Massachusetts Legislature to promote public health, public safety, and ecological restoration.	Program has provided significant funding to municipalities across Massachusetts to address deteriorating dams and refurbishing critical coastal infrastructure, which in turn improves their storm readiness and resiliency to climate change. $11.5 million was provided in 2018 that provided support for ten dam repair projects, six dam removals, and six coastal protection reconstruction projects. Since its inception, the program has awarded over $46 million in grant and loans	Unchanged.
Land and Recreation Grants & Loans	EOEEA	EOEEA offers various grants and loans for land and recreational projects, including the acquisition and/or conservation of areas that are vulnerable to the adverse effects of natural hazards and climate change. EOEEA has incorporated resiliency criteria into many of these programs.	Very successful and well managed. For example, shortly after establishing the Parkland Acquisitions and Renovations for Communities (PARC) Grant Program, more than 100,000 acres had already been acquired, which has reduced the impact of flood issues within those areas.	Unchanged.
Massachusetts State Revolving Fund	EOEEA	Through the Executive Office of Environmental Affairs, grants may be provided to assist communities in funding stormwater management projects. Funding opportunities for stormwater management projects help to minimize or eliminate flooding in areas of poor drainage.	This program successfully promotes funding for mitigation projects.	Unchanged.
Statewide Comprehensive Outdoor Recreation Plan	EOEEA	The SCORP must be completed every 5 years in order for MA to remain eligible for funding from the Land and Water Conservation Fund from The National Park Service. The SCORP contains the Commonwealth's goals for outdoor recreation.	Funding is directed towards acquiring open spaces, renovating parks, developing new parks, and constructing trails	New to plan (2023).
Massachusetts Statewide Matching FEMA Assistance	Legislature	Following a presidential disaster declaration, the Commonwealth may contribute a portion of the 25% non-federal share for federal Infrastructure Support funds.	Very effective. Assists in funding cost-effective measures that reduce or eliminate continued impacts from various types of disaster events.	Unchanged.
Massachusetts Special Appropriations Following State Disasters	Legislature	While there is no separate state disaster relief fund in the Commonwealth, the legislation may enact special appropriations for communities sustaining damage following natural disasters that do not reach the level of a presidential disaster declaration.	Very effective. Assists in restoring the local communities impacted by disasters for events not rising to the level of a federal disaster.	Unchanged.

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Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Emergency Assistance Program for Massachusetts Libraries	Massachusetts Board of Library Commissioners (MBLC)	The Massachusetts Board of Library Commissioners administers a grant program for libraries to undertake flood loss prevention actions.	One staff person works full time on mitigation activities, and the Massachusetts Board of Library Commissioners provides an important source of funds for mitigation actions.	Unchanged.
Asset Management Planning Grant Program	Massachusetts Clean Water Trust and MassDEP	Provides grant funding for completing/updating Asset Management Plans (AMP) for existing water infrastructure systems (drinking water, wastewater, and/or stormwater)	Supports informed water infrastructure management through funding activities such as asset inventory, risk analysis, asset management planning, public education, and cybersecurity risk assessment	New to plan (2023).
Massachusetts Preservation Projects Fund (MPPF)	Massachusetts Historical Commission (MHC)	State-funded, 50% reimbursable matching grant program established to support the preservation of properties, landscapes, and sites (cultural resources). Grant funding is for pre-development and "bricks and mortar" physical development projects on State Register-listed buildings owned by municipalities and non-profits. There is also emergency funding available outside of the grant cycle for immediate stabilization needs, roof issues, etc. for buildings not on the State Register.	Supports preservation and maintenance of sites. Could be used for hazard mitigation efforts.	New to plan (2023)
Massachusetts Historical Commission Survey and Planning Grant Program	Massachusetts Historical Commission (MHC)	Program provides matching funds that communities can use to document their historic resources (adding them to MACRIS), list resources on the National Register, develop a communitywide preservation plan, and other planning and documentation projects.	Supports documentation of resources so that MHC and other agencies can assess and account for all listed resources	New to plan (2023)
Hazard Mitigation Grant Program	MEMA	Established pursuant to Section 404 of the Stafford Disaster Relief and Emergency Relief Act (PL 100-707), this program provides matching grants (75% federal, 25% non-federal) for FEMA-approved hazard mitigation projects following a presidentially-declared disaster. These grants are available to state, local and tribal governments as well as eligible non-profit organizations.	Program implementation continues as part of the Commonwealth's Mitigation Program. Since 1991 approximately $100 million in HMGP funds have been obligated to cost-effective risk reduction projects.	Unchanged.
Pre-Disaster Mitigation Program Grants for Mitigation Planning and Projects	MEMA	This all hazards mitigation grant program provides funding for hazard mitigation planning and projects. Originally allocated to states under a formula based on risk estimates, these matching grants (75% federal, 25% non-federal) for FEMA-approved hazard mitigation projects are now awarded through an annual national competition. Provides critical funding for multi-jurisdictional plans with local annexes to be developed to help identify potential hazard mitigation projects and for mitigation projects.	There has been demonstrated success in this program. Since 2002 more than $12 million in PDM funds have been obligated to cost-effective risk reduction projects. Continued funding allows for ongoing focus on repetitive loss properties and complements current funding under the HMGP program.	Unchanged.
Flood Mitigation Assistance Planning & Project Grants	MEMA	Since 1997, this program has provided annual pre-disaster funding for developing local flood mitigation plans and corresponding flood mitigation projects on a cost-shared basis (75% federal, 25% non-federal). Program focuses on mitigation of NFIP repetitive loss properties. Program is often the sole source of funding for flood mitigation plans and projects, which have resulted in cost savings for communities and property owners	There has been demonstrated success in this program. Since 1997 more than $7 million in FMA funds have been obligated to cost-effective risk reduction projects. Continued funding allows for ongoing focus on repetitive loss properties and complements current funding under the PDM and HMGP programs.	Unchanged.

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Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Emergency Management Performance Grant (EMPG) – Local Assistance	MEMA	A grant program with a goal to assist local emergency management departments in building and maintaining an all-hazards emergency preparedness system. Communities may use EMPG funds towards planning; organizational support; equipment; training; and exercises.	Communities may use EMPG funds towards planning; organizational support; equipment; training; and exercises include mitigation related planning. As well as fixed generators and other risk reduction.	Part of MEMA's new building design and construction.
Title III, Chapter 29, Section 2DDD Hazardous Materials Teams	State Fire Marshal	Allocation of funding by state fire marshal for mitigation of hazardous-material emergency response incidents	The funds provide for reimbursement of all reasonable costs associated with hazardous-material mitigation efforts.	Unchanged.
Emergency Watershed Protection Program	U.S. Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS)	Provides technical and financial assistance to localities to reduce vulnerability of life and property in small watersheds damaged by severe natural events.	Allows immediate action to stabilize storm damage in streams following a presidentially-declared natural disaster.	Unchanged.
Community Development Block Grants (CDBG)	U.S. Department of Housing and Urban Development (HUD)	In 1997 and 1998, additional funding for hazard mitigation projects became available under HUD's Community Development Block Grant Disaster Recovery Initiative (CDBG-DR).	CDBG-DR can be very effective in supporting the Commonwealth's risk and vulnerability reduction efforts, particularly for addressing unmet needs in areas of low-to-moderate income following major disaster events.	Unchanged. More collaboration is needed with this program to try and expand funding opportunities and maximize benefits of this funding.
Education, Outreach, and Capacity Building				
Cultural Resource Protection	Coordinated Statewide Emergency Preparedness for Massachusetts (COSTEP MA)	Cultural resources exist throughout Massachusetts, are located in a wide variety of buildings and geographical locations, and are threatened by flooding and other natural hazards. COSTEP MA promotes proactive steps to reduce losses from natural hazards, especially flooding or water damage following fires but also including all such hazards, through cooperative team-building activities in communities and through educational activities within the cultural heritage and emergency management communities.	COSTEP MA has worked to develop an annex to the Commonwealth's Comprehensive Emergency Management Plans and to promote education and cooperation in communities to enhance the protection of cultural resources from natural disasters. This is a progressive and engaged group that is quickly becoming a national model.	Unchanged.
Massachusetts CZM Historical Shoreline Change Project	CZM	The CZM Shoreline Change Project illustrates how the ocean-facing shoreline of Massachusetts has shifted between the mid-1800s and 2018. Using data from historical and modern sources, shorelines depicting the local high water line have been generated. Transects at 50-meter (164-foot) intervals along the shoreline are used to calculate rates of change.	Effective. Measures the changes in the state's coastline caused by erosion and accretion. Assists in identifying potential areas and structures at high risk from coastal erosion and shoreline change. Utilized by many stakeholders, including developers of local hazard mitigation plans, and is updated as needed.	Updated shoreline dates and description.
Interpreting FEMA Flood Maps and Studies in the Coastal Zone	CZM	Updated in 2017, this publication developed by CZM in cooperation with the DCR's Flood Hazard Management Program, provides guidance on how to use FEMA Flood Maps and Studies to better understand the potential effects of flooding on buildings, properties, and the underlying natural resource areas.	Very effective. This information can be used by homeowners and consultants to ensure that the safest possible coastal projects are designed, as well as by public officials to successfully evaluate projects to ensure they are designed to minimize storm damage, protect public safety, and reduce the financial burden on individuals and municipalities from losses due to coastal storms.	Unchanged.

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Coastal Manual	CZM and MassDEP	The Massachusetts "Coastal Manual" was published in 2017 after a 12-year effort, under the official title of *"Applying the Massachusetts Coastal Wetlands Regulations: A Practical Manual for Conservation Commissions to Protect the Storm Damage Prevention and Flood Control Functions of Coastal Resource Areas."* This resource provides technical and regulatory information to help local Conservation Commissions evaluate projects proposed in coastal resource areas for their potential to impact the storm damage prevention and flood control interests of the Wetlands Protection Act (WPA). https://www.mass.gov/service-details/applying-the-massachusetts-coastal-wetlands-regulations	Very effective resource for local officials. In coastal communities, local Conservation Commissions implement the WPA and associated regulations to protect coastal resource areas and their functions. The Coastal Manual provides the Commissions with the necessary tools, data, and information (including step-by-step instructions, checklists, and example scenarios) to build their capacity to give careful attention to storm damage prevention and flood control while evaluating projects proposed in coastal resource areas.	Unchanged.
Interpretive Program	DCR	Climate is being integrated into existing interpretive program to provide education to be able to bring themes on climate adaptation in all of our park programs and offerings.		New to plan (2023).
Regional Restoration Partnerships Program	Department of Fish and Game, Division of Ecological Restoration (DER)	Since 2018, DER has established the Partnerships Program (supported by the hire of a new full-time staff position) to build capacity of local and regional organizations to restore aquatic ecosystems and increase climate change resiliency. The Partnerships Program launched with a competitive selection process in 2021 which resulted in the selection of three organizations (Housatonic Valley Association, Buzzard's Bay Coalition, and Merrimack River Watershed Council). Over a three-year award period, with two, 1-year options to extend, the selected organizations will lead and support Partnerships that identify, prioritize, and advance ecological restoration actions collaboratively with local Stakeholders. Lessons and relationships that emerge from the Partnerships will inform and improve the future activities and operations of the DER Partnerships Program. DER will provide grants through the Partnerships Program to support both staffing costs to coordinate selected Partnerships and to support implementation efforts that advance Partnership priorities.	The Regional Restoration Partnerships Program seeks to increase the pace and scale of ecological restoration and climate change resiliency efforts by building local and regional capacity to advance restoration work.	New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
New Staff and Expansion Plan	Department of Fish and Game, Division of Ecological Restoration (DER)	Since 2018, DER has added 10 new positions focused on internal operations, restoration project management, and external partner capacity building. DER also developed a comprehensive expansion plan in 2020 with the following goals: Expand and improve DER's ecological restoration work; Strengthen DER's internal capacity; Expand external capacity; Learn and share knowledge about restoration outcomes and best practices. The expansion plan includes specific actions related to hazard mitigation and climate adaptation including: promoting ecological restoration as an integral part of the Commonwealth's climate adaptation programs, participate in emerging policy, program, and funding initiatives on the issue of climate adaptation and hazard mitigation, and improve and document our understanding of how restoration practices relate to climate adaptation benefits. As part of the strategic plan, DER will continue to hire new positions in the coming years.	DER has and is continuing to increase its capacity to manage restoration project, execute technical service and grants contracts, manage federal grants, and build external partner capacity which in turn leads to more restoration projects with climate resilience benefits.	New to plan (2023).
Capacity to Address the Health Impacts of Climate Change in Massachusetts - Findings from a Statewide Survey of Local Health Departments	Department of Public Health (DPH), Bureau of Environmental Health (BEH)	The purpose of this report was to summarize results of a comprehensive survey aimed at assessing the capacity of local health departments to respond to the public health impacts associated with climate change, and to develop plans for reducing these health impacts.	Effective. The survey helped identify communities that may be more vulnerable to projected climate change risks. State and local communities can use this knowledge to increase resiliency and adaptive capacity by more effectively guiding and targeting resources and actions to vulnerable health departments.	Update. BEH leveraged results from local health survey to develop data resources and tools to support local health/municipal stakeholders and other public health professionals with developing climate adaptation and hazard mitigation planning with consideration for populations most vulnerable to the effects of climate change. These online tools include climate-enhanced community profiles for 351 MA communities, Climate Hazard Assessment Profiles, and Climate and health pathways matrix.
MHOA Training for CyanoHABS and recreational water quality monitoring	Department of Public Health (DPH), Bureau of Environmental Health (BEH)	BEH conducts Massachusetts Health Officer's Association (MHOA) Trainings for local health and municipal workers on CyanoHABs and recreational water quality. These trainings increase local health capacity and resilience through environmental health interventions such as posting waterbodies that are unsafe for swimming. BEH strives to deliver these trainings annually to increase statewide resilience to climate-related events associated with the public use of recreational waterbodies.	Focus on increasing state resilience in relation to recreation.	New to plan (2023).
Heat-related illness outreach for summer camps and correctional facilities	Department of Public Health (DPH), Bureau of Environmental Health (BEH)	BEH Community Sanitation conducted email outreach to recreational summer camps regarding prolonged heat events in July and August of 2022, advising that outdoor activities which may involve strenuous physical exercise performed during the extreme heat and humidity put people, including young and healthy children, at risk of heat-related illness. CDC guidance relative to preventative measures for avoiding heat-related illness was included in the 2022 advisory. This program has also issued guidance for correctional facilities on actions to take during extreme heat events.	Provides guidance for resilience (heat related) measures.	New to plan (2023).
Guidance on prevention of mold growth in public buildings	Department of Public Health (DPH), Bureau of Environmental Health (BEH)	The BEH Indoor Air Quality Program has issued resiliency guidance to respond to hot, humid weather impacts that include water damage and mold growth.	Provides guidance for resilience measures.	New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Interactive Flood Map Tool	Department of Public Health (DPH), Bureau of Environmental Health (BEH)	Interactive tool for flooding hazards in Massachusetts. This tool replaced an outdated but popular flood zone map available on the Massachusetts Environmental Public Health Tracking (EPHT) Website.	Provides address-level flood hazard information for Massachusetts areas with NFHL or Q3 maps (no data for Franklin County)	
Environmental Justice Tool	Department of Public Health (DPH), Bureau of Environmental Health (BEH)	EJ Tool identifies populations that meet the EJ criteria set forth in the Executive Office of Energy and Environmental Affairs (EOEEA) EJ Policy. The MA DPH EJ Tool also makes data on vulnerable health criteria more accessible to facilitate the use of the EOEEA EJ Policy, to enhance inclusive community planning for environmental assessment, and to inform a wide range of activities.	Provides charts, maps, and data tables for locating environmental justice populations and assessing health vulnerability.	
Climate Hazard Adaptation Profiles (CHAPs)	Department of Public Health (DPH), Bureau of Environmental Health (BEH)	Two-page hazard-based summaries of climate change health impacts, vulnerable populations, and adaptations designed for municipal officials, available on Mass.gov	Provides a convenient summary of health impacts and adaptation options for major climate hazards in MA	
Emergency Populations Preparedness Planning Tool	Department of Public Health (DPH), Bureau of Environmental Health (BEH) and Office of Preparedness and Emergency Management (OPEM)	Tool developed by OPEM in conjunction with BEH EPHT to support local government development of emergency response and evacuation plans	Provides local-scale maps and reports detailing critical facilities, hazards, and vulnerable populations.	
Continuity of Operations planning for substance addiction treatment services	Department of Public Health (DPH), Bureau of Substances Addiction Services (BSAS)	The DPH Bureau of Substances Addiction Services (BSAS) has strengthened regulations regarding emergency and continuity of operations planning specifically by requiring programs to bolster their emergency and all hazards plans to include preparing for and responding to all types of emergencies including natural disasters and currently identified threats such as cyber-attacks. Also, through the new regulations BSAS has implemented an OTP	Prepare for emergencies and support development of hazard plans.	New to plan (2023).
Drought management outreach and webinars	EEA	Facilitated multiple webinars to local health departments, public water supply operators, and municipal leaders on drought status, management, and mitigation efforts during prolonged drought conditions in 2022. Collaborative effort including EEA, Department of Public Health (DPH), Office of Local and Regional Health (OLRH), Dept of Environmental Protection (DEP), Dept of Agricultural Resources (DAR), Regional Planning Agencies (RPAs),	Focus on mitigation efforts.	New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Drought Management Task Force	EEA	The Drought Management Task Force (DMTF) chaired by the Executive Office of Energy and Environmental Affairs and the Massachusetts Emergency Management Agency, consists of officials from state and federal agencies and professional organizations with responsibility for areas likely to be affected by drought conditions. It also includes representatives of agencies that provide data used to assess the severity of drought conditions or that have the ability to respond to drought conditions, and public health and safety professionals.	Focus on assessment on the severity of drought conditions or that have the ability to respond to drought conditions, and public health and safety professionals	New to plan (2023).
Climate Adaptation Forums	Environmental Business Council of New England (EBC); University of Massachusetts Boston	Beginning in 2017, the EBC and the Sustainable Solutions Lab at UMass Boston have collaborated on a quarterly series of half-day Climate Adaptation Forums that provide cutting-edge thought leadership on adaptation to climate change for environmental and energy professionals, policy makers, municipal officials, NGOs, and practitioners.	Effective. These quarterly forums are open to anyone and address everything from infrastructure and design solutions to communication challenges and barriers to implementation to policy solutions to the nexus of climate and equity. Local, national and global speakers represent forward-thinking institutions, global firms, academia, government and other high-level practitioners.	Unchanged.
Municipal Vulnerability Preparedness Program	EOEAA	See description under "Financial" category.	See description under "Financial" category.	See description under "Financial" category.
Massachusetts Climate Change Clearinghouse	EOEAA	See description under "Administrative and Technical" category.	See description under "Administrative and Technical" category.	See description under "Administrative and Technical" category.
Climate Change 101 Training	EOEEA	Development of state agency staff training on climate change, climate resilience and adaptation, and state action	Intended to create foundational knowledge needed to support engagement in SHMCAP update and implementation.	New to plan (2023). Launched in fall 2022.
Massachusetts Board of Library Commissioners: Emergency Assistance Program	Massachusetts Board of Library Commissioners	A program of education and training regarding preparedness, mitigation, response and recovery; caches of supplies; technical assistance; and freezing and drying capabilities for affected materials. The last component is limited to public libraries. A Weather Alert distribution list permits the agency to provide a heads up to the cultural heritage community regarding weather events that could impact their facilities and collections.	Effective. One dedicated staff person spends a considerable amount of time dealing with disaster mitigation, preparedness, response, and recovery activities for these institutions. This role is an important one in educating the cultural heritage community about disaster mitigation.	Unchanged.
Slope Stability Map of Massachusetts	Massachusetts Geological Survey (MGS) and UMass-Amherst	Landslides are common in the Commonwealth, but until recently limited data existed to support mitigation strategies to reduce impacts from landslide events. In 2013, the MGS and UMass-Amherst published a Slope Stability Map of Massachusetts which identifies areas where landslides have occurred in the past, or where they may possibly occur in the future under the right conditions of prolonged antecedent moisture and high intensity rainfall.	Very effective in raising risk awareness and improving data to support mitigation planning, projects, or policies for landslide risk reduction. The map has also been included in the risk assessment for this plan and is referenced throughout the section on Landslides. It is also anticipated that MassDOT and municipalities will find this information useful in planning upgrades and improvements to culverts and drainage along roadways in the future.	Unchanged.

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Water Utility Resilience Program (WURP)	MassDEP	The program provides assistance to water utilities for critical infrastructure mapping, identifies helpful and practical resiliency resources, and coordinates training and other opportunities for local and regional partnerships. Additionally, the program develops mapping products to assist MassDEP and other agencies across the Commonwealth.	Effective. WURP works closely with the MassDEP Bureau of Water Resources to ensure climate change resilience is part of an all-hazards approach to technical assistance for drinking water and wastewater utilities. Owners and operators stand to benefit from increased capacity-building that helps communities identify and address vulnerable elements of their critical water infrastructure.	The program provided GIS mapping assistance through FY22 to 9 water utilities and continued service area mapping for drinking water and wastewater utilities. WURP is preparing for mapping assistance for SFY24.
Massachusetts Ocean Resource Information System (MORIS)	MassGIS and CZM	Massachusetts Ocean Resource Information System (MORIS) is an online mapping tool to search and display spatial data pertaining to the Massachusetts coastal zone; specifically, tide gauge stations, marine protected areas, access points, eelgrass beds, etc.	It is very beneficial to identify coastal infrastructure. This has assisted in all emergency management planning processes.	Unchanged.
Interagency Collaboration	MBTA	The MBTA is a participant in Resilient MA Action Team (RMAT) activities and meetings with stakeholders and is currently assisting with the latest MA Climate Assessment. The MBTA has collaborated with MassDOT in the past to ensure its activities were concomitant. The MBTA also has coordinated externally with agencies such as DCR, MEMA, Boston Water & Sewer Commission, MWRA, and utility companies such as Eversource & National Grid and regularly communicates with other state agencies if/when its priorities overlap (e.g., when the Charlestown seawall was reconstructed, both for maintenance and climate resiliency, and DCR constructed a bike path on top of the seawall). The MBTA has supported the Boston Groundwater Trust in collecting data on sea level rise near Aquarium Station and most recently engaged with the U.S. Army Corps of Engineers' Costal Storm Risk Management Study alongside the City of Boston.		New to plan (2023).
Massachusetts Statewide Mitigation Planning Strategy	MEMA and Regional Planning Agencies	The Commonwealth continues to partner with and fund multi-jurisdictional hazard mitigation plans with local annexes for all 13 Massachusetts regional planning agencies.	Effective in facilitating regional collaboration on the development or multi-jurisdictional risk assessments and hazard mitigation plans.	Unchanged.
Police Training and Certification	Municipal Police Training Committe	The MPTC is responsible for the development, delivery, and enforcement of training standards of municipal, MBTA, environmental, UMass, campus police officers, and deputy sheriffs performing police duties and function. National Emergency Number Association (MassNENA).	Develop and deliver training, to set and enforce training standards, and to provide record keeping services regarding training to Municipal Police Departments statewide (Massachusetts General Laws, Chapter 41, Section 96B).	New to plan (2023).
Drone Pilot Project	Rail Division (MassDOT)	The Rail Division has partnered with the Aeronautics Division to run the drone pilot program to reduce the risk of embankment failures in the Cape Main Line. In addition to this partnership, the Rail Division wants to build a partnership with the Planning Department and GIS Group to analyze drone data. The Rail Division is also building relationships with the farmers association to share data collected to reduce the risk of embankment failures.	Effective. These partnerships have facilitated our work, and it is reducing embankment failures	New to plan (2023).

Appendix 4.A: State Capabilities and Approaches Supporting Documentation (June 2023)

Existing Capability / Approaches	Lead / Responsible Agency	Description of Capability/Approaches	Effectiveness for Reducing Risk and Vulnerability	2023 Update Notes / Opportunities for Improvement
Massachusetts Telecommunicator Emergency Response Taskforce (TERT) program	State 911	The MA TERT program is a team of certified and credentialed public safety telecommunicators who respond, relieve, assist and/or augment PSAPs affected by manmade or natural disasters	TERT dispatcher is specially trained to provide mutual aid response in the aftermath of disasters and other special circumstances.	New to plan (2023). The Massachusetts Executive Office of Public Safety and Security (EOPSS) and State 911 Department are pleased to announce the implementation of Massachusetts Telecommunicator Emergency Response Taskforce (TERT) program. This program is being developed in partnership with the Statewide Office of Public Safety Interoperability (SIEC), and the Massachusetts Chapter of NENA. We expect TERT to be implemented by **December 1, 2022.**
Massachusetts Fire Academy	State Fire Marshal	The Massachusetts Fire Academy, operated by the Office of the State Fire Marshal, provides instruction on methods of fire suppression and specialized training to municipal fire fighters to qualify them for the U.S. Forest Service Red Card, which is required for deployment to any out of state fire.	Very effective and accomplished. Well-trained and educated firefighters for both structural and wildfires will more effectively and safely extinguish such fires and prevent future fires.	Unchanged.
National Earthquake Hazard Reduction Program NEHERP	Weston Observatory, Boston College	Monitor earthquakes that can affect Massachusetts. Deliver timely information on the location, magnitude, and impacts of regional earthquakes. Assess the potential occurrences and impacts of future earthquakes.	Effective for earthquake risk education and awareness, particularly as it relates to information dissemination during or immediately after real-time seismic events.	Unchanged.

Appendix 4.B:
2023 MA SHMCAP State Capability, Adaptive Capacity, and Vulnerability Assessment Survey

This survey addresses the State Capability and Adaptive Capacity Analysis (Task A2) and the State Agency Vulnerability Assessments (Task A4) in the 2023 MA SHMCAP (State Hazard Mitigation and Climate Adaptation Plan) scope of work and process.

This revised document contains all proposed survey questions and associated content, including introductory text, definitions, instructions, and skip logic.

Questions will reference other sources of information that are readily available and provide relevant links to survey respondents when appropriate (e.g., from the 2018 MA SHMCAP Vulnerability Assessment and Adaptive Capacity reports).

Survey approach
Climate coordinators will fill out a Google Form regarding existing vulnerability assessments for agencies that fall under their Executive Office, as well as which agencies should take the survey and a lead contact for each relevant agency. ERG will review and assess Google Form responses/existing vulnerability assessments to determine which organizations will fill out the short or long survey, applying a filter—if existing vulnerability assessments do not have adequate details/information, ERG will request these agencies to fill out the long survey.

Each organization will be sent one of the following surveys: 1) the long survey with all questions (for agencies with no existing vulnerability assessments or for agencies where existing assessments do not contain sufficient information, as determined based on the process described above), or 2) the short survey, which will have *all* capacity and capability questions and *only some* selected state agency vulnerability assessment questions.

The agency lead will be responsible for gathering information from internal staff for the team-based survey and will input information into the survey platform once the information is gathered. This will result in one survey response per agency. Note that each agency will receive a link and log-in information for the survey that allows multiple individuals to view and edit the same survey before submitting responses; this will enable collaboration within agencies and also facilitate review of responses by agency leadership. For agencies with existing vulnerability assessments that have sufficient information, ERG will review and compile information from the existing assessment and use this information to bolster and complete the full survey (all questions). ERG will send out regular follow-up reminders regarding the survey and will work closely with the PMT and Climate Coordinators to facilitate robust responses from all agencies.

Opening Page

Thank you for taking the time to respond to this survey!

The Commonwealth of Massachusetts is in the process of updating its State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP), which is required by FEMA and was last updated in 2018. As part of the 2018 MA SHMCAP and under Executive Order No. 569—Establishing an Integrated Climate Change Strategy for the Commonwealth, many agencies completed vulnerability assessment surveys. This participation is also necessary for the 2023 MA SHMCAP update. Later in the survey, we will provide you with a link to your agency's responses to the 2018 MA SHMCAP survey to help with your responses.

There are three objectives to the survey:

1) To assist in updating your agency's vulnerability assessment.
2) Assess the capability and adaptive capacity of your agency to implement actions to reduce risks from hazards and climate change impacts, which are increasing the intensity, duration, and frequency of those hazards.
3) 3) Determine the vulnerability of your agency's physical assets, non-physical assets, functions, and programs, policies, and other services.

You received an invitation to respond to this survey because you were selected as the agency lead for the 2023 MA SHMCAP survey. As agency lead, you are responsible for working with others in your agency to gather information and submit survey responses. Please note that you can share the log-in information for the survey that you received with others in your agency. This will allow them to access the survey, review the questions, and provide responses and other information. The shared log-in can also assist in any review of survey responses needed from your agency's leadership prior to submission. You can also use the PDF/Word Document version of the survey we shared with you for your reference if you prefer to gather responses from others in your agency in another file sharing platform (e.g., SharePoint) before uploading or entering your agency's responses into Qualtrics. If you need more background regarding the survey process and content, you can view this recording link to recording of the September 14 survey training meeting.

If you require assistance at any point during the 2023 MA SHMCAP survey, Eastern Research Group Inc. (ERG), the contractor supporting the Commonwealth with the 2023 MA SHMCAP update, has an open help line to assist in any content-related questions or technical issues you may encounter. Additionally, ERG will hold two Zoom "office hour" sessions to answer questions that you may have while taking the survey. Please see below for the drop-in office hours and contact information.

Contacts

Topic	Name	Email
State Capabilities and Adaptive Capacity	Jennifer Lam	Jennifer.lam@erg.com
Vulnerability Assessment	Diana Pietri	Diana.pietri@erg.com
Technical Survey Assistance	Brielle Kissel Meade	Brielle.kissel@erg.com

Zoom Office Hours

- **Thursday, October 6, 2022**: 2:00—3:00 PM ET
- **Wednesday, October 19, 2022:** 2:00—3:00 PM ET

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Definitions

The definitions listed below are used throughout the survey. Please print or save these pages to use as reference throughout taking the survey.

Adaptive Capacity: The ability of state agencies (including their assets, functions, missions, and services/programs) to adjust or modify their operations, policies, or other functions to adapt to changing hazards and climate change impacts, both in the short and long term. For example, an agency which can operate remotely likely has greater adaptive capacity than an agency which must operate from a damaged building. Similarly, a community or facility that can continue to operate during extended periods of drought due to a resilient, redundant water supply system has greater adaptive capacity than one that may encounter water restrictions.

Assets:
For the purposes of this survey, there are two main types of assets: physical and non-physical.
These are defined below:

> **Physical assets**: These include any tangible facilities, equipment, landholdings, natural resources, etc. that meet the definition of criticality below by playing a significant role in the operation and mission of your agency.
>
> **Non-physical assets**: This category captures non-tangible resources, such as power, internet connectivity, transit services, recreation services and programs, public K-12 education, emergency preparedness and response, public health and safety functions and services, waste management, youth programs and foster care services, animal shelter and safety services, cloud-based data, and more that make up many of your agency's functions (functions are defined below).

Climate adaptation: Measures taken in response to actual or projected climate change to eliminate, minimize, or manage related impacts on people, infrastructure, and the environment.

Criticality: This definition is provided to aid agencies with the identification of critical assets or functions for the purpose of this survey. Criticality is based on three parameters: scope, time, and severity.

> **Scope** describes the geographic area and population that would be affected by the loss or inoperability of an asset or function. An asset or function is considered critical if it serves a region or the entire state or would affect greater than 10,000 people.
>
> **Time** describes the length of time that an asset or function can be inoperable without consequences. An asset or function is considered critical if it is inoperable immediately after a hazard event or one to two days after an event.
>
> **Severity** describes the consequences of the loss and inoperability of an asset or function. There are a multitude of consequences, including public health and safety, economic losses, environmental effects, interdependencies, political effects, and psychological effects. An asset or function is considered critical if the consequences include loss of life or severe injuries, significant economic loss, extensive environmental contamination, significant impact on other agencies, significant impact to service delivery, or significant loss of confidence in the agency.

These parameters and examples should be taken into consideration when identifying your critical assets and functions for the purpose of this survey.

Exposure: The extent to which physical and non-physical assets, functions, and population groups are in direct contact with natural hazards or their related climate change impacts. Exposure is often determined by examining the number of people or assets that lie within a geographic area affected by a natural hazard or by determining the magnitude of the climate change impact. For example, measurement of flood depth outside a building or number of heat waves experienced by a county are measurements of exposure.

Functions: The programs and services an agency provides to its customers in order to fulfill its mission. These programs and services depend on the mission of your agency and could include activities such as planning, policy development, regulatory enforcement, research, permitting, grant-making, outreach/education, or stewardship of critical resources.

Hazard mitigation: Hazard mitigation is any sustained action taken to reduce or eliminate the long-term risk to human life and property from natural and non-natural hazards. An example of hazard mitigation is elevating or strengthening a bridge to reduce damage, disruption, or loss from a flood or an earthquake. It also includes the development of regulations to require new construction to include methods and procedures to reduce risks from current hazards and increasing risks from climate change.

Resilience: Ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies.

Sensitivity: Sensitivity refers to the impact on a system, service, or asset when exposed to natural hazards. For example, if a facility is exposed to storm surge, how will its ability to function be affected?
When a critical threshold has been identified, the level of sensitivity of your agency, a specific asset, function, or population group served to a hazard indicates how much or to what extent the occurrence of a hazard exceeds the critical threshold for that asset or function such that it would disrupt the ability of the agency/asset/function to continue normal operation. If the critical threshold is not exceeded, then the sensitivity to a certain hazard is low, even if it is exposed.

State Capability: Includes the authorities, laws, policies, programs, staff, funding, and other resources available to the Commonwealth to support and advance hazard mitigation and climate adaptation efforts at state and local levels. Examples of a state capability for hazard mitigation and climate adaptation is having dedicated staff who work primarily on hazard mitigation and climate adaptation or including hazard mitigation in existing plans/planning processes to assess risk and implement actions to reduce that risk.

Underserved communities: Refers to populations sharing a particular characteristic, as well as geographic communities and environmental justice populations, that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life. The barriers to opportunity and participation these communities face have occurred throughout history and continue today.

Vulnerability: The overall vulnerability of your agency to a hazard is determined by combining your exposure, sensitivity, and adaptive capacity. Agencies or assets that are highly vulnerable may be highly sensitive to a certain natural hazard or climate change impact, highly exposed, and/or have low adaptive capacity. On the other hand, agencies or assets that have low sensitivity or high adaptive capacity may not be impacted by a natural hazard or climate change impact at all.

Part 1: State Capability and Adaptive Capacity

The first set of questions for the survey relate to the capability and adaptive capacity of your agency.

1. How does your agency consider hazards and climate change impacts that can result in damage, disruption, and loss to physical and non-physical assets and functions (e.g., services, programs) that your agency is responsible for, in its work? Choose all that apply.
    - ☐ Develops policies, plans, and/or programs to guide and support hazard mitigation and climate adaptation.
    - ☐ Provides funding and financing for hazard mitigation and climate adaptation.
    - ☐ Engages in outreach and education on hazard mitigation and climate adaptation.
    - ☐ Develops and implements regulations and codes (e.g., building codes) that reduce risk and adapt to changing hazards and climate change impacts.
    - ☐ Oversees land use planning and policy development that affects hazard mitigation and climate adaptation.
    - ☐ Is responsible for emergency response and recovery.
    - ☐ Manages, maintains, and constructs physical assets at risk from current and future hazards that will be affected by climate change.
    - ☐ Manages, maintains, and develops functions that are at risk from hazards and climate change, which will, in most cases, increase the intensity, duration, geographic area, and frequency of current hazards. For example, sea level rise due to climate change is projected to increase the geographic area of coastal flood risk, as well as the duration and depth of flooding in areas that already experience coastal flooding.
    - ☐ Conserves, manages, and restores natural areas and open spaces that are at risk from current and future hazards that will be affected by climate change.
    - ☐ Other (please specify):

2. How is your agency **addressing hazard mitigation and climate adaptation** in its existing (open-ended responses):
   - ☐ plans? ___________________________
   - ☐ programs? __________________________
   - ☐ policies and procedures (e.g., regulations, laws)? ____________________
   - ☐ decision-making (e.g., governance) processes? ______________________
   - ☐ capital planning and finance? __________________________

   Examples of hazard mitigation and climate adaptation actions could include assessing risks from hazards and climate change for new construction, revising policies to include new climate projections, developing a climate and health communication plan that identifies interventions that can be used to address climate change impacts with a particular focus on environmental equity and populations that will be most vulnerable to climate change, adding new regulations to ensure that new construction and retrofits are built to standards to withstand hazards that are increasing in duration, intensity, and geographic scope due to climate projections. Work could also include revising maintenance and operations schedules or approaches to address increasing frequency or intensity of storms or providing new personal protective equipment for outdoor workers during high heat days.

3. Does your agency have any **staff dedicated** to efforts to reduce the risks posed by the damage, disruption, and loss to physical and non-physical assets that your agency owns, manages, leases, and/or functions you implement or for which your agency is responsible? Check all that apply.
   - ☐ Yes, full time staff
   - ☐ Yes, part time staff
   - ☐ Yes, contractor/on call staff
   - ☐ No staff dedicated
   - ☐ Other: please describe

4. Does your agency conduct **cost benefit or other economic and social analysis** of the costs avoided by reducing risk to physical and non-physical assets and functions, including direct and indirect economic and social costs avoided by taking action to reduce risk to lives, property, the economy, the environment and other critical physical and non-physical assets and functions?
   - ☐ Yes
   - ☐ No
   - ☐ I don’t know

5. Based on your experience with past hazards and your understanding of climate change effects that will increase the intensity, frequency, duration, and geographic location of hazards, do you feel that your agency has an **adequate number of staff** to address mitigating hazards and climate change effects?
   - ☐ Yes
   - ☐ No. If no, please describe what your agency needs.____________________________

6. Outline and briefly describe your agency's **existing funding sources** (public/private) that may be used/leveraged for hazard mitigation and climate adaptation. (open-ended response)
    a. Does your agency **provide funding** that may be used/leveraged for hazard mitigation and climate adaptation efforts for Tribes, local governments, regional partnerships, or communities? If so, please outline and briefly describe or provide a link to the programs. (open-ended response)

7. Outline and briefly describe your agency's **available resources** to reduce risks to its physical and non-physical assets and functions, as well as populations served, from damage, disruption, and loss due to current and future hazards that will be affected by climate change. (open-ended response)

    This should include but not be limited to any physical and non-physical assets inventories, inventory of vulnerabilities, methodologies and prioritization documents (e.g., capital prioritization process and how it includes climate change considerations), vulnerability assessments (including how a hazard can impact day-to-day operations, such as client-facing services [e.g., emergency response/project management, in-patient care, group home settings]), remote operation capability, capital improvement, climate change adaptation plans, adaptive management plans to retrofit, relocate, or retire your physical assets over time.

8. Is your agency/department currently **involved in conducting any studies or developing any plans and/or programs** which could further support the State's hazard mitigation and climate adaptation program? If so, please add the name and a brief description of the study or plan or program. (open-ended response)

9. Building on the 2018 State Capability and Adaptive Capacity Analysis (see Appendix C provided here), are there any **updated** or **new capabilities** your agency has? If so, please add to the Appendix C link directly. *Note, if any information from the 2018 report needs to be corrected, please edit corrections directly in the Appendix C link.*

    Examples include updating the State Forest Action Plan to enhance climate change mitigation and adaptation strategies, prioritizing investments in clean energy resiliency infrastructure projects, assessing potential effects of climate change on Commonwealth travel and tourism industry and assets, reviewing the state building code to assess feasibility of incorporating hazard mitigation and resilience into standards, and facilitating a program for sharing resources between municipalities for tree maintenance.

10. Building on the 2018 State Capability and Adaptive Capacity Analysis (see Appendix C provided here), has your agency **updated** or developed **new approaches to improve the resilience of your agency, and continuity of operations** (e.g., coordination units or functional groups, community partnerships, planning for underserved communities, mutual aid agreements, new staff positions added, new funding/financing sources)? If so, please add to the Appendix C link directly.

Note, if any information from the 2018 report needs to be corrected, please edit corrections directly in the Appendix C link.

For example, see *https://resilientma.mass.gov/shmcap-portal/index.html#/action-tracker/, and https://www.mass.gov/topics/climate-action). Include any plans and/or programs that address current and future hazards that will be affected by climate change (including sea level rise, increased heat, extreme temperatures, disease/pandemics, cyber security, nuclear power, hazardous materials, infrastructure/energy protection, and anti-terrorism). Studies can include hazard specific information, vulnerability assessments and planning for underserved populations, data gathering which supports risk assessments, including economic data, or statistical data of other types.*

11. Outline and briefly describe the approaches your agency takes to **deal with repeated hazard damages or challenges** to your physical and non-physical assets and functions. (open-ended response)

12. Does your agency have the following **resources to reduce damage, disruption, loss, and effects on public health and safety, community, environment, and economy** from current and future hazards? If not, what is missing/a challenge and how could it be addressed? Please complete your responses in the table below. *Note the following definitions for this question:*
    - **Adequate**: The resource is available and accessible to my agency; my agency is not constrained in its implementation of climate adaptation and hazard mitigation actions, strategies, and projects based on a lack of this resource or the ability and authority to use it.
    - **Limited:** The resource is available and accessible in a limited way to my agency; my agency has some limits regarding availability, access, or capacity related to this resource. These limits have an effect on my agency's ability to implement climate adaptation and hazard mitigation actions, strategies, and projects.
    - **Constrained**: This resource is not available and/or accessible to my agency; my agency is constrained in its implementation of climate adaptation and hazard mitigation actions, strategies, and projects based on the lack of this resource and/or the ability and authority to use it.

Resource Category	**Specific resource type** (open-ended response)	**My agency has capacity and capability to reduce impacts from current and future hazards** (Drop-down options: Adequate, limited, constrained)	**This is a significant challenge for our agency** (Drop-down options: Y/N; if Y, then open-ended response to describe)	**Opportunities to address this challenge** (Open-ended response)
Funding?				
Staff?				
Data/information?				
Expertise/skills?				

Authority (e.g., policy, laws, programs)**?**				
Infrastructure/hardware?				
Other necessary resources? [write in]				

The next couple of questions are related to interagency collaborations.

13. What are the **interagency collaborations/partnerships your agency is involved** with that directly/indirectly focus on hazard mitigation and climate adaptation? If any, please outline and briefly describe key actions/priorities. (open-ended response)

14. Are there any **challenges/gaps that hinder the success or effectiveness** of these interagency collaborations/partnerships? If so, please outline and briefly describe **opportunities** to address these challenges and increase effectiveness of these collaborations. (open-ended response)

Part 2: State Agency Vulnerability Assessment

This second part of the survey will help assess the vulnerability of your agency's physical and non-physical assets and functions to hazards and climate change. The questions will address your agency's physical and non-physical assets and functions, physical vulnerabilities, and functional vulnerabilities.

Agency Physical and Non-physical Assets and Functions

Note that the following set of questions will only be asked of agencies that have not completed vulnerability assessments (or that have, but for which data is not sufficient for ERG to populate the survey).

15. Please indicate which of the following **categories of physical assets, non-physical assets, and functions** your agency is directly responsible for implementing, administering, regulating, owning, managing, providing routine guidance related to, or leasing as part of its regular operations. (Note that it is not necessary for your agency to own these assets if management or influence over the assets is part of the agency's functions. Influence over the assets could include a role in permitting, regulating, providing guidance, designing and managing codes, providing service to or receiving service from, or a planning and policy role.) Please check all that apply.
    - ☐ **Communication physical and non-physical assets and functions** (e.g., land line telephone systems, cable systems, cellular telephone antennae, underground communication conduits, Internet and telecommunications provision)
    - ☐ **Community physical and non-physical assets and functions** (e.g., day cares, food banks, grocery stores, senior centers, education and research institutions, youth and elder care, housing, courthouses, research, waste transfer stations, landfills, recycling and reclamation facilities, incinerators, waste collection and transfer, household hazardous waste collection sites, social or transitional services such as unemployment assistance, job placement, job centers, workers compensation and paid family/medical leave support)
    - ☐ **Critical physical and non-physical assets and functions** (e.g., hospitals and medical facilities, prisons, animal care facilities, medical services, police stations, fire stations, safety and education services, public schools, emergency response services, critical infrastructure support, workplace safety services)
    - ☐ **Hazardous materials sites and contaminated lands physical and non-physical assets and functions** (e.g., hazardous materials, landfills, cleanup sites, hazardous waste disposal and transfer, toxic and contaminant reduction)
    - ☐ **Ports and maritime physical and non-physical assets and functions** (e.g., seaports and marine terminals, shipping and commerce services, seawalls and riprap, docks, nature-based flood and storm water systems)
    - ☐ **Recreation, open space, natural areas, and working lands physical and non-physical assets and functions** (e.g., park and recreation facilities, designated open space, cultural and historic resources, bike/pedestrian trails, natural areas, agricultural and working lands, natural and working lands resource management, natural and working lands regulations and programs, recreational opportunities, wildlife habitat, wildland-urban interface buffer provision)

- ☐ **Transportation and mobility physical and non-physical assets and functions** (e.g., local streets and roads, state highways, bus shelters, bus and train stations, bridges and tunnels, railroads and freight lines, transit services [bus, light rail], ferry and boating services, movement of goods, bike/pedestrian routes, airports)
- ☐ **Utilities and infrastructure physical and non-physical assets and functions** (e.g., reservoirs, dams, industrial and sanitary sewer systems, flood control infrastructure, stormwater systems, power utilities, fuel and natural gas pipelines, oil refineries, power provision, flood control, drinking water provision)
- ☐ **Other** (please write in any additional physical or non-physical assets and functions not listed above in the space provided) [open-ended response]

  ____

16. We have reviewed the information provided in the 2018 MA SHMCAP State Agency Vulnerability Assessment survey. Please find a link to your agency's 2018 responses here [**insert unique link**]. [*Will link to agency-specific responses to the 2018 survey that includes the compiled assets for each agency*]. Are there any **additional physical or non-physical assets or functions** that you would add to those listed in the 2018 survey? If so, please write these in the space provided below. (open-ended response)
    a. Are there any physical or non-physical assets or functions that should be removed from this list? If so, please write these in the space provided below. (open-ended response)

17. With respect to the physical and non-physical assets and functions indicated in the 2018 MA SHMCAP survey and Q16, please provide more detail regarding what **specific services** your agency offers. Examples of services include (but are not limited to) providing design guidance on facilities, managing trails and natural areas, managing facilities, coordinating emergency response, reviewing and approving permits, supporting planning processes, providing regulatory oversight, providing K-12 education, recreation programs, community safety, health services, food support and security, etc. (open-ended response)

18. With respect to the collective physical and non-physical assets and functions indicated in the 2018 MA SHMCAP survey and Q16, what **populations** (e.g., general residents, visitors, youth, elderly, underserved populations, incarcerated, small businesses, mobility or people with disabilities/disabled populations, etc.) does your agency serve? (open-ended response)

19. Does your agency manage any **physical assets**?
    - ☐ Yes
    - ☐ No

20. [**If yes to Q19**] For any physical assets your agency is responsible for, are there any assets that you manage but do not own?
    - ☐ Yes

- ☐ No
- ☐ I Don't Know
- ☐ Not Applicable

21. [**If yes to Q19**] Does the ownership and management status of these physical assets **present any concerns** that could affect your agency's ability to reduce the asset's vulnerability? (open-ended response)

22. [**If yes to Q19]** Does your agency keep an **asset management** database?
    - ☐ Yes
    - ☐ No
    - ☐ I don't know
    - ☐ In GIS format?

23. [**If yes to Q22**] Is the information available to share? Who could we contact (name and email) to get this information? Please list the information in the space provided below. (open-ended response)

24. [**If yes to Q19]** For the physical assets that your agency owns, manages, leases or otherwise influences, what **type of information** is available to assess vulnerability of these assets (e.g., existing conditions reports, as-built drawings, monitoring, or inspection reports, completed vulnerability assessments, etc.)? Please list in the space provided below. (open-ended response)

For the following set of questions, we would like you to consider <u>**collectively**</u> **the** physical and non-physical assets and functions indicated in the 2018 MA SHMCAP survey and Q16 **that your agency is responsible for managing directly or has influence over through guidance, regulations, policies, or plans.**

25. Please list in the space provided below the **major types of updates, improvements, repairs, or replacements or relocation since 2018** that your agency has made to assets or functions that were designed or intended to substantively reduce vulnerability or provide support for reducing vulnerability. Please note that this includes improvements or updates to non-physical assets and functions, such as key policies or programs your agency is responsible for that were updated or new plans, policies, or regulations added to support reduced vulnerabilities. (open-ended response)

26. [**If yes to Q19]** For the major or primary physical assets that your agency owns, manages, leases or otherwise has influence over, how do you **incorporate climate adaptation and hazard mitigation improvements** when conducting any needed or schedule maintenance or repairs? Please write your response in the space provided below. (open-ended response)

27. For agencies with non-physical assets and functions (including regulatory support and oversight, polices, and programs), do your agency's major plans, policies, mission, capital planning, partnerships, and/or regulations and codes **include goals and objectives designed to reduce risks and provide for**

climate adaptation? If yes, please indicate in the space provided below the plans, policies, regulations, etc., and briefly describe the goals and objectives it contains related to risk reduction and climate adaptation.

- ☐ Yes
- ☐ No
- ☐ I don't know

28. Have any of your agency's primary physical or non-physical assets or functions been **damaged, disrupted, or lost** in the past due to unplanned events (e.g., weather-related closures or cessation of functions, emergency repairs)? Please note that cessation of functions can relate to non-physical assets and functions, such as disruption of regulatory policies and programs or community programs and support, education, outreach, etc.
    - ☐ Yes
    - ☐ No
    - ☐ I don't know

29. [**If yes to Q2828**] How **long** did the disruptions last? (open-ended response)

30. [**If yes to Q2828**] What were the **consequences** of the disruption to: (open-ended response)
    a. The asset(s) itself? ____
    b. The related functions your agency provides? ______________________________________
    c. The populations affected? ____
    d. Affects to public health and safety? ____
    e. Any climate vulnerable populations? ____
    f. Costs associated with the damage, disruption, or loss and subsequent repairs or replacements? ____

31. [**If no to Q2828**] Does your agency **track disruptions, damage, and loss** due to hazard events? If yes, please describe how so in the space provide below.
    - ☐ Yes
    - ☐ No
    - ☐ I don't know

Vulnerabilities to Physical Assets, Non-Physical Assets, and Functions

This section includes questions regarding vulnerabilities to physical assets, non-physical assets, and functions (including programs and services).

Note that the following set of questions will only be asked of agencies that have not completed vulnerability assessments (or that have, but for which data is not sufficient for ERG to populate the survey).

32. Has your agency conducted any **climate vulnerability assessments** for the physical and non-physical assets and functions described in the previous section of the survey or for your agency at any scale?
    - ☐ Yes
    - ☐ No
    - ☐ I don't know

33. [**If yes to Q32**] In the space below, please indicate what you've conducted a climate vulnerability assessment for, when the assessment was conducted, and share any relevant links to the information related to the vulnerability assessment or indicate who ERG could contact (name and email) to get more information related to the vulnerability assessment. (open-ended response)

For the following set of questions, we would like you to respond to these <u>for each of the categories of physical and non-physical assets and functions</u> checked in Q15. Please use your agency's responses on the 2018 survey [insert unique link] as a reference as needed. [*Survey will prompt respondents to go through questions for each of the <u>categories of physical and non-physical assets and functions</u> they check in Q15*.]

34. Thinking about potential future risks from climate change, what are your **primary concerns for the services that your agency provides** in relation to each of the following hazards? Concerns should include both potential consequences to services provided, populations served, and any potential disproportionate impacts to underserved populations. What improvements or enhancements are required to address these concerns? Please fill in your responses in the table below. (open-ended responses)

Climate Driver	Hazard	Primary Concerns Regarding Impacts from Hazards	Updates, Improvements or Enhancements Required to Address Concerns
Changes in precipitation	Inland flooding	Services: Populations served: Potential disproportionate impacts:	
	Drought	Services: Populations served: Potential disproportionate impacts:	
	Landslide	Services: Populations served: Potential disproportionate impacts:	
	Soil erosion	Services: Populations served: Potential disproportionate impacts:	
	Freshwater ecosystem degradation	Services: Populations served: Potential disproportionate impacts:	
	Dam overtopping	Services: Populations served: Potential disproportionate impacts:	
Sea-level rise	Coastal flooding	Services: Populations served: Potential disproportionate impacts:	
	Coastal erosion	Services: Populations served: Potential disproportionate impacts:	

Climate Driver	Hazard	Primary Concerns Regarding Impacts from Hazards	Updates, Improvements or Enhancements Required to Address Concerns
	Coastal wetland degradation	Services: Populations served: Potential disproportionate impacts:	
	Marine ecosystem degradation	Services: Populations served: Potential disproportionate impacts:	
	Groundwater rise	Services: Populations served: Potential disproportionate impacts:	
Rising temperatures	Average/extreme temperature	Services: Populations served: Potential disproportionate impacts:	
	Wildfires	Services: Populations served: Potential disproportionate impacts:	
	Health and cognitive effects from extreme heat	Services: Populations served: Potential disproportionate impacts:	
	Forest health degradation	Services: Populations served: Potential disproportionate impacts:	
	Increase in vector-borne disease incidence and bacterial infections	Services: Populations served: Potential disproportionate impacts:	
	Shifting distribution of invasive and native species	Services: Populations served: Potential disproportionate impacts:	
Extreme weather	Hurricanes/tropical storms	Services: Populations served: Potential disproportionate impacts:	
	Winter storms/Nor'easters	Services: Populations served: Potential disproportionate impacts:	
	Tornadoes	Services: Populations served: Potential disproportionate impacts:	
Non-climate influenced hazards	Earthquake	Services: Populations served: Potential disproportionate impacts:	
	Ground failure	Services: Populations served: Potential disproportionate impacts:	
	Tsunami	Services: Populations served: Potential disproportionate impacts:	

35. What **external services** (e.g., power, communications, food, fuel, other supplies, and materials) beyond those your agency provides do your agency's assets and services rely on? (open-ended response) [*Respondents will be prompted to answer for each of the categories of physical and non-physical assets and functions that they selected in Q15.*]
    a. If there were disruptions, damage, or loss in external services, are there back-up supplies in place or redundancies available and how long would they last? (open-ended)

Other Vulnerabilities

Note that these questions will not be linked to the categories of physical and non-physical assets and functions; thus, respondents will only need to respond to this set of questions once. All respondents (including those who have completed their own vulnerability assessments and were not required to respond to the previous vulnerability and asset questions) will be asked to respond to these questions.

36. Do any of your agency's physical and non-physical assets or functions provide **services or shelter** to underserved populations, elderly, very young, incarcerated, housing or transportation cost-burdened individuals, renters, those without a car, or animals? Please check all that apply.
    - ☐ Yes, my agency manages physical assets that serve, provide shelter to, or house these communities
    - ☐ Yes, my agency manages non-physical assets or provides functions (e.g., regulatory functions, public programs, education services, health services, food security, emergency management, supportive housing) that serve these communities
    - ☐ No, my agency does not provide functions, shelter, or housing to these populations

37. [**If checked first response option in Q36**] What systems or plans are in place to enable either shelter-in-place or safe evacuation and relocation, if necessary? (open-ended response)

38. What types of **programs or plans are in place to provide alternate access or redundancies** in services (e.g., power, water, transportation, critical facilities) as needed in the event of a disaster? Please write in your responses in the table below. (open-ended responses)

Asset or Service Provides:	Programs in Place to Provide Alternate Access or Redundancies	Please indicate if these have been put into place before	Please indicate if employees are regularly trained and updated on these plans and procedures
Critical access road			
Emergency or lifeline route			
Sole or limited access to communities for facilities			
Service to transit dependent communities			
Power services			
Operations of critical facilities			

39. Do any of the physical or non-physical assets you own, manage, lease, or otherwise influence provide **recreational access or opportunities** that are unique or limited in the area and/or region (e.g., access for persons with limited mobility, interpretive programs, access to unique ecosystems, etc.)?
    - ☐ Yes
    - ☐ No
    - ☐ I don't know
    - ☐ Other (please write in)
    a. [**If yes**] Could these functions easily be replaced in other areas in the event of damage to the assets? Please indicate how. (open-ended response)
    b. [**If yes**] Do these assets already exist in other places that could serve as replacements in the event of damage to one of the assets? Please indicate how. (open-ended response)

40. Do any of the physical or non-physical assets you manage or the functions your agency offers **provide or protect habitat for threatened or endangered species**?
    - ☐ Yes
    - ☐ No
    - ☐ I don't know
    a. [**If yes**] Is that habitat scarce in the region? Could this habitat be established in other areas? (open-ended response)
    b. [**If yes**] What specific habitat or species benefits would be lost if the asset was damaged, lost, or had its function otherwise impaired? (open-ended response)

41. What **consequences would occur** to the communities your agency supports if your operations were temporarily interrupted or damaged by a hazard or extreme weather event? Please describe the specific populations and consequences to those populations. (open-ended response)
    a. How quickly would those impacts be experienced by the community?
    b. How long (months, days, weeks, hours) would it take to restore these functions?
    c. What would be the anticipated cost to restore these functions?

42. Is it necessary for your agency to **partner with other agencies and organizations** for your day-to-day or frequent operations and functions, such as utilities, regional authorities, or local municipalities? If so, please list. (open-ended response)

43. What other state agencies, regional authorities, or local municipalities could be **impacted by loss of your agency's operations**? Please describe which agencies and how they could be impacted. (open-ended response)

44. Would any of the following be **impacted by loss of your agency's operations**? Please check all that apply and use the space below to describe how.
    - ☐ Education
    - ☐ Food support and security

- ☐ Goods movement
- ☐ Health services
- ☐ Local businesses
- ☐ Natural resource management and protection
- ☐ Permits
- ☐ Public health and safety
- ☐ Recreational opportunities
- ☐ Regulatory programs
- ☐ Transit and transportation
- ☐ Youth services
- ☐ Other (open-ended)____

45. For the functions that would be impacted by loss of your agency's operations checked in Q44, for each function, in the space below please indicate **how long it would take for the resource to be impacted and how long it would take to recover following impacts**. (open-ended response) [*survey will include space for respondents to write in responses in relation to each of the options checked in Q44*]

2. CONCLUSION

46. Is there anything else you would like to add about the vulnerability of your agency and/or the role your agency plays, both in its functions and overall mission, to the effects of hazards and climate change? (open-ended response)

Appendix 4.C:
Funding Sources for Hazard Mitigation and Climate Adaptation Actions

Appendix 4.C: Funding Sources for Hazard Mitigation and Climate Adaptation Actions

Purpose: To provide an inventory of existing federal, state, local, and private funding sources that could support climate adaptation and hazard mitigation in Massachusetts.

Building on and updating the previous federal resilience funding study conducted by EEA in 2021, below is a snapshot of relevant funds that could be applicable to the Commonwealth of Massachusetts as of June 2023.

Funding Mechanism or Program Name	Focus (Climate Adaptation, Hazard Mitigation, or Both	Brief Description	Administering Body	Relevant State Agency/Organization	Potentially Relevant State Programs*	Funding Range	Required Match % (0-100)	Funding Available for: Planning, Engagement, Implementation, or All	Frequency/Availability of Grant	Application Submission Date	State Deadline*	Sector Specific	Focus on Social Vulnerabilities?	Link to Overview
FEDERAL														
American Rescue Plan Act (ARPA)	**Both**	ARPA provided fundings to state, local, and Tribal governments in the form of Coronavirus State and Local Fiscal Recovery Funds (CSLFRF). The funding is to be used to support response and recovery from the COVID-19 public health emergency and invest in long-term growth and opportunities for recovery.	US Department of the Treasury	Massachusetts Executive Office for Administration and Finance: Federal Funds Office	Coronavirus State Fiscal Recovery Fund, Coronavirus Local Fiscal Recovery Fund	$8.7 billion provided to Massachusetts: $5.3 billion from the Coronavirus State Fiscal Recovery Fund and $3.4 billion from the Coronavirus Local Fiscal Recovery Fund. Tribes in the Commonwealth received $25 million.	Unknown	All	3 periods of fund allocation in MA: May 2021, December 2021, and planned late 2022.	Unknown	N/A	all	Provided aid to disproportionately impacted communities	https://home.treasury.gov/policy-issues/coronavirus/assistance-for-state-local-and-tribal-governments/state-and-local-fiscal-recovery-funds
Building Resilient Infrastructure and Communities (BRIC)	**Hazard Mitigation**	Building Resilient Infrastructure and Communities (BRIC) supports states, local communities, tribes and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards. The BRIC program guiding principles are supporting communities through capability- and capacity-building; encouraging and enabling innovation; promoting partnerships; enabling large projects; maintaining flexibility; and providing consistency.	FEMA	Massachusetts Emergency Management Agency (MEMA)	BRIC	Up to 6% annual set aside from post disaster grant funding. State, territory and tribal set-asides and national competition for balance, large and small grants. $2.295 billion expected in FY22, up from $1 billion in FY21 and $500M in round 1 (FY20). Up to $2M available to each state and US territory. Up to $2M available per tribal government applicant. Up to $2M per applicant for capability and capacity-building projects. https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities/before-apply	25% - Generally 10-25% - Economically Disadvantaged Rural Communities 0% - insular areas (i.e., island territories) when non-fed cost is <$200k 0% - Management costs	All	Annual	1/27/2023	12/5/2022	all	Economically Disadvantaged Rural Communities can obtain a greater share of federal funding (up to 90% of project funding compared to up to 75% normally)	https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities
Clean Water State Revolving Fund (CWSRF)	**Both**	The Clean Water State Revolving Fund (CWSRF) program is a federal-state partnership that provides communities low-cost financing for a wide range of water quality infrastructure projects.	U.S. EPA	Massachusetts Clean Water Trust (the Trust)	https://www.mass.gov/service-details/srf-clean-water-program	Small to large loans, provided $8.2 billion in assistance in 2021. 1700 loans, ranging from $2400 to $285 million. In 2022, in MA, $354.4 million was committed to 46 CWSRF projects. https://www.epa.gov/system/files/documents/2022-12/2021-CWSRF-Annual-Report.pdf Other types of assistance also provided: refinancing, guarantees, etc.	Repayment starts 12 months after construction, can match with FEMA and USDA. States contribute an additional 20% to match federal grants.	Mainly Implementation	Annual	Different for different states	Proposal solicitation launched in June, proposals due in August	water		https://www.epa.gov/cwsrf
Community Development Block Grant (CDBG) Disaster Recovery	**Both**	HUD provides flexible grants to help cities, counties, and states to recover from Presidentially declared disasters, especially in low-income areas, subject to the availability of supplemental appropriations. In response to Presidentially declared disasters, Congress may appropriate additional funding for the Community Development Block Grant (CDBG) Program as Disaster Recovery grants to rebuild the affected areas and provide crucial seed money to start the recovery process. Since CDBG Disaster Recovery (CDBG-DR) assistance may fund a broad range of recovery activities, HUD can help communities and neighborhoods that otherwise might not recover due to limited resources.	HUD	Department of Housing and Community Development (DHCD)	Disaster and Flood Insurance Steps	$5 billion appropriated in FY2021 for disaster events that occurred in 2020 and 2021. https://www.hudexchange.info/programs/cdbg-dr/cdbg-dr-grantee-contact-information/#congressional-appropriations-by-year As of May 2021, there are 62 active grantees managing 130 active grants, consisting of $67 billion in active grant funding. There are no annual appropriations, each appropriation must be approved by Congress after a presidentially declared disaster https://files.hudexchange.info/resources/documents/CDBG-Disaster-Recovery-Overview.pdf	0	Implementation	After Presidential Disaster Declaration	Depends	Depends	housing, water, transportation, electricity, economic development		https://www.hudexchange.info/programs/cdbg-dr/
Community Development Block Grant Mitigation (CDBG-MIT)	**Hazard Mitigation**	The Community Development Block Grant Mitigation (CDBG-MIT) Program is a unique and significant opportunity for eligible grantees to use this assistance in areas impacted by recent disasters to carry out strategic and high-impact activities to mitigate disaster risks and reduce future losses.	HUD	Department of Housing and Community Development (DHCD)	Emergency Housing Assistance Programs	$16 billion total worth of funds allocated in last appropriation in FY18. $8.29B was allocated to Puerto Rico in a special appropriation in January 2020.	Maximum 25% with Flexible Match provision	All	Disaster affected regions are granted funding; Massachusetts currently does not have a grant.	Not Specified	N/A	all		https://www.hudexchange.info/programs/cdbg-mit/
Conservation Innovation Grants (CIG)	**Both**	Conservation Innovation Grants are competitive grants that stimulate the development and adoption of innovative approaches and technologies for conservation on agricultural lands. There are three types of grant opportunity: National, State, and On-Farm Trials	USDA Natural Resources Conservation Service	Massachusetts Natural Resources Conservation Service	State Conservation Innovation Grants	Up to $1 million or $2 million (decided annually). On average, $20 million in funding is available	Must match at least 1:1 with non federal funding	Planning, implementation	Annual	May vary by program	May vary by program	agriculture	Up to 10 percent of annual national CIG funds are set aside for applicants who are historically underserved (beginning, limited resource, socially disadvantaged, military veteran farmers and ranchers, or American Indian tribes) or community-based organizations that include or represent these groups.	https://cig.sc.egov.usda.gov/?utm_source=nrcs-cig&utm_medium=site&utm_campaign=obv-redirect
Emergency Management Performance Grant (EMPG)	**Both**	EMPG funds support local, state, and tribal governments with emergency management activities in the following categories: planning, organizational, equipment, training, and exercises. The objective is to implement the National Preparedness System and support the National Preparedness Goal of a secure and resilient nation.	FEMA	Massachusetts Emergency Management Agency (MEMA)	EMPG	Nationwide, $405.1 million available for FY2022. For Massachusetts, $8 million has been awarded, and MEMA has allocated $2.5 million for pass-through grants. https://www.mass.gov/doc/22empg-nofo/download	For MEMA subgrant projects, dollar for dollar match is required	All	Annual	Closed 6/13/2022	FY2022 MEMA subgrant application period ended 11/30/2022	all	The first of three goals in the 2022 - 2026 FEMA Strategic Plan is to "instill equity as a foundation of emergency management". Projects receiving funding must consider how they can support FEMA's strategic goals	https://www.fema.gov/grants/preparedness/emergency-management-performance#nofos
Environmental and Climate Justice Grants	**TBD**	The Environmental and Climate Justice Program was created under the Inflation Reduction Act. Funding will be used to support grants and technical assistance for environmental/climate justice projects that benefit overburdened communities. As of February 2023, EPA was seeking public input on this program.	EPA	TBD	TBD	$3 billion in funding available to distribute	TBD	TBD	TBD	TBD	TBD	TBD	Focus is on addressing environmental and climate justice in overburdened communities	https://www.epa.gov/inflation-reduction-act/inflation-reduction-act-environmental-and-climate-justice-program
Environmental Justice Small Grants Program	**Climate Adaptation**	EPA's EJ Small Grants Program supports and empowers communities working on solutions to local environmental and public health issues. The program is designed to help communities understand and address exposure to multiple environmental harms and risks.	U.S. EPA	Massachusetts Department of Environmental Protection (MassDEP)	Updated 2021 EJ Policy, Tools and resources like EJ Maps, programs such as Parkland Acquisitions and Renovations for Communities (PARC).	Up to $100,000 per project, 16 - 20 projects. Most recent opportunity was for Tribal government applicants only.	No	Mainly Engagement	Annual	Closed 5/20/2022	Unknown	education, public health, water	Main focus is environmental justice	https://www.epa.gov/environmentaljustice/environmental-justice-small-grants-program

Appendix 4.C: Funding Sources for Hazard Mitigation and Climate Adaptation Actions
Purpose: To provide an inventory of existing federal, state, local, and private funding sources that could support climate adaptation and hazard mitigation in Massachusetts.

Building on and updating the previous federal resilience funding study conducted by EEA in 2021, below is a snapshot of relevant funds that could be applicable to the Commonwealth of Massachusetts as of June 2023.

Funding Mechanism or Program Name	Focus (Climate Adaptation, Hazard Mitigation, or Both	Brief Description	Administering Body	Relevant State Agency/Organization	Potentially Relevant State Programs*	Funding Range	Required Match % (0-100)	Funding Available for: Planning, Engagement, Implementation, or All	Frequency/Availability of Grant	Application Submission Date	State Deadline*	Sector Specific	Focus on Social Vulnerabilities?	Link to Overview
Flood Mitigation Assistance (FMA)	**Hazard Mitigation**	The Flood Mitigation Assistance Program is a competitive grant program that provides funding to states, local communities, federally recognized tribes and territories. Funds can be used for projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the National Flood Insurance Program.	FEMA	Massachusetts Emergency Management Agency (MEMA)	FMA	$800M in FY22, up from $160 million in FY21. Funding caps per subapplication are: $100k for Multi-Hazard Mitigation Plans $50k for state Technical Assistance $900k for Project Scoping $300k for additional Capability and Capacity-Building activities $50M for Localized Flood Risk Reduction projects (aka Community Flood Mitigation projects) https://www.fema.gov/sites/default/files/documents/fema_fy22-fma-nofo_08052022_0.pdf	0% - Severe Repetitive Loss 10% - Repetitive Loss 25% - Generally	Planning, Implementation	Annual	1/27/2023	12/5/2022	housing, flooding		https://www.fema.gov/grants/mitigation/floods
Forest Health Protection Special Project Program Grants	**Hazard Mitigation**	The Forest Health Protection (FHP) group under State & Private Forestry has a number of Special Project Program funding opportunities: Special Technology Development Program (STDP), Forest Service Pesticide Impact Assessment Program (FSPIAP), Biological Control of Invasive Forest Pests (BCIFP), Forest Health Evaluation Monitoring Projects (EM), and the Emerging Pest Program. This grants help support projects that provide forest insect, disease and invasive plant survey and monitoring information, and technical and financial assistance to prevent, suppress and control outbreaks threatening forest resources.	USDA Forest Service	Massachusetts Department of Conservation and Recreation		May vary by program and project	50% cost share, but can be reduced or waived on a case-by-case basis	Planning, implementation	Annual	May vary by program	May vary by program	forestry		https://www.fs.usda.gov/foresthealth/working-with-us/index.shtml
Hazard Mitigation Grant Program (HMGP) - Section 404	**Hazard Mitigation**	FEMA's Hazard Mitigation Grant Program provides funding to state, local, tribal and territorial governments so they can rebuild in a way that reduces, or mitigates, future disaster losses in their communities. This grant funding is available after a presidentially declared disaster.	FEMA	Massachusetts Emergency Management Agency (MEMA)	HMGP	Allocated using a "sliding scale" formula based on the percentage of funds spent on FEMA Public Assistance and Individual Assistance for each Presidentially declared disaster. The formula provides up to 15% of the first $2 billion of estimated aggregate amounts of disaster assistance, up to 10% for amounts between $2 billion and $10 billion, and 7.5% for amounts between $10 billion and $35.333 billion. For states with FEMA Enhanced Mitigation Plans, up to 20% is available for amounts up to $35.333 billion. In FY21 $3.46 billion is available through HMGP due to the COVID-19 pandemic. In MA, $110.8 million is available statewide, with a soft cap of $15 mil per project	25% - Generally 10% - Under HMGP disaster 4496 (COVID-19 pandemic) 0% - insular areas (i.e., island territories) when non-fed cost is <$200k 0% - Management costs	Planning, Implementation	After Presidential Disaster Declaration	Within 12 months of Presidential Disaster Declaration	12/5/2022	housing, flooding, infrastructure (retrofitting, construction)		https://www.fema.gov/grants/mitigation/hazard-mitigation
High Hazard Potential Dams Grant	**Hazard Mitigation**	FEMA's Rehabilitation of High Hazard Potential Dams (HHPD) grant program provides technical, planning, design, and construction assistance for eligible rehabilitation activities that reduce dam risk and increase community preparedness.	FEMA	Massachusetts Emergency Management Agency (MEMA)	High Hazard Potential Dams Grant	$22 million total appropriated in FY22 ($11.6 million for planning and design activities, $10.4 million for construction-ready activities)	35%	Planning, Implementation	Annual	Closed 7/15/2022	Unknown	flooding/dams		https://www.fema.gov/emergency-managers/risk-management/dam-safety/grants/resources
Land and Water Conservation Fund (LWCF)	**Climate Adaptation**	LWCF was created to safeguard natural areas, water resources and cultural heritage, and to provide recreation opportunities to all Americans. The LWCF program can be divided into the "State Side" which provides grants to State and local governments, and the "Federal Side" which is used to acquire lands, waters, and interests therein necessary to achieve the natural, cultural, wildlife, and recreation management objectives of federal land management agencies.	National Park Service	Massachusetts Department of Environmental Protection (MassDEP)/MassWildlife	Tools and resources for landowners, towns, land trusts, educators, etc.	The Great American Outdoors Act, signed into law in September 2020, established permanent funding of $900M/year for LWCF. https://www.nps.gov/subjects/legal/great-american-outdoors-act.htm	N/A	Implementation	Annual	Unknown	Unknown	natural resources		https://www.nps.gov/subjects/lwcf/index.htm
Landscape Scale Restoration Program	**Climate Adaptation**	The Landscape Scale Restoration Program is a competitive grant program that supports restoration of forest landscapes. Projects address large-scale issues such as wildfire risk reduction, watershed protection and restoration, and the spread of invasive species and insect infestations.	USDA Forest Service	Mass DEP	Massachusetts Forest Action Plan	$12.536 million in funding for FY 2021 for 52 projects. Funding for individual projects ranged from $67k to $500k. file:///C:/Users/ohemond/Downloads/FY2021%20LSR%20Funded%20Projects.pdf	50%	All	Annual	2023 Tribes deadline was 12/15/2022	NA	natural resources		https://www.fs.usda.gov/managing-land/private-land/landscape-scale-restoration
National Coastal Zone Management Program	**Both**	Protect and restore ecologically significant habitats, including conserving lands that play a critical role in helping communities become more resilient to natural hazards. Funding currently provided by the Infrastructure Investment and Jobs Act.	NOAA Office for Coastal Management	Massachusetts Office of Coastal Zone Management (CZM)	CZM Coastal Habitat Program	Approximately $40 million available per year, with each project estimated to cost between $200,000 up to $6 million	No match required, but leveraged funding is strongly encouraged	Planning, implementation	Annual, funding supports five years of awards (2023 - 2027)	Closed 10/28/2022	NA	coastal natural resources	The NOAA Office for Coastal Management (OCM) encourages applicants and awardees to support the principles of equity and inclusion when writing their proposals and performing their work.	https://coast.noaa.gov/funding/infrastructure.html
National Estuarine Research Reserve System	**Both**	Protect and restore ecologically significant habitats, including conserving lands that play a critical role in helping communities become more resilient to natural hazards. Funding currently provided by the Infrastructure Investment and Jobs Act.	NOAA Office for Coastal Management	Waquoit Bay National Estuarine Research Reserve		Approximately $15 million available per year, with each project estimated to cost between $200,000 up to $4 million	No match required, but leveraged funding is strongly encouraged	Planning, implementation	Annual, funding supports five years of awards (2023 - 2027)	Closed 10/28/2022	NA	coastal natural resources	DOC/NOAA supports cultural and gender diversity and is strongly committed to broadening the participation of historically black colleges and universities, Hispanic serving institutions, tribal colleges and universities, and institutions that work in underserved areas. While this program limits applicants to NERRS lead agencies or universities, DOC/NOAA encourages applicants to include partners and contributors from any of the above institutions.	https://coast.noaa.gov/funding/infrastructure.html
Neighborhood Access and Equity Grants	**Hazard Mitigation**	This is a new program funded by the Inflation Reduction Act. It will provide grants to help reconnect neighborhoods divided by infrastructure, mitigate negative impacts of transportation facilities or construction projects on communities, and support equitable transportation planning.	Federal Highway Administration	MassDOT	TBD	Total budget: $3 billion over 5 years, including $117 million for fence line air monitoring, $50 million for ambient air quality monitoring, and $20 million for methane monitoring. Specifics for individual grants TBD	20% standard match required 0% match for underserved or disadvantaged communities	TBD	Annual	Not yet known	Not yet known	infrastructure/transportation	Roughly a third of this program's money is set aside for projects in low-income communities that have an anti-displacement policy, community benefits agreement, and local hiring plan. No matching funds required for disadvantaged communities.	https://fundingnaturebasedsolutions.nwf.org/programs/neighborhood-access-and-equity-grant-program/

Appendix 4.C: Funding Sources for Hazard Mitigation and Climate Adaptation Actions

Purpose: To provide an inventory of existing federal, state, local, and private funding sources that could support climate adaptation and hazard mitigation in Massachusetts.

Building on and updating the previous federal resilience funding study conducted by EEA in 2021, below is a snapshot of relevant funds that could be applicable to the Commonwealth of Massachusetts as of June 2023.

Funding Mechanism or Program Name	Focus (Climate Adaptation, Hazard Mitigation, or Both	Brief Description	Administering Body	Relevant State Agency/Organization	Potentially Relevant State Programs*	Funding Range	Required Match % (0-100)	Funding Available for: Planning, Engagement, Implementation, or All	Frequency/Availability of Grant	Application Submission Date	State Deadline*	Sector Specific	Focus on Social Vulnerabilities?	Link to Overview
Planning Assistance to States	**Both**	USACE can partner with states to provide Comprehensive Plans or Technical Assistance to states, local governments, and tribes related to the development, utilization, and conservation of water and related land resources. Types of studies conducted in recent years under the program include the following: water supply/demand, water conservation, water quality, environmental/conservation, wetlands evaluation/restoration, dam safety/failure, flood damage reduction, coastal zone protection, and harbor planning.	U.S. Army Corp of Engineers	Multiple		Maximum of $5 million in federal funding can be spent in a given state/territory/tribe in a single fiscal year	50%	Planning	Evaluated as requested by state/non-federal entity	NA	NA	water, natural resources	Local cost sharing requirements are waived for federally recognized tribes and US territories	https://www.nae.usace.army.mil/missions/public-services/planning-assistance-to-states/
Plant Pest and Disease Management and Disaster Prevention Program (PPDMDPP)	**Hazard Mitigation**	Through the Plant Pest and Disease Management and Disaster Prevention Program, APHIS provides funding to strengthen and safeguard the nation's agricultural infrastructure. Grants support projects that expand or enhance pest survey, identification, inspection, mitigation, risk analysis, and public education and outreach. There is also funding reserved for responding to pest and plant health emergencies throughout the year.	USDA Animal and Plant Health Inspection Service (APHIS)	Massachusetts Department of Agricultural Resources (DoAR)		In FY 2023, APHIS is allocating $62.9 million to fund 322 projects	Unknown	All	Annual	Unknown	Unknown	agriculture		https://www.aphis.usda.gov/aphis/resources/ppa-projects
Regional Ocean Partnerships Program	**Climate Adaptation**	Coordinate interstate and intertribal management of ocean and coastal resources and implement priority actions identified by established regional ocean partnerships, including data sharing and integration. Funding currently provided by the Infrastructure Investment and Jobs Act.	NOAA Office for Coastal Management	Massachusetts Office of Coastal Zone Management (CZM)	CZM is involved in the following regional partnerships: Northeast Regional Ocean Council (NROC), Gulf of Maine Council on the Marine Environment, Northeast Regional Association of Coastal and Ocean Observing Systems (NERACOOS)	Approximately $11 million available per year ($20.5 million awarded to 13 projects for FY22-23)	No match requirement	All	Annual, funding supports five years of awards (2023 - 2027)	Unknown	NA	coastal natural resources	$1 million in funding each year is designated to be awarded to federally recognized tribes	https://coast.noaa.gov/funding/infrastructure.html
Regional Resiliency Assessment Program (RRAP)	**Both**	The Regional Resiliency Assessment Program (RRAP) is a voluntary, cooperative assessment of specific critical infrastructure that identifies a range of security and resilience issues that could have regionally or nationally significant consequences. The goal of the RRAP is to generate greater understanding and action among public and private sector partners to improve the resilience of a region's critical infrastructure.	DHS, Cybersecurity and Infrastructure Security Agency	Homeland Security Division	Homeland Security State-Share Grant Program, Regional Homeland Security Grant Program	N/A	N/A	N/A	Annual	Not Specified	Unknown	infrastructure (could include housing, water, transportation, electricity, law enforcement)		https://www.cisa.gov/regional-resiliency-assessment-program
Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) Act	**Hazard Mitigation**	The STORM act provides capitalization grants to states, tribes, PR, and DC to establish revolving loan funds for projects designed to reduce risks from disaster, natural hazards and other related environmental harm.	FEMA	Massachusetts Emergency Management Agency (MEMA)	BRIC, FMA, HMGP	$5.1 million or greater capitalization grant per project.	Grant recipients must deposit at least 10% the amount of the grant into the loan fund in order to receive funding	N/A (state decides which projects they will give loans to)	Annual	Application period: 2/1/2023 - 4/28/2023	N/A	housing, water, natural resources, buildings/development		https://www.fema.gov/grants/mitigation/storm-rlf
State Transportation Improvement Program (STIP)	**Climate Adaptation**	STIP is a list of projects prepared yearly by the Office of Transportation Planning. Projects include improvements to bicycle paths, bridges, roadways, sidewalks, and transit systems. The MBTA, the fifteen Massachusetts Regional Transit Authorities, local officials, and the MassDOT Rail and Transit Division plan, develop, and implement transit investments which constitute the STIP.	US Department of Transportation (DOT)	Mass Department of Transportation (DOT)	STIP https://www.mass.gov/service-details/state-transportation-improvement-program-stip	Under BIL in 2021, funding is approximately $800 million annually for Massachusetts. Funding was previously between $600 - $650 million for the state.	Not sure how much is required, but the state does provide some amount of matching funds to the federal aid	Planning, Implementation	Annual	Metropolitan Planning Organizations (MPOs) choose preferred projects for their planning region and MassDOT compiles those endorsed projects. Process happens Jan - June.	Unknown	transportation		https://www.transit.dot.gov/regulations-and-guidance/transportation-planning/statewide-transportation-improvement-program-stip
The Environmental Justice Collaborative Problem-Solving (CPS) Cooperative Agreement Program	**Both**	EPA's EJ Collaborative Problem-Solving Cooperative Agreement Program provides funding for eligible applicants for projects that address local environmental and public health issues within an affected community. The CPS Program assists recipients in building collaborative partnerships to help them understand and address environmental and public health concerns in their communities.	U.S. EPA	Massachusetts Department of Environmental Protection (MassDEP)	Updated 2021 EJ Policy, Tools and resources like EJ Maps, programs such as Parkland Acquisitions and Renovations for Communities (PARC).	FY21 $4.3 million ARP funds + $2.5 million from EPA EJ annual appropriation. Awarded up to $200,000 each for 34 projects. https://www.epa.gov/system/files/documents/2021-12/2021-selected-ejcps-project-descriptions.pdf	N/A	All	Available yearly for projects durations of 2 years.	Currently closed	Unknown	all	Main focus is environmental justice	https://www.epa.gov/environmental-justice/environmental-justice-collaborative-problem-solving-cooperative-agreement-0
The Environmental Justice Government-to-Government (EJG2G) Program (formerly the State Environmental Justice Cooperative Agreement Program (SEJCA))	**Both**	EPA's EJG2G program provides funding to governmental entities at the state, local, territorial and tribal level to support and/or create model government activities that lead to measurable environmental or public health results in communities disproportionately burdened by environmental harms and risks. These models should leverage or utilize existing resources or assets of state agencies to develop key tools and processes that integrate environmental justice considerations into governments and government programs at all levels.	U.S. EPA	Massachusetts Department of Environmental Protection (MassDEP)	Updated 2021 EJ Policy, Tools and resources like EJ Maps, programs such as Parkland Acquisitions and Renovations for Communities (PARC).	Grants up to $200,000. There were 21 projects selected for 2021. https://www.epa.gov/system/files/documents/2022-05/2021%20SEJCA%20Selections%20Project%20Descriptions.pdf	No	All	Administered in 2021, 2020, and 2009. 2022 competition coming soon.	Currently closed	Unknown	education, public health, water, natural resources	Main focus is environmental justice	https://www.epa.gov/environmentaljustice/state-environmental-justice-cooperative-agreement-program
Urban and Community Forestry Program	**Climate Adaptation**	The Forest Service Urban & Community Forestry Program is a technical, financial, and educational assistance program, delivering nature-based solutions to ensure a resilient and equitable tree canopy in urban areas, where more than 84 percent of Americans live.	USDA Forest Service	Massachusetts Department of Conservation and Recreation	Urban and Community Forestry Challenge Grants	$1,000 to $40,000 per project	50% standard match 25% for environmental justice projects	All	Annual	Unknown	Intent to apply Oct 1, final app Nov 1	forestry	Projects in environmental justice neighborhoods where grant work will serve environmental justice populations can get a greater degree of financial support (75-25 matching grant as opposed to 50-50)	https://www.mass.gov/guides/urban-and-community-forestry-challenge-grants
Urban Heat Island Mapping Campaign	**Both**	The campaign supports communities in mapping temperature and humidity data at a high resolution to identify heat islands and learn where action is needed to protect community members from high heat.	NOAA (Office of Education, Climate Program Office, National Integrated Heat Health Information System (NIHHIS))	Can vary, numerous types of organizations are welcome to apply		Around $15,000 for smaller cities and $30,000 for larger cities	No requirement. Typically cities contribute 50%	All	Annual	Closed 12/16/2022	Same	urban planning	Covered program under the Justice40 initiative, required to track and report on benefits allocated to EJ communities	https://www.heat.gov/pages/mapping-campaigns

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Water Infrastructure Finance and Innovation Act (WIFIA)	**Climate Adaptation**	A federal credit program administered by EPA for eligible water and wastewater infrastructure projects.	U.S. EPA	Massachusetts Department of Environmental Protection (MassDEP)/Executive Office of Energy and Environmental Affairs (EO EEA)	Water resources grants, loans, and other programs	Provides long-term, low-cost loans. $20 million limit for large communities, $5 million limit for small communities	WIFIA can fund a maximum of 49% of the project costs, max of 80% can come from federal sources.	Implementation	Available yearly but states have different deadlines.	Rolling submission, opened 9/6/2022	Unknown	water		https://www.epa.gov/wifia
Water Resources Development Act	**Both**	WRDA includes key provisions to invest in ports, harbors and inland waterways; build more resilient communities; and ensure that the U.S. Army Corps of Engineers carries out projects in an economically and environmentally responsible manner.	U.S. Army Corps of Engineers	Massachusetts Department of Environmental Protection (MassDEP)/Division of Ecological Restoration	Aquatic restoration programs pertaining to dam removal, culvert replacement, Streamflow restoration, etc.	WRDA 2022 provides $6.58 billion in environmental infrastructure assistance for community-driven projects and statewide infrastructure projects. https://transportation.house.gov/imo/media/doc/WRDA%202022%20Fact%20Sheet_FINAL.pdf	N/A	Planning, Implementation	Every two years; most recent cycle is 2022; previously administered in 2020, 2018, and 2016	Closed 2/1/2022	Unknown	water, natural resources		https://transportation.house.gov/committee-activity/issue/water-resources-development-act-of-2020
Weatherization Assistance Program (WAP)	**Both**	The U.S. Department of Energy (DOE) Weatherization Assistance Program (WAP) reduces energy costs for low-income households by increasing the energy efficiency of their homes, while ensuring their health and safety. The program supports 8,500 jobs and provides weatherization services to approximately 35,000 homes every year using DOE funds.	U.S. Department of Energy	Department of Housing and Community Development (DHCD)	Low-Income Home Energy Assistance Program	Max $4,725 per household		Implementation	Annual	Application period: 10/1/2022 - 4/30/2023	Application period: 10/1/2022 - 4/30/2023	housing	Only low income households (making 60% or less of the state median income) are eligible to apply	https://www.energy.gov/eere/wap/weatherization-assistance-program
STATE/LOCAL														
Culvert Replacement Municipal Assistance Grants	**Both**	DER's Culvert Replacement Municipal Assistance Grant Program can be used by municipalities to replace undersized, perched, and/or degraded culverts in areas of high ecological value. Improved culverts can meet higher structural and environmental standards and flood resiliency criteria. Projects must intend to meet the goals of the MA Stream Crossing Standards	Mass DER	Mass DER	NA	$1.8 million awarded to 13 municipalities for 2023. Awards typically range from $25k to $400k, depending on the project.	No requirement, but applicants are recommended to identify additional sources of funding for their project	Planning, Implementation	Annual	Pre-RFR inquiries will be accepted 11/30/2022 - 2/1/2023. Bid opening date is 2/12/2023.	(same)	water, natural resources	Grant applicants should describe how the project can provide climate resiliency, public safety, and/or socio-economic benefits for environmental justice communities	https://www.mass.gov/how-to/culvert-replacement-municipal-assistance-grant-program
CZM Coastal Resilience Grant Program	**Both**	The Coastal Resilience Grant Program provides financial and technical support to a variety of coastal resilience projects: from planning, public outreach, feasibility assessment, and shoreline vulnerability analysis to design, permitting, construction, and monitoring. The program aims to increase community understanding of coastal impacts, evaluate vulnerabilities, conduct adaptation planning, redesign and retrofit infrastructure, and restore shorelines.	Office of Coastal Zone Management (CZM)	Office of Coastal Zone Management (CZM)	StormSmart Coasts Program, MVP	In 2022 (for FY 2023), $12.6 million in grants was awarded to 27 projects. Grants ranged from $70k to $2 million per project. Since the program's start in 2014, $37.7 million has been invested in 201 coastal resilience projects.	Match requirement on hold for FY23. Applicants are encouraged to provide 25% or more of the total project cost	All	Annual	FY2023 application is closed. Grants were awarded on 9/19/2022.	(same)	natural resources, infrastructure	Environmental Justice considerations are taken into account when evaluating applicants	https://www.mass.gov/service-details/coastal-resilience-grant-program
District Local Technical Assistance (DLTA) and the Technical Assistance Program (TAP)	**Both**	DLTA funds technical assistance for cities and towns to support a variety of planning and implementation projects, including zoning, housing production, economic development, and conservation planning. DLTA funds are distributed between the 13 regional planning agencies (RPAs) in MA. Through TAP, DLTA funds are leveraged to support community-based projects.	Metropolitan Area Planning Council (MAPC)	Metropolitan Area Planning Council (MAPC)	DLTA helps fund the MAPC Technical Assistance Program (TAP). Other relevant programs: Community Compact, Chapter 40R Smart Growth Overlay Districts, Complete Streets, Shared Streets and Spaces Grant Program, Community One Stop for Growth, EEA Planning Assistance Grants	During 2022, $712,085 in funding was available for DLTA projects.	No requirement, but municipalities are encouraged to find additional funding sources. It is also common for MAPC to provide TAP funds while helping applicants secure other state grants for their projects	All	Annual	TAP FY2023 initial deadline is 1/16/2023. If additional funds are available after the first round of funding decisions are announced, then additional awards may be made on a rolling basis.	(same)	ALL	In 2023, community projects will be prioritized for funding based upon if they advance racial and social equity, include multiple communities working together, and/or prioritize including Affordable Housing provisions in their plans	https://www.mapc.org/get-involved/legislative-priorities/district-local-technical-assistance-dlta/ and https://www.mapc.org/about-mapc/funding-opportunities/
Food Security Infrastructure Grant Program	**Climate Adaptation**	The Food Security Infrastructure Grant Program works to secure equitable access to food, especially to locally produced food, for people throughout MA. It also helps connect farmers, fisherman, and other food producers to a resilient food system.	Executive Office of Energy and Environmental Affairs (EEA)	Executive Office of Energy and Environmental Affairs (EEA)	NA	Created in response to the COVID-19 pandemic, the Food Security Infrastructure Grant Program received $36 million in funding in 2020. That funding has now been awarded to over 360 recipients. Budget was up to $500k per proposal.	No requirement	Implementation	Multiple rounds of funding were available in FY21 and FY22.	Program is now closed. Last opportunity for proposals closed 10/31/2021	(same)	food	Projects evaluated on their ability to ensure equitable access to food	https://www.mass.gov/service-details/food-security-infrastructure-grant-program
MassWildlife Habitat Management Grant Program	**Climate Adaptation**	The MassWildlife Habitat Management Grant Program provides assistance to private and municipal owners of protected lands to enhance wildlife habitat, while promoting public access for outdoor recreation. Program objectives include: improve habitat for game species, manage habitat for Species of Greatest Conservation Need, enhance ecological communities that are disproportionately susceptible to climate change, and promote public recreational opportunities on conserved lands.	Division of Fisheries and Wildlife (MassWildlife)	Division of Fisheries and Wildlife (MassWildlife)	NA	$10,000 - $75,000 per grant	No requirement	Implementation	Annual	2022 application round closed 8/31/2022	(same)	natural resources		https://www.mass.gov/guides/masswildlife-habitat-management-grant-program
MassWorks Infrastructure Program	**Both**	The MassWorks Infrastructure Program provides grants to communities, primarily for housing public infrastructure projects. The program prioritizes the production of multi-family housing in mixed-use districts that supports job creation and economic development. The program also supports improvements to other publicly owned infrastructure systems.	Executive Office of Housing and Economic Development (EOHED)	Executive Office of Housing and Economic Development (EOHED)	Community One Stop for Growth	Since 2015, over $600 million in grants has been invested through 326 awards to 181 communities throughout the state. There is no specific maximum or minimum award amount for projects.	No requirement, but applicants with other sources of funding will be considered more competitive.	Planning, Implementation	Annual	2022 application round closed 6/3/2022	(same)	housing, water, electricity, transportation	Follows the Commonwealth's Sustainable Development Principles, which promote equitable and sustainable development	https://www.mass.gov/service-details/massworks-infrastructure-program
Municipality Vulnerability Preparedness (MVP) Program	**Climate Adaptation**	The Municipal Vulnerability Preparedness (MVP) grant program created in 2017 as part of Governor Baker's Executive Order 569 provides support for cities and towns in Massachusetts to identify climate hazards, assess vulnerabilities, and develop action plans to improve resilience to climate change. Communities that complete the MVP Planning Grant process become designated as an MVP Community and are eligible for MVP Action Grant funding to implement the priority actions identified through the planning process.	Executive Office of Energy and Environmental Affairs (EEA)	Executive Office of Energy and Environmental Affairs (EEA)	Two grant types: MVP Planning Grant and MVP Action Grant	For FY23 MVP Planning Grant, between $15k to $100k per municipality/regional group may be awarded. For FY24 MVP Action Grant, $20 million in funding is anticipated.	Action Grant: 25% match required	All	Annual	Planning grant deadline: 1/6/2023 Action grant: applications currently closed, next round expected in spring 2023	(same)	all, except probably not law enforcement	One of the program's core principles is increasing equitable outcomes and supporting environmental justice populations. Planning and Action grant applications are supposed to incorporate these goals into their projects.	https://www.mass.gov/municipal-vulnerability-preparedness-mvp-program

Appendix 4.C: Funding Sources for Hazard Mitigation and Climate Adaptation Actions
Purpose: To provide an inventory of existing federal, state, local, and private funding sources that could support climate adaptation and hazard mitigation in Massachusetts.

Building on and updating the previous federal resilience funding study conducted by EEA in 2021, below is a snapshot of relevant funds that could be applicable to the Commonwealth of Massachusetts as of June 2023.

Funding Mechanism or Program Name	Focus (Climate Adaptation, Hazard Mitigation, or Both	Brief Description	Administering Body	Relevant State Agency/Organization	Potentially Relevant State Programs*	Funding Range	Required Match % (0-100)	Funding Available for: Planning, Engagement, Implementation, or All	Frequency/Availability of Grant	Application Submission Date	State Deadline*	Sector Specific	Focus on Social Vulnerabilities?	Link to Overview
Regional Restoration Partnerships Program	**Both**	DER's Partnerships Program supports restoration work on degraded aquatic ecosystems and increases climate change resiliency. Nonprofit organizations and MA Regional Planning Agencies can apply to develop, lead, and support partnerships among regional and local partners for aquatic restoration projects.	Mass DER	Mass DER	NA	$180,472 awarded at the end of 2021 to three partnerships: Berkshire Clean, Cold, Connected Restoration Partnership; Buzzard's Bay Watershed Restoration Partnership; Merrimack Restoration Partnership Funding is available to support a FTE Restoration Coordinator and for project implementation activities	25% match required to support Restoration Coordinator salary and fringe benefits costs. No match required for implementation funding.	All	Annual	Unknown, currently closed	(same)	natural resources		https://www.mass.gov/how-to/ders-partnerships-program
Water Utility Resilience Program	**Both**	The Water Utility Resilience Program (WURP) provides assistance to local drinking water and wastewater utilities to build more resilient water infrastructure. The program can provide support in the following areas: critical infrastructure mapping, emergency & security preparedness, and climate change information & resources.	Mass DEP	Mass DEP	Water Management Act Grant Programs, MVP Program, Clean Energy Results Program	The program can support critical infrastructure mapping for up to 20 water utilities, depending on utility size. In SFY21 and SFY22, the program completed critical infrastructure mapping for 15 and 9 utilities, respectively.	0%	All	Annual, based on funding availability	Dependent on contract structure. Request for Interest is forthcoming.	Dependent on contract structure	water		https://www.mass.gov/guides/water-utility-resilience-program
PRIVATE/FOUNDATION														
America the Beautiful Challenge	**Both**	The America the Beautiful Challenge coordinates public and private funding into one grant program. Grants are used to support locally-led ecosystem restoration projects that invest in watershed restoration, resilience, equitable access, workforce development, corridors and connectivity, and collaborative conservation.	National Fish and Wildlife Foundation	NA	NA	$85 million for 2022. Four grant categories: States, Territories, and Tribal Implementation Grants: $1 million to $5 million Planning, Collaboration and Engagement for States, Territories, and Tribes: $200k to $1 million Grants to Buffer and Benefit Public Lands: $250k to $1.5 million Private Forests, Rangeland and Farmland Grants: $200k to $500k	0% - DoD Conservation and Restoration Funds 3-10% - DOI Conservation and Restoration Funds 50% - NRCS Technical Assistance Funds 20% - USFS Conservation and Restoration Funds	All	Annually. Expected to be a five year program (2022 - 2026)	Closed 7/21/2022	N/A	natural resources		https://www.nfwf.org/programs/america-beautiful-challenge?activeTab=tab-1
Climate Resilience Grant Program	**Both**	Goal: Increase capacity in Metro Boston to prepare for and adapt to the impacts of climate change. Priorities: Build awareness and mobilize a diverse constituency for action on climate risks, impacts, and resilience strategies. Mobilize key stakeholders to advance equitable policies and resilience plans. Catalyze momentum through demonstration projects that integrate resilience into the fabric of cities.	Barr Foundation	NA	NA	Awards range from $20k to $4.2M, depending on the project; geographic focus on Greater Boston	Not available	All	Based on requests submitted	Express interest via online form	NA	All	Most interested in putting resources toward the following movement-building activities: -Equitably reducing greenhouse gas emissions to improve the health and well-being of communities of color by improving air quality and access to clean, reliable, affordable energy and mobility options -Building communities that are prepared for climate change, and protect and work for all people -Providing career pathways and support for professionals of color working in the climate movement in our region -Investing in capacity-building of POC-led equity-centered organizations so that they can become stronger and healthier and build more power in the communities they serve -Supporting an increase in the number of POC-led equity-centered organizations that are engaged in climate action Fostering authentic and meaningful allyship among the legacy climate organizations Ensuring climate and environmental narratives are inclusive of diverse voices and center community needs, perspectives, and solutions	https://www.barrfoundation.org/climate#inquiries
Emergency Coastal Resilience Fund	**Both**	The Emergency Coastal Resilience Fund was established to increase the resilience of coastal communities located within federally declared disaster areas. The first round of funding was directed towards communities impacted by hurricanes Florence and Michael, Typhoon Yutu and wildfires in 2018. The second round of funding was for communities that received a federal Major Disaster Declaration with a Public Assistance designation in 2020 or 2021. The fund supports conservation projects that help recover from disasters and strengthen natural systems at a scale that will protect coastal communities from the future impacts of storms, floods and other natural hazards.	National Fish and Wildlife Foundation	Massachusetts Department of Environmental Protection (MassDEP)/Massachusetts Office of Coastal Zone Management (CZM)	Coastal Habitat Program, StormSmart Coasts Program	$25.2 million for 16 projects 2022. Total awards to date are $73.6 million. https://www.nfwf.org/sites/default/files/2022-06/NFWF-ECRF-20220531-GS-Final.pdf	Due to the emergency nature of these funds, a non-federal match in cash and/or in-kind services is not required. If the request includes match, it can be any combination of cash and/or in-kind goods and services.	Implementation	Emergency basis: Currently available for projects within counties in the National Coastal Resilience Fund (NCRF) Coastal Areas that received a federal Major Disaster Declaration with a Public Assistance designation as a result of hurricanes or wildfires in 2020 and 2021	Closed 2/3/2022	Unknown	natural resources		https://www.nfwf.org/programs/emergency-coastal-resilience-fund
Environmental Conservation Program	**Both**	The Foundation's Environmental Conservation Program balances long-term conservation with sustainable use. It protects critical ecosystems. It establishes models for collaboration that can be replicated and expanded around the globe. And it seeks to create lasting change in how land, freshwater and coastal marine ecosystems are managed. The Foundation actively works with grantees to coordinate multiple partners, integrate diverse points of view and adapt to changing circumstances. In partnership with communities, businesses, governments, NGOs and others, the Foundation strives to ensure that ecosystems remain healthy, resilient and productive.	Gordon and Betty Moore Foundation	NA	NA	Varies	Not available	All	Based on funding availability	The Foundation does not accept unsolicited grant proposals. Please contact communications@moore.org for more information.	NA	All		https://www.moore.org/programs/environmental-conservation
National Coastal Resilience Fund	**Both**	The National Coastal Resilience Fund invests in natural coastal infrastructure to protect coastal communities and enhance wildlife habitats. Projects may conserve, restore, or expand coastal marshes, wetlands, dune and beach systems, oyster and coral reefs, forests, coastal rivers and floodplains, and barrier islands.	National Fish and Wildlife Foundation and NOAA	Office of Coastal Zone Management	Coastal Resilience Grant Program	$277 million since the program's start in 2018; $144 million in 2022 to support 96 coastal resilience projects. https://www.nfwf.org/sites/default/files/2022-12/NFWF-NCRF-20221129-Nov-FS.pdf	Varies by project	All	Annual (though in 2022 there were both August and November grant rounds)	Closed 6/30/2022	N/A, but pre-proposals were due 4/21/2022	natural resources		https://www.nfwf.org/programs/national-coastal-resilience-fund

Appendix 4.C: Funding Sources for Hazard Mitigation and Climate Adaptation Actions
Purpose: To provide an inventory of existing federal, state, local, and private funding sources that could support climate adaptation and hazard mitigation in Massachusetts.

Building on and updating the previous federal resilience funding study conducted by EEA in 2021, below is a snapshot of relevant funds that could be applicable to the Commonwealth of Massachusetts as of June 2023.

Funding Mechanism or Program Name	Focus (Climate Adaptation, Hazard Mitigation, or Both	Brief Description	Administering Body	Relevant State Agency/Organization	Potentially Relevant State Programs*	Funding Range	Required Match % (0-100)	Funding Available for: Planning, Engagement, Implementation, or All	Frequency/Availability of Grant	Application Submission Date	State Deadline*	Sector Specific	Focus on Social Vulnerabilities?	Link to Overview
Five Star and Urban Waters Restoration Grant Program	**Both**	This program seeks to develop community capacity by providing modest assistance to diverse local partnerships for river, wetland, riparian, forest and coastal restoration, and wildlife conservation. Water monitoring, stormwater management, source water protection, urban tree canopy restoration, and projects designed to prevent trash from entering waterways are just some of the types of projects that are awarded grants.	National Fish and Wildlife Foundation	NA		$1.6 million awarded nationwide for 2023, individual awards between approximately $25,000 and $50,000. https://www.nfwf.org/programs/five-star-and-urban-waters-restoration-grant-program/five-star-and-urban-waters-restoration-grant-program-2023-request-proposals	Required to meet or exceed a 1:1 match ratio (so provide 50% or more)	All	Annual	Closed 1/31/2023 for 2023 round of funding	NA	natural resources, water		https://www.nfwf.org/programs/five-star-and-urban-waters-restoration-grant-program?activeTab=tab-1
Various Grant Programs	**Both**	Solving climate change requires more than lowering emissions. The Bezos Earth Fund focuses on spurring innovation and progress in several key areas that will help us move closer to a more equitable and sustainable future. We are committed to fighting climate change and protecting nature.	Bezos Earth Fund	NA	NA	The Bezos Earth Fund will make small and large grants. In some cases, the timely provision of a $1 million grant will leverage a large change. In others, the award of a $100 million grant can drive a game-changing shift in technology, policy, or behavior – and catalyze billions of dollars of investment. In September 2022, Bezos Earth Fund announced that its August grants include $127 million to protect nature and fight climate change over 6 grants.	Not available	All	Not available - however, grants have been made to a group of cross-sector grantees, including government.	The Bezos Earth Fund has a team of professionals that make proposals for funding. They do not accept unsolicited project proposals. For further inquiry, please reach out to the Fund at info@bezosearthfund.org	NA	All	The positive links between meeting climate, nature, and justice objectives are undeniable. Those least responsible for causing damage, suffer most from it. Frontline communities are also powerful agents of change. The Bezos Earth Fund partners with communities, coalitions, and initiatives that explicitly address these inequalities.	https://www.bezosearthfund.org/our-programs

*Note that Potentially Relevant State Programs have been identified as potentially eligible based on cursory research; insight from the Commonwealth is needed to validate the applicability of federal funds to the identified state programs. State deadlines labeled as "unknown" are not listed on state agency websites and may need to be solicited from specific agencies.

Appendix 5.A:
Historic Occurrences

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Tables

Acronyms and Abbreviations

FEMA	Federal Emergency Management Agency
NCDC	National Climatic Data Center
NESIS	Northeast Snowfall Impact Scale
NOAA	National Oceanic and Atmospheric Administration
SHMP	State Hazard Mitigation Plan
USACE	U.S. Army Corps of Engineers

1. Historical Disaster Occurrences

1.1 Presidentially-Declared Disasters

As described in the Risk Assessment, many hazards discussed in this plan occur concurrently or as a result of one storm event. Therefore, all events that received presidential disaster declarations are listed together in chronologic order in Table 1-1. Additional detail on the impacts from each event is provided under the relevant/applicable hazards in the Risk Assessment. Additional information on each of these events is also provided after Table 1-1 in chronologic order. The information on presidentially declared disasters after 2018 is retrieved from the FEMA Declared Disasters database using a search for all declaration and incident types in Massachusetts.

Table 1-1. Presidentially-Declared Disasters, 1991-March 2023

Disaster Name/ Disaster Number	Date of Event	Declared Areas
Hurricane Bob/ FEMA-914-DR-MA	August 1991	Counties of Barnstable, Bristol, Dukes, Essex, Hampden, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk
Severe Coastal Storm/ FEMA –920-DR-MA	October 1991	Counties of Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk
Winter Coastal Storm/ FEMA-975-DR-MA	December 1992	Counties of Barnstable, Dukes, Essex, Plymouth, Suffolk
Blizzard/ FEMA-3103-EM	March 1993	All 14 Counties
Russell Fire/ FEMA-2116-EM	September 1995	DEM and National Guard
Blizzard/ FEMA-1090-EM	January 1996	All 14 Counties
Severe Storms, Flood/ FEMA-1142-DR-MA	October 1996	Counties of Essex, Middlesex, Plymouth, Norfolk, and Suffolk
Heavy Rain, Flood/ FEMA-1224-DR-MA	June 1998	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, and Worcester
Worcester Fire/ FEMA-3153-EM	December 1999	City of Worcester, State Fire Mobilization Communities, and various state agencies
Severe Storms and Flooding/ FEMA-1364-DR-MA	March 2001	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Snowstorm/ FEMA-3165-EM	March 2001	Counties of Berkshire, Essex, Franklin, Hampshire, Middlesex, Norfolk, and Worcester
Snowstorm/ FEMA-3175-EM	February 2003	All 14 Counties

Disaster Name/ Disaster Number	Date of Event	Declared Areas
Snowstorm/ FEMA-3191-EM	December 2003	Counties of Barnstable, Berkshire, Bristol, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, Plymouth, Suffolk, and Worcester
Flooding/ FEMA-1512-DR	April 2004	Counties of Essex, Middlesex, Norfolk, Suffolk, and Worcester
Snow/ FEMA-3201-EM	January 2005	All 14 Counties
Hurricane Katrina/ FEMA-3252-EM	August 2005	All 14 Counties
Severe Storms and Flooding/ FEMA-3264-EM	October 2005	Bristol County (Taunton Dam)
Severe Storms and Flooding/ FEMA-1614-DR-MA	October 2005	All 14 Counties
Severe Storms and Flooding/ FEMA-1642-DR-MA	May 2006	All 14 Counties
Severe Storms & Inland, Coastal Flooding/ FEMA-1701-DR-MA	April 2007	All 14 Counties
Severe Winter Storm/ FEMA-3296-EM- MA	December 2008	Berkshire, Bristol, Essex, Franklin, Hampden, Hampshire, Middlesex, Suffolk, and Worcester
Severe Storms and Flooding FEMA-1813-DR-MA /	December 2008	All 14 Counties
Severe Storms and Flooding/ FEMA-1895-DR-MA	March-April 2010	Bristol, Essex, Middlesex, Norfolk, Plymouth, Suffolk, Worcester
Severe Winter Storm and Snowstorm/ FEMA-1959-DR-MA	January 2011	Berkshire, Essex, Hampden, Hampshire, Middlesex, Norfolk, Suffolk
Severe Storms and Tornadoes/ FEMA-1994-DR-MA	June 2011	Hampden, Worcester
Tropical Storm Irene/ FEMA-4028-DR-MA	August 2011	Barnstable, Berkshire, Bristol, Dukes, Franklin, Hampden, Hampshire, Norfolk, Plymouth
Severe Storm and Snowstorm/ FEMA-4051-DR-MA	October 2011	Berkshire, Franklin, Hampden, Hampshire, Middlesex, Worcester
Hurricane Sandy/ FEMA-4097-DR-MA	October-November 2012	Barnstable, Bristol, Dukes, Nantucket, Plymouth, Suffolk
Severe Winter Storm, Snowstorm and Flooding/FEMA-4110-DR-MA	April 2013	All 14 counties
Severe Winter Storm, Snowstorm, and Flooding /FEMA-4214-DR-MA	April 2015	Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester

Disaster Name/ Disaster Number	Date of Event	Declared Areas
Severe Winter Storm and Flooding/FEMA-4372-DR	March 2018	Barnstable, Bristol, Essex, Nantucket, Norfolk, Plymouth
Severe Winter Storm and Snowstorm/FEMA-4379-DR	March 2018	Essex, Middlesex, Norfolk, Suffolk, Worcester
Massachusetts Covid-19 Pandemic/ DR-4496-MA	January 2020 – ongoing on March 2023	All 14 counties Wampanoag Tribe of Gay Head (Aquinnah) in Dukes / EM-3497 Mashpee Wampanoag Tribe in Barnstable / EM-3484
Mashpee Wampanoag Tribe Tropical Storm Henri/ 3566-EM-Mashpee Wampanoag Tribe	August 2021	Mashpee Wampanoag Tribe, Barnstable
Severe Winter Storm and Snowstorm/FEMA-4651-DR-MA	January 2022	Bristol, Norfolk, Plymouth, Suffolk

1.1.1 Hurricane Bob (FEMA DR-914)—August 1991

Hurricane Bob was the second named storm and the first hurricane of the 1991 hurricane season, reaching a Category 3 status. Winds reaching 115 mph impacted North Carolina, the Mid-Atlantic states, New England, and Atlantic Canada, causing 15 fatalities. In Massachusetts, this storm struck the southern coast, causing $900 million in property damage from Westport east to New Bedford, Buzzards Bay, Cape Cod, and the Islands. Damage to crops was approximately $10 million, including a loss of 20 to 50% of the apple crop. Corn and vegetable crops were also seriously damaged or destroyed. The eye of the storm tracked north-northeast between Fall River and Providence, passing through Bristol and Plymouth Counties at a speed of 40 mph. Many boats were either heavily damaged or destroyed. Over 500 boats broke away from their moorings, sank, or were driven ashore. The tidal surge reached 5.8 feet in New Bedford, inundating barrier beaches from Westport to Marion and flooding beaches around Buzzards Bay. Across Cape Cod and the islands, thousands of trees were blown down, causing power outages. Winds exceeded 80 mph with gusts of up to 143 mph, and rainfall totals ranged between two and seven inches in the Commonwealth. This event resulted in a presidential disaster declaration (FEMA DR-914).

1.1.2 Severe Coastal Storm (FEMA DR-920)—October-November 1991

This storm was an unusual event, as the large nor’easter moved south and gained strength when it joined what remained of Hurricane Grace, becoming what some refer to as the Perfect Storm. This storm event, also known as the Halloween Nor'easter of 1991 and the Halloween Storm of 1991, impacted the entire east coast of the United States as well as Puerto Rico. The storm was a devastating extratropical event that developed east of Nova Scotia, Canada and moved unexpectedly west. Winds from this event were measured at over 80 mph, with waves over 30 feet in some parts of the coastline. The storm brought unusual wave periods in excess of 20 seconds, compared to more typical 12 to 14 second periods associated with a typical New England nor'easter. Deepwater wave heights of over 40 feet were also observed. This storm caused flooding, wind damage, and erosion in several counties. Wind gusts greater than 60 miles per hour were recorded in Chatham for over 15 hours straight and gusts of over 70 mph for six hours. On October 30, National Oceanic and Atmospheric Administration (NOAA) buoys reported wave heights up to 31 feet (buoy 44008) and 25 (buoy 44013) southeast of Nantucket and in Massachusetts Bay. Peak water levels of 11.2 feet were recorded in Sandwich. The duration of the storm in Boston was approximately 90 hours, exposing the shoreline to higher than normal water levels for a longer time than previous storm events like the Blizzard of 1978. Had the storm occurred five days earlier, the Stillwater level at Boston would have been about 1.5 feet high, which could have led to extreme coastal damages. Municipalities in Massachusetts received $9,704,600 (1991 dollars) for activities including debris clearance, protective measures, road systems, public utilities, and more from FEMA (USACE, 1994). This event resulted in a presidential disaster declaration (FEMA DR-920).

1.1.3 Winter Coastal Storm (FEMA DR-975)—December 1992

From December 11 to 13, 1992, a strong nor'easter affected the Commonwealth. Impacts included intense snowfall, freezing rain, and heavy rainfall near the coast, coastal flooding, and damaging winds. Storm total snowfall in Massachusetts was as high as 4 feet over the higher elevations of the Berkshires, with 48" reported in Beckett, Savoy, and Peru. Snow drifts as high as 12 feet were created in the Berkshires. Snowfall of 18" to 32" was common over central Massachusetts, with 6 to 20" over interior eastern Massachusetts. Some locations also experienced a coating of ice. Strong winds combined with wet, heavy snow and ice caused considerable tree damage and widespread power outages. The weight of the snow taxed snow removal equipment in many communities and also caused roof damage. There were 135,000 customers without power in the Commonwealth during the storm. The central part of the Commonwealth suffered the brunt of the outages where 30,000 households were without power, just in Worcester County.

Precipitation totals for this storm were extraordinary. Much of southern New England received up to 5 inches of liquid equivalent precipitation during a 2 to 3 day period, with locally close to 8 inches recorded in parts of southeast Massachusetts. Along coastal sections and in some interior valleys, much of the precipitation fell as rain or rain mixed with snow. This caused considerable ponding and localized flooding in poorly drained areas.

The greatest damage from this storm was due to coastal flooding. Serious coastal flooding occurred along the Massachusetts coastline from December 11 to 13, the most damaging storm tide occurring early afternoon on December 12. The Boston tide gage recorded a peak elevation of 14.21 feet above mean lower low water, 1 foot less than the highest elevation on record at that location, from the blizzard of 1978. A 350-foot breach of Hull's Nantasket Beach seawall occurred. Most east-facing shoreline communities from Chatham to Provincetown and Plymouth to the North Shore, as well as Nantucket Island, experienced some level of coastal flood damage. Dunes were washed away in Hull and Duxbury. As much as 20 feet of dune was lost in Sandwich and up to 25 feet in Ipswich. Many coastal road closings occurred. Dock damage occurred, and some cottages were destroyed by the sea. This event resulted in a presidential disaster declaration (FEMA DR-975).

1.1.4 Blizzards, High Winds and Record Snowfall (FEMA EM-3103)—March 13-17, 1993

The March 13-17, 1993 storm brought high winds and heavy snow to Massachusetts. Boston's Logan Airport recorded a wind gust to 81 mph, and a gust to 83 mph occurred at the Blue Hill Observatory. Snowfall was generally 10 to 20 inches across the area except 20 to 30 inches over the Berkshires. Snowfall totals included 12.8 inches at Boston, 20.2 inches at Worcester, and 30 inches at both Florida and Peru in the Berkshires. Blizzard conditions existed for a 3 to 6 hour period during the afternoon of March 13. Unlike the December 1992 storm, the snow was a dry enough to minimize accumulation on trees and wires. This precluded widespread power outages. The storm's occurrence on the weekend mitigated traffic issues. The coastal flood potential was not realized, since the strongest onshore winds did not correspond to high tide and the duration was not long enough to produce exceptionally large waves. This storm impacted the entire eastern third of the country and resulted in a presidential disaster declaration (FEMA EM-3103).

1.1.5 Hurricane Earl (FEMA EM-3315)—September 2010

Earl was the fifth named storm of the 2010 hurricane season, reaching peak intensity on September 2nd with maximum sustained winds of 145 mph. Hurricane Earl was considered a Category 4 hurricane. Damage was estimated to be low, but one fatality occurred in Massachusetts, as well as three in Florida and two in New Jersey.

1.1.6 Russell Fire (FEMA FM-2116)—September 1995

The most recent large-scale wildfire occurred in the Town of Russell in Hampden County in September 1995. This wildfire, which initiated the federal Fire Suppression Agreement under a presidentially declared disaster (FEMA FM-2116), was finally controlled after two weeks. The fire's location on extremely steep terrain made access particularly difficult. The fire burned several days because of ready fuel and prolonged regional drought conditions. More than 500 acres were burned and several dwellings and farms in the Town of Russell were threatened.

1.1.7 Blizzard (FEMA DR-1090)—January 7-8, 1996

This storm was one of the most significant winter storms to hit southern New England in the past 20 years. It brought record snowfalls to the Mid-Atlantic States to southern New England. Snowfall totals of 13 to 18 inches were reported in Cape Cod. Between 15 and 25 inches fell in Plymouth and Bristol Counties. More than 20 inches were reported in Hampden and Hampshire Counties and more than 30 inches in the Berkshires. Strong to gale-force northeast winds was also associated with this event. Storm surges were between 1.9 and 2.7 feet at the Boston tide gauge. Minor coastal flooding was experienced. On the eastern shore of Nantucket Island, high waves and strong currents eroded sand dunes. The Commonwealth experienced over $350,000 in property damage. MEMA reported damage claims of approximately $32 million from 350 communities, mostly for the cost of snow removal. This event resulted in a presidential disaster declaration (FEMA DR-1090).

1.1.8 Severe Storms and Flooding (FEMA DR-1142)—October 1996

On October 19 through October 20, a slow-moving system produced record-breaking rainfall in northeast Massachusetts. This event also brought strong winds with gusts of over 45 mph and a peak gust of 63 mph. Rainfall totals were nearly eight inches, which resulted in widespread small stream and tributary flooding. In Essex County (Newburyport), 13.03 inches of rain was reported. There was widespread urban flooding in Boston. In Lowell, the Merrimack River gage recorded the height of the river at 53.10 feet with a discharge of 48,600 cubic feet per second. Major roadways were flooded, and many basements of homes were flooded and homes were severely damaged. Damage was estimated at over $60 million.

1.1.9 Heavy Rain and Flooding (FEMA DR-1224)—June-July 1998

Between June 12 and June 14, a slow-moving storm system moved through southeast New England, producing between six and 12 inches of rain over much of eastern Massachusetts. This led to widespread urban, small stream, and river flooding. Between June 15 and June 20, another storm brought thunderstorms to the area, causing several flash floods. Flooding was reported along many brooks, streams, and rivers. Yet another storm on June 30 brought heavy rain and continued the flooding from the previous events.

1.1.10 Worcester Fire (FEMA EM-3153) —December 1999

This six-alarm fire razed a warehouse in Worcester and took the lives of six firemen.

1.1.11 Severe Storms and Flooding (FEMA DR-1364)—March-April 2001

A series of storm events occurred in Massachusetts between March 5 and April 16. On March 5, a major winter storm affected Massachusetts with near-blizzard conditions, high winds, and coastal flooding. Over two feet of snow fell across the interior portion of the Commonwealth. Approximately 80,000 people were without power, and businesses and schools were closed for several days. Snowfall totals ranged between two and 30 inches across Massachusetts. During this storm event, high tides ran two to three feet above normal, resulting in widespread coastal flooding along the entire east-facing coastline. Beachfront homes and roadways were flooded, and sea walls were damaged. Between March 22 and March 31, a series of flooding events occurred throughout Massachusetts as a result of melting snow and heavy rainfall. The most severe flooding occurred in the Merrimack Valley. Another event occurred on March 30, bringing heavy snow to parts of interior Massachusetts and heavy rain and strong winds to the coastal communities, causing flooding along rivers and streams in the eastern portion. Over six inches of rain fell in some areas.

1.1.12 Heavy Snow (FEMA EM-3165)—March 5-6, 2001

A major winter storm impacted Massachusetts with near blizzard conditions, high winds, and coastal flooding. It brought over two feet of snow across the interior and caused power outages to approximately 80,000 people. Businesses and schools were closed for several days. There were numerous reports of downed trees and wires during the height of the storm. After the storm, the weight of the snow caused several roof collapses throughout the Commonwealth. The highest snowfall totals were reported from the east slopes of the Berkshires across Worcester County and into northeast Massachusetts. Northeast winds affected much of the east coast and southeast of Massachusetts. Speeds of 50 to 60 mph were observed. High tides during the storm were two to three feet above normal, which resulted in widespread coastal flooding. This event resulted in a presidential emergency declaration (FEMA EM-3165). Those counties included in the declaration received over $21 million in public assistance grants from FEMA.

1.1.13 Winter Storm (FEMA EM-3175)—February 17-18, 2003

A major winter storm struck southern New England, bringing heavy snow and strong winds. This event was the most significant of the 2002-2003 winters, with snowfall totals of one to two feet. The highest totals were around two feet and were reported in two areas: east slopes of the Berkshires into northern Worcester County and over Boston’s South Shore communities. This snowstorm ranked in the top 10 for Boston and Worcester. This event resulted in a presidential emergency declaration (FEMA EM-3175). Those counties included in the declaration received over $28 million in public assistance grants from FEMA.

1.1.14 Winter Storm (FEMA EM-3191)—December 6-7, 2003

A major winter storm brought 1 to 3 feet of snow and strong winds to southern New England. In Massachusetts, snowfall amounts averaged between one and two feet across the Commonwealth. Some areas near Cape Cod only received between six and 12 inches. The highest snowfall was reported in Peabody, where 36 inches of snow fell. Minor coastal flooding was reported due to high seas of up to 30 feet off the eastern coast. One fatality was indirectly attributed to the storm. A commuter-rail work was struck by a freight train as they were clearing snow from the tracks near the Wellesley Hills station. This event resulted in a presidential emergency declaration (FEMA EM-3191). Those counties included in the declaration received over $35 million in public assistance grants from FEMA.

1.1.15 Flooding (FEMA DR-1512)—April 2004

Between March 31 and April 2, as much as four inches of rain fell in parts of Massachusetts, with the Merrimack Valley receiving seven inches of rain. The heavy rain, combined with snowmelt produced an excessive runoff of water, causing many streams and rivers to flood. Many roadways were closed due to flooding and some residents were forced to evacuate their homes. A second event occurred on April 15. Two inches of rain fell on already saturated ground from the floods earlier in the month. Assabet River flooded; however, it was minor and there no reports of damage. Massachusetts received over $2.7 million in individual assistance as a result of this event.

1.1.16 Blizzard (FEMA EM-3201)—January 22-23, 2005

A major winter storm brought heavy snow, high winds, and coastal flooding to southern New England. In Massachusetts, blizzard conditions were reported on Nantucket. This was the first blizzard to affect the Commonwealth since the April 1997 storm. Near-blizzard conditions were reported in other areas and brought between one and three feet of snow and produced wind gusts of up to 65 mph.

The highest snowfall totals were reported in eastern Massachusetts (between two and three feet). Minor to moderate coastal flooding was observed around high tide in eastern Massachusetts coast. Coastal flooding was most severe near Hull, Scituate, and Marshfield, where several roads were inundated and evacuations occurred. This event resulted in a presidential emergency declaration (FEMA EM-3201). Those counties included in the disaster received over $49 million in public assistance from FEMA.

1.1.17 Severe Storms and Flooding (FEMA DR-1614)—October 2005

On October 9, the remnants of Tropical Storm Tammy produced significant rain and flooding across western Massachusetts. It was reported that between nine and 11 inches of rain fell. The heavy rainfall washed out many roads in Hampshire and Franklin Counties. The Green River flooded a mobile home park. Several people had to be evacuated from their homes. On October 15, a low-pressure system, combined with tropical moisture, resulted in heavy rain and flooding across Massachusetts. Approximately 1,000 evacuations occurred due to severe urban flooding and near record flooding along the Blackstone and Quinebaug Rivers. Many streets were flooded and shut down, including state and interstate highways. This series of storms resulted in a presidential disaster declaration (FEMA-DR-1614) and Massachusetts received over $13 million in individual and public assistance.

1.1.18 Hurricane Katrina (FEMA-EM-3252)—August 2005

The remnants of Hurricane Katrina dropped up to 4.17 in (106 mm) of rain and cause gusty winds that blew down trees and tree limbs.

1.1.19 Severe Storms and Flooding (FEMA-EM-3264)—October 2005

Whittenton Pond Dam, Taunton, an aged timber crib structure, was excessively stressed on October 18, 2005. Around 11.5 inches of rain fell across the Mill River watershed during October 2005. Most of this rain fell within a 6-hour time period. This resulted in the threat of an imminent catastrophic failure of the dam. A dam expert team decided construction of a rock dam/spillway downstream of the aged dam should occur, with a subsequent disassembly of Whittenton Pond Dam. Days later the new spillway was completed, just prior to another significant rainfall episode. The dam did not breach and no one in

Taunton was harmed during this incident; however, approximately 2,000 people were evacuated, including a housing development for the elderly.

1.1.20 Severe Storms and Flooding "Mother's Day Flood" (FEMA DR-1642)—May 2006

Between May 13 and 15, 2006, heavy rain caused widespread flooding across much of eastern Massachusetts. Rainfall totals ranged between eight and 12 inches. Both small streams and main stem rivers flooded. Some areas experienced their worst flooding since the 1938 hurricane and the floods of March 1936. There was also severe urban drainage flooding in portions of the northeast, especially in the Peabody area. This severe storm and flooding event caused two fatalities and the state received over $56 million in individual and public assistance.

1.1.21 Severe Storms and Flooding (Nor'easter) (FEMA DR-1701)—April 2007

An intense coastal storm (April 15-16, 2007) brought wet snow, sleet and rain to parts of western Massachusetts. Snowmelt and heavy rain between three and six inches led to moderate flooding of small streams and creeks in parts of the Commonwealth, particularly in the lower Merrimack River Basin/mainstream and tributaries. This event resulted in a presidential disaster declaration (FEMA DR-1701). Those counties included in this disaster received over $8 million in public assistance from FEMA. The storm was primarily a rain event due to warmer temperatures; however, higher elevations experienced significant snow and ice accumulations.

1.1.22 Severe Winter Storm (FEMA EM-3296- MA)—December 2008

This storm was considered the worst ice storm New England had experienced in a decade. Damage primary occurred as a result of fallen trees and fallen utility wires and poles. The storm resulted in 1.7 million households without power, many of whom were still without power a week after the storm. A public works employee in Massachusetts died as a result of the storm after falling into a reservoir while inspecting damage to trees.

1.1.23 Severe Winter Storm and Flooding "Patriot's Day Storm" (FEMA DR-1813)—December 2008

A major ice storm and significant precipitation affected much of New England on December 11th and 12th. The ice storm struck across interior Massachusetts, southern New Hampshire, and much of northern New England. The hardest hit areas were the Worcester Hills in central Massachusetts and the east slopes of the Berkshires in western Massachusetts. At least half an inch of ice formed on many exposed surfaces. The ice downed many trees, branches, and power lines, which resulted in widespread power outages. More than 300,000 people were without power in the Commonwealth. Heavy rain fell in parts of Massachusetts (Berkshire, Worcester, Bristol, and Middlesex Counties), leading to minor and moderate flooding and ponding of water in low-lying, poor drainage areas, streams, creeks, and brooks. Several roadways were closed due to flooding. Rainfall totals ranged between one and four inches. There was one death in Massachusetts associated with this storm. Those counties included in the disaster received over $51 million in public assistance from FEMA.

1.1.24 Severe Storm and Flooding Event (FEMA DR-1895)—April 2010

A series of severe storms brought widespread rainfall to Massachusetts in March 2010, causing small streams to rise above their flood stages. Flooding continued into April, with prolonged river, reservoir, and lake flooding. This prolonged flooding, coupled with heavy rain and poor drainage flooding caused three injuries. Massachusetts received over $85 million in individual and public assistance as a result of this storm.

1.1.25 Severe Winter Storm and Snowstorm (FEMA DR-1959)—January 11-12, 2011

A developing Nor'easter coastal storm brought up to two feet of snow across Massachusetts in a 24-hour period. Strong winds, combined with heavy snow, produced numerous downed trees and wires and resulted in power outages to 100,000 homes statewide. Wind gusts between 49 and 57 mph were recorded in Eastham, Barnstable, Harwich, and Chatham. Between seven and 10 inches of snow was reported in southern Bristol County. The County had approximately $75,000 in property damage. This event resulted in a presidential disaster declaration (FEMA DR-1959) for the following counties: Berkshire, Essex, Hampden, Hampshire, Middlesex, Norfolk, and Suffolk. Those counties received over $25 million in public assistance grants.

1.1.26 Severe Storms and Tornadoes (FEMA DR-1994)—June 2011

The most recent tornado occurred June 1, 2011, impacting Hampden and Worcester Counties. Thunderstorms developed during the morning of June 1 and entered western Massachusetts in the form of supercells. A supercell eventually produced a tornado that entered Hampden County from the Berkshires. The cell produced an EF3 tornado, touching down in Westfield and continued on a 38-mile-long path through West Springfield, Springfield, Wilbraham, Monson, Brimfield, and Sturbridge. The tornado was on the ground for approximately 70 minutes. Two hours later, another supercell tracked north of the path of the EF3 tornado. It produced brief tornadoes in Wilbraham, North Brimfield, and Sturbridge. This series of tornadoes caused extensive property damage (over $227 million).

1.1.27 Tropical Storm/Hurricane Irene (FEMA DR-4028)—August 2011

Tropical Storm Irene (August 27-29, 2011) produced significant amounts of rain, storm surge, inland and coastal flooding, and wind damage across southern New England and much of the east coast of the U.S. In Massachusetts, rainfall totals ranged between 0.03 inches (Nantucket Memorial Airport) to 9.92 inches (Conway, MA). Wind speeds ranged between 46 and 67 mph. Tide data included tides of 6.43 feet at Boston, 4.04 feet at Chatham, 5.57 feet at Fort Point, 5.39 feet at Plymouth, and 3.11 feet at Woods Hole. A presidential disaster was declared (FEMA DR-4028), and the Commonwealth received over $31 million in individual and public assistance from FEMA.

1.1.28 Severe Storm/Nor'easter (FEMA DR-4051)—October 29-30, 2011

A rare October Nor'easter brought heavy snow to portions of southern New England on October 29. Snowfall accumulations of one to two feet were common in the Monadnocks, Berkshires, Connecticut Valley, and higher elevations in central Massachusetts. Up to 31 inches of snow was reported in Plainfield, Massachusetts. The accumulation of the heavy, wet snow on trees and power lines resulted in widespread tree damage and power outages across central and western Massachusetts. At the peak, approximately 665,000 customers in Massachusetts were without power. Seventy-seven shelters were opened and housed over 2,000 residents. Governor Patrick declared a state of emergency on October 29. Six fatalities occurred during and in the aftermath of the storm. The Commonwealth had approximately $300,000 in property damage from this Nor'easter event. This event resulted in a presidential emergency declaration (FEMA EM-3343) for the following counties: Berkshire, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, and Worcester.

1.1.29 Hurricane Sandy (FEMA DR-4097)—October-November 2012

Hurricane Sandy was the largest Atlantic hurricane on record, spanning 1,100 miles in diameter. The storm's winds reached sustained speeds of 110 mph. Total losses in the U.S. as a result of this storm reached above $75 billion. According to NOAA records, a total of 157 deaths were attributed to this storm in the U.S.

1.1.30 Severe Winter Storm, Snowstorm, and Flooding (FEMA DR-4110)—February 8-10, 2013

The storm known as the "Blizzard of 2013" resulted from the convergence of several large low-pressure areas and produced widespread heavy snowfall. The storm caused snowfall greater than two feet in many areas throughout Massachusetts, with snowfall rates of one to two inches per hour at times, as well as wind gusts of up to 74 miles per hour. Many roads flooded, leading to evacuations and school closures. Travel was significantly affected across the Commonwealth and nearly 400,000 customers lost power. At least 15 people died throughout the Northeast as a result of this storm. Governor Patrick declared a state of emergency for all counties in Massachusetts on April 19 2013. The total Public Assistance cost estimate for this event was $43,265,351.

1.1.31 Severe Winter Storm, Snowstorm, and Flooding (FEMA DR-4214) —January 26-29, 2015

This storm brought two to three feet of snow to areas throughout southern New England. Daily snowfall records were set throughout the Commonwealth. Some of the highest totals reported in Massachusetts include Hudson (36 inches), Acton (34 inches), and Methuen (31.5 inches). All of the precipitation associated with this storm fell as snow. Blizzard conditions were reported in Marshfield, Hyannis, Nantucket, Boston, Chatham, Worcester, and Beverly. The storm also produced strong winds with gusts of up to 78 miles per hour in some locations. Significant flooding also occurred, particularly on the coastline south of Boston, where significant shoreline erosion was reported following the storm. The governor declared a travel ban on January 27 and Logan International Airport closed through January 28. 40 shelters opened as a result of this storm, serving 450 individuals. Two fatalities were reported – a 97-year-old man who died while trying to clear a vent in his home, and a 53 year old man who died while snow-blowing his neighbor's driveway.

1.1.32 Severe Winter Storm and Flooding (FEMA DR-4372)—March 2-3, 2018

This extraordinary storm caused significant impacts across many communities, including historic flooding and damaging winds to the North Shore, Boston Harbor, South Shore, Cape Cod, and Nantucket. During the storm there were numerous recordings of wind gusts from 80-90 miles per hour, and recordings of gusts reaching 92-97 miles per hour. The strong winds, which reached hurricane-force levels, brought down hundreds of trees, damaged utility company wires, poles, and infrastructure, and caused widespread power outages throughout eastern Massachusetts. At the height of the storm, nearly 450,000 customers were without power. Twenty-seven long-term care facilities and several hospitals operated on backup generator power for up to 72 hours. The event caused widespread beach and dune erosion, flooding, and over wash and erosion affecting coastal roads, buildings, and infrastructure. There were two storm-related deaths: one person was killed by a tree that fell on their car and another person died of carbon monoxide poisoning attributable to the use of a generator at a home without power. The Massachusetts National Guard deployed soldiers and resources into 19 communities to perform 126 high water evacuation and rescue missions. In total, 355 people were rescued from flooded areas and evacuated to safety by the National Guard.

1.1.33 Severe Winter Storm and Snowstorm (FEMA DR-4379)—March 13-14, 2018

This significant severe winter storm occurred less than two weeks after FEMA DR-4372 and was the third event in a series of intense March storms. The storm system created very heavy snowfall, including record and near record snowfall, across much of the region and hurricane-force wind gusts on Cape Cod and the Islands. Numerous utility poles and trees were downed by the combination of heavy snow and damaging winds. Additional coastal flooding occurred, resulting in further erosion and additional damage to structures impacted by the previous two March storms, including the March 2, 2018 storm whose damage totals far exceeded the state threshold required for a major disaster declaration. Hurricane force wind gusts and temperatures between 32ºF and 34ºF made the impacts on Cape Cod and the Islands far worse, with hundreds of thousands of people yet again without power. The Massachusetts Steamship Authority cancelled all ferry trips to and from Martha's Vineyard and Nantucket. Amtrak service was also suspended between Boston and New York City. According to the National Weather Service, Blizzard conditions were reached at many locations across eastern and southeastern Massachusetts during the storm on March 13, 2018. During the storm, there were recordings of wind gusts from 70-81 miles per hour. The strong winds, which in some areas reached hurricane-force levels, brought down trees; damaged utility company wires, poles, and infrastructure; and caused widespread power outages throughout eastern Massachusetts. At the height of the storm over 218,000 customers were without power. Thirty-one long-term critical care facilities and four hospitals resorted to operating on backup generator power. The Massachusetts Office of Coastal Zone Management reported additional beach and dune erosion, flooding, and over wash and erosion affecting coastal roads, buildings and infrastructure. Possible further damage to seawalls and other shore protection structures originally damaged in the previous March storms was also reported.

1.1.34 Tropical Storm Henri (3566-EM-Mashpee Wampanoag Tribe) – August 15-23, 2021

Category 1 Hurricane Henri made landfall as a 55-kt tropical storm in Rhode Island on August 22, 2021. Henri was of non-tropical origin – the storm system formed off the U.S. Mid-Atlantic coast. Henri moved westward towards the U.S. East Coast and became a 65-kt hurricane while located 170 nautical mile southeast of Cape Hatteras, North Carolina. While moving north of the Gulf Stream, Henri weakened and was reduced to a tropical storm when it made landfall. The storm system caused extensive flooding in parts of northeastern U.S. Storm surge inundation measured at 1.7 feet MHHW at several locations in southeastern Massachusetts. A National Hurricane Center Tropical Cyclone Report from NOAA (AL082821) indicated that flooding was the most significant impact. There was also wind damage associated with Henri, mostly because of downed trees throughout the coast of Massachusetts, Rhode Island, Connecticut, southeastern New York, and New Jersey. Over 1,200 customers across the three power companies in Massachusetts lost power. President Joseph R. Biden approved an emergency declaration for the state of Rhode Island on Saturday, August 21 and for the state of Connecticut, the Mashpee Wampanoag Tribe and the states of New York and Vermont on Sunday, August 22. According to the National Centers for Environment Information, an estimated $700 in damage was associated with Henri.

1.1.35 Severe Winter Storm and Snowstorm (FEMA-DR-4651) – January 28-29, 2022

On January 29-29, 2022, Winter Storm Kenan impacted several counties in southeastern Massachusetts. The event was part of a “bomb cyclone” that produced blizzard conditions through the eastern counties of the state. The NOAA NCDC Storm Events Database recorded an “explosive cyclogenesis of a low-pressure center off the Mid Atlantic coast brought a strong winter storm with blizzard conditions to all of southern New England Saturday and Saturday night. The storm tracked from east of the Carolinas to the 70w/40n benchmark bringing extreme snowfall rates of 2 to 4 inches per hour and winds gusting to hurricane force along the coast and 50 to 60 mph inland. The heaviest snow, just under 30 inches, fell over southeast MA.” The same database recorded some damage to property in Worcester, Essex, and Barnstable, adding up to $4,500 dollars. A disaster declaration was designated for counties of (FEMA-4651-DR-MA) for Bristol, Norfolk, Plymouth and Suffolk counties, and the Mashpee Wampanoag Tribe. The event producer record, or near record snowfall. The snow removal and de-icing requirements were deemed to require “extraordinary measures”, according to a December 23, 2022 FEMA press release. The Public Assistance program was activated and enabled federal funding available for eligible disaster-related costs such as emergency work and permanent repair and replacement of facilities damaged as a direct result of the storm, as well as Snow Assistance for a 48-hour period. As noted in a FEMA press release from February, 2023, the city of Boston received $1.4 million for plowing costs and had to clear parking lots, building entrances and walkways at 73 fire station, 121 public schools, 25 libraries, five municipal facilities, 35 Boston Center for Youth and Families Community Centers, 16 stations for 26 Boston EMS ambulances, and the harbor

1.2 Additional Historical Events

Although the most severe and damaging events receive presidential disaster declarations, many other notable disaster events have occurred in the Commonwealth's history. The amount and type of information available about these events varies by hazard. Sources for each table are provided below the table. For additional information on Dam safety and risks from dam failures, please see section 5.8 (Flooding from Precipitation).

Table 1-2. Notable Dam Failure Events (Inland Flooding)

Date	Counties Impacted
May 16, 1874	The Williamsburg Reservoir in Williamsburg, Massachusetts, broke and flooded a valley in the town which contained factories and farms. The flood resulting from the dam failure killed 139 people which made it the deadliest dam failure in the United States at the time. The dam failure was blamed on negligence by the mill owners who owned the dam.
April 20, 1886	The Mud Pond Dam in East Lee, MA, failed and heavy damaged or destroyed approximately 12 shops and industries along Greenwater Brook. This failure killed seven people. The cause of the failure was unknown.
January 7, 1909	The Ashley Dam in Massachusetts failed due to piping during the first filling. No additional information regarding this failure was provided.
March 24, 1968	The Lee Lake Dam near East Lee, Massachusetts failed, destroying six homes, damaging 20 homes and one manufacturing plant. The failure caused two fatalities. The cause of the failure was unknown.
September 1999	Hurricane Floyd caused two dam failures and one overtopping in Massachusetts. One complete failure of a run of the river cyclopean structure almost took out a campground. The first overtopping was of an earthen dam that unraveled and exposed a water line that services a major city. The second overtopping was a roadway dam overtopping and failed; a road had to be closed and a pond was drained in a state park. Information regarding the location of these dam failures and overtopping were not provided.
April 4, 2004	Smiths Pond Dam in Leominster, Massachusetts failed due to heavy rains. The dam overtopped and the spillway was clogged by debris. Divers from the Leominster EMA and crane operators worked to clear the spillway.
February 2010	Forge Pond Dam, Freetown, is an earth filled dam more than 200 years old. In, heavy rains caused the dam to overtop and become unsafe. The DCR Office of

Date	Counties Impacted
	Dam Safety determined that the dam posed a serious threat to public safety. Emergency actions were taken to stabilize the privately owned dam and no major damage occurred.
May 29, 2015	Crosby Pond Dam, Concord is a concrete dam built primarily for recreational purposes. An uncontrolled release of the impoundment flooded a heavily traveled road. While no one was injured, their road was closed all day and resulted in significant traffic delays.

Source: 2013 SHMP, Lemoult, 2017; Association of State Dam Safety, 2022 https://damsafety.org/Incidents

Table 1-3. Landslide 1901-2023

Date	Description
1901	11 landslides occurred along the east face of Mount Greylock after heavy rains. This slide was reactivated again on May 13, 1990 producing an estimated 17,000 cubic yards of material.
1936	One home was destroyed and six others evacuated during a slide in North Adams.
August 7, 1990	A debris flow on Money Brook on the west side of Mount Greylock mobilized 3100 cubic yards of material.
June 13, 1996	Thunderstorms brought torrential rain and strong winds to several municipalities in western and central Franklin County. There were numerous reports of downed trees and power lines in Ashfield, Deerfield, Greenfield, and Whatley. Mudslides and flooding damaged the Ashfield Inn, the Greenfield Senior Citizens Center, and several homes in Greenfield.
April 16, 2007	A strong coastal storm brought heavy snow, strong winds, river and stream flooding, and significant coastal flooding. In Franklin County, multiple roads were closed to flooding. In the Town of Colrain, the flooding caused a mudslide to occur, which closed a portion of Route 112.
September 6, 2008	Remnants of Tropical Storm Hanna brought heavy rain to the area. Rainfall totals ranged between 3.5 to 5.5 inches. This resulted in widespread flooding across central Hampden County. In Wilbraham, multiple roads were flooded, including Main Street and several locations on Routes 20 and 32. Minor mudslides occurred on Route 32.
September 2008	A small landslide occurred in Holyoke covering several cars and a large, paved area under several feet of mud and debris. It is thought the cause of this slide was saturated soils due to days of rain and poor urban drainage.
July 7, 2009	A system across southern New England produced showers and thunderstorms. In Middlesex County, numerous roads were flooded, and some were closed due to the rain. The most affected areas include Framingham and Marlborough. In Framingham, roads were closed due to mudslides, as well as flooding, including Routes 126 and 9.

Date	Description
March 14, 2010	Widespread rainfall across portions of Massachusetts totaled between three and six inches. This resulted in major flooding across eastern Massachusetts. A state of emergency was declared which led to a presidential disaster declaration (DR-1985). In Essex County, heavy rain resulted in the rapid erosion of a hill slope in Topsfield. This resulted in a mudslide across Route 1, which closed the road in both directions between Salem Road and the Danvers town line.
March 7, 2011	During this event, heavy rain, combined with melting snow, resulted in flooding of tributaries and major rivers. In Franklin County, in the Town of Greenfield, a water-soaked ridge near the Green River Cemetery gave way, resulting in a mudslide 13 inches deep that slid over Meridian and Water Streets. Three cars were buried, and the mud was up the foundations of three homes. This resulted in the evacuation of 17 people and approximately $100,000 in property damage.
August 2011	Hurricane Irene caused damage throughout portions of the Commonwealth, including a 5.8-mile section of Route 2 that was closed from West Charlemont to South County Road in Florida due to erosion and undercutting of the roadway, damage to retaining walls, debris flows, landslides, and bridge damage. The estimated cost of initial repairs was $23.5 million.
November 13-14, 2011	Landslides occurred in Deerfield in response to the October 31, 2011 snowstorm. These events caused clogging of culverts under the railroad and Routes 5 and 10, leading to siltation of a wetland and subsequent flooding of nearby homes.
September 30, 2013	In Southbridge MA, about 20,000 cubic yards of stockpiled topsoil at the landfill slid toward protected wetlands near Charlton, and some of the material apparently got into the wetlands, officials say. As a result, the state allowed Casella Waste Systems to remove the sediment that may have gotten into the wetlands. Casella was issued an order to stabilize the material from the landslide and make sure erosion has been controlled to stop additional soil from going toward the wetlands. This event appears in the USGS Landslide inventory have a confidence level of 2- “probable landslide in the area” and were reported by local sources.
November 14, 2014	Work on a new strip–mall in Attleboro is on hold after part of a hill collapsed, putting the safety of a local church at risk. The report does not confirm the source of the displacement but suggest it may be related to mining. This event appears in the USGS Landslide inventory have a confidence level of 2- “probable landslide in the area” and were reported by local sources
July 27, 2015	In Hampshire County a mud slide was reported above the road on Route 9 in Goshen. Route 9 in Goshen. Massachusetts state police said Route 9 in Goshen is closed, due to a mudslide as a result of heavy thunderstorms and precipitation. A Local news outlet reported that in Williamsburg, a section of Route 9 was completely washed out. Just after 5:00 P.M., a flash

Date	Description
	flood created a mudslide that washed out the eastbound lane of Route 9. This event appears in the USGS Landslide inventory have a confidence level of 2- “probable landslide in the area” and were reported by local sources
July 7, 2017	A small urban land displacement was experienced 38 Academy Dr, Buzzards Bay, Massachusetts in connection to a torrential downpour on July 7, 2017. This event appears in the USGS Landslide inventory have a confidence level of 2- “probable landslide in the area” and were reported by local sources

Source for events before 2011: Cleland, 1902; New York Times, 1936; Dethier et al., 1992; Mabee and Kopera, 2011.
Source for events after 2012: Jones et al. 2019, doi:10.5066/P9E2A37P

Table 1-4: Notable Coastal Flooding Events 2006-2022

Date	Counties Impacted	Damage Estimates
01/31/2006	Eastern Plymouth, Suffolk, Eastern Essex, Barnstable, Nantucket	$155,000
10/28/2006	Southern Bristol	$10,000
04/15/2007	Southern Bristol, Southern Plymouth, Eastern Plymouth, Eastern Essex, Nantucket, Dukes, Barnstable, Eastern Norfolk, Suffolk	$45,000
04/16/2007	Southern Bristol, Southern Plymouth, Eastern Plymouth, Suffolk, Eastern Essex, Barnstable, Dukes, Nantucket	$45,000
04/17/2007	Suffolk, Eastern Plymouth, Eastern Essex, Eastern Norfolk, Dukes, Barnstable, Nantucket	$85,000
11/03/2007	Eastern Essex, Nantucket, Barnstable	$10,000
01/28/2008	Barnstable	$30,000
03/08/2008	Southern Plymouth	$5,000
11/25/2008	Eastern Essex	N/R
06/21/2009	Eastern Essex	N/R
06/22/2009	Barnstable	$3,000
10/18/2009	Nantucket, Dukes, Eastern Plymouth, Suffolk	N/R
12/03/2009	Southern Bristol	$5,000
01/02/2010	Eastern Essex	N/R
01/02/2010	Suffolk	N/R
01/02/2010	Eastern Plymouth, Eastern Norfolk	N/R
02/25/2010	Eastern Essex, Eastern Plymouth	N/R
03/01/2010	Eastern Essex, Eastern Norfolk	$20,000
03/04/2010	Eastern Plymouth, Eastern Essex	N/R

Date	Counties Impacted	Damage Estimates
03/14/2010	Suffolk	N/R
03/15/2010	Eastern Plymouth, Eastern Essex	N/R
09/03/2010	Nantucket	N/R
10/06/2010	Eastern Plymouth	N/R
11/08/2010	Eastern Plymouth	$1,000
12/27/2010	Eastern Norfolk, Suffolk, Eastern Plymouth, Eastern Essex	$2,425,000
10/30/2011	Barnstable, Eastern Essex, Eastern Plymouth	$20,000
11/23/2011	Eastern Plymouth, Suffolk	N/R
06/02/2012	Eastern Essex	N/R
06/03/2012	Suffolk, Eastern Plymouth, Eastern Essex, Barnstable, Eastern Norfolk	$115,000
06/04/2012	Eastern Essex, Eastern Plymouth, Easter Norfolk, Dukes, Eastern Plymouth, Suffolk, Barnstable	$490,000
10/29/2012	Southern Bristol, Dukes, Barnstable, Nantucket, Suffolk, Eastern Norfolk, Eastern Plymouth, Southern Plymouth	$15,041,000
12/27/2012	Barnstable, Dukes, Southern Plymouth, Eastern Norfolk, Eastern Plymouth, Eastern Essex	N/R
02/09/2013	Eastern Essex	$5,800,000
02/09/2013	Eastern Norfolk	$500,000
02/09/2013	Eastern Plymouth	$9,200,000
02/09/2013	Suffolk	$30,000
02/09/2013	Nantucket	$100,000
02/09/2013	Barnstable	$5,300,000
03/07/2013	Suffolk, Eastern Essex, Barnstable, Eastern Norfolk, Eastern Plymouth, Nantucket	$1,850,000
03/08/2013	Dukes	N/R
12/15/2013	Eastern Plymouth, Eastern Norfolk	N/R
01/02/2014	Eastern Essex, Eastern Plymouth, Suffolk, Eastern Norfolk, Eastern Plymouth	N/R
01/03/2014	Barnstable, Eastern Plymouth, Suffolk, Eastern Norfolk, Eastern Essex, Nantucket, Barnstable	N/R
03/26/2014	Eastern Plymouth, Nantucket, Barnstable	N/R
08/13/2014	Suffolk	N/R
10/22/2014	Eastern Plymouth	$75,000
10/23/2014	Suffolk, Eastern Plymouth, Eastern Norfolk	N/R

Date	Counties Impacted	Damage Estimates
11/02/2014	Eastern Plymouth, Barnstable, Nantucket, Eastern Norfolk	N/R
01/27/2015	Eastern Plymouth	$1,500,000
01/27/2015	Barnstable	$750,000
01/27/2015	Eastern Norfolk	N/R
01/27/2015	Suffolk, Eastern Essex, Nantucket, Dukes	$100,000
02/15/2015	Eastern Plymouth, Barnstable, Nantucket	N/R
09/30/2015	Southern Bristol	N/R
10/02/2015	Eastern Plymouth, Suffolk	N/R
01/23/2016	Eastern Plymouth	N/R
01/24/2016	Eastern Plymouth, Eastern Essex, Suffolk, Nantucket	$3,000
02/08/2016	Dukes, Eastern Plymouth, Suffolk, Eastern Norfolk, Nantucket, Eastern Essex	N/R
05/25/2017	Eastern Essex	$40,000
01/04/2018	Barnstable, Dukes, Eastern Plymouth, Eastern Essex, Nantucket, Eastern Norfolk, Suffolk	$1,200,00
01/30/2018	Barnstable, Dukes, Eastern Plymouth, Eastern Essex, Nantucket, Eastern Norfolk, Suffolk	$20,000
03/02/2018	Barnstable, Dukes, Eastern Plymouth, Eastern Essex, Eastern Norfolk, Suffolk	N/R
03/03/2018	Nantucket	N/R
03/08/2018	Eastern Plymouth	N/R
10/27/2018	Barnstable, Eastern Plymouth, Eastern Essex, Suffolk	N/R
11/25/2018	Eastern Plymouth, Eastern Essex, Suffolk	N/R
11/27/2018	Southern Bristol	N/R
01/20/2019	Eastern Plymouth, Suffolk	N/R
09/07/2019	Nantucket	N/R
10/11/2019	Nantucket	N/R
10/28/2019	Eastern Essex, Eastern Norfolk, Suffolk	N/R
04/03/2020	Dukes, Eastern Plymouth, Suffolk, Nantucket	$2,000
04/09/2020	Eastern Essex, Suffolk	N/R
09/22/2020	Barnstable, Eastern Plymouth, Eastern Essex, Suffolk	N/R
02/02/2021	Eastern Plymouth, Eastern Essex, Suffolk	N/R
07/23/2021	Suffolk	N/R
10/27/2021	Barnstable, Eastern Plymouth	N/R

Date	Counties Impacted	Damage Estimates
01/17/2022	Barnstable, Dukes, Eastern Plymouth, Eastern Essex, Southern Bristol, Suffolk	N/R
01/29/2022	Barnstable, Dukes, Eastern Plymouth, Eastern Essex, Nantucket	N/R
12/23/2022	Bristol, Plymouth, Dukes, Nantucket, Barnstable, Essex, Plymouth, Suffolk, Norfolk	N/R

N/R indicates that no damages were reported to the NCDC

Source: NOAA NCDC Storm Events Database

Table 1-5: Notable Temperature Events 1994-March 2023

Low Temperatures		High Temperatures	
Date	**Type**	**Date**	**Type**
01/15/1994	Cold	01/13/1995	Record Warmth
01/18/1994	Cold	07/13/1995	Record Heat
01/19/1994	Cold	02/22/1997	Record Warmth
01/27/1994	Cold	01/03/1998	Record Warmth
01/17/2000	Extreme Cold	03/27/1998	Record Warmth
05/20/2002	Freeze	03/28/1998	Record Warmth
05/22/2002	Freeze	03/31/1998	Record Warmth
10/15/2002	Freeze	09/27/1998	Record Heat
01/15/2004	Extreme Cold/Wind Chill	12/02/1998	Record Warmth
01/25/2007	Cold/Wind Chill	12/07/1998	Record Warmth
02/03/2007	Extreme Cold/Wind Chill	01/24/1999	Record Warmth
01/01/2009	Cold/Wind Chill	02/12/1999	Record Warmth
01/16/2009	Cold/Wind Chill	03/18/1999	Record Warmth
04/29/2009	Frost/Freeze	06/07/1999	Excessive Heat
05/19/2009	Frost/Freeze	06/07/1999	Record Heat
06/01/2009	Frost/Freeze	07/04/1999	Excessive Heat
05/09/2010	Frost/Freeze	07/05/1999	Record Heat
05/13/2010	Frost/Freeze	07/16/1999	Record Warmth
01/23/2011	Extreme Cold/Wind Chill	07/17/1999	Record Warmth
01/22–01/24/2013	Cold/Wind Chill	07/18/1999	Record Warmth
01/02/2014	Cold/Wind Chill	09/07/1999	Record Warmth
01/07/2014	Cold/Wind Chill	03/08/2000	Record Warmth

Low Temperatures		High Temperatures	
Date	**Type**	**Date**	**Type**
01/21/2014	Cold/Wind Chill	05/08/2000	Record Heat
01/26–01/28/2014	Cold/Wind Chill	05/09/2000	Record Heat
01/07/2015	Extreme Cold/Wind Chill	10/14/2000	Record Warmth
01/30–02/2/2015	Cold/Wind Chill	12/17/2000	Record Warmth
02/05/2015	Cold/Wind Chill	04/24/2001	Record Heat
02/13/2015	Cold/Wind Chill	05/02/2001	Record Heat
02/15–02/16/2015	Extreme Cold/Wind Chill	05/03/2001	Record Heat
02/19–02/20/2015	Extreme Cold/Wind Chill	05/04/2001	Record Heat
02/23/2015	Cold/Wind Chill	05/12/2001	Record Heat
02/13–02/14/16	Extreme Cold/Wind Chill	07/06/2010	Excessive Heat
12/15/2016	Cold/Wind Chill	07/21/2011	Excessive Heat
03/11/2017	Cold/Wind Chill	07/05–02/06/2013	Heat
01/01/2018	Extreme Cold/Wind Chill	07/19/2013	Heat
01/01/2018	Extreme Cold/Wind Chill	07/01/2018	Excessive Heat
01/01/2018	Extreme Cold/Wind Chill	07/03/2018	Excessive Heat
01/5–01/06/2018	Extreme Cold/Wind Chill	08/28/2018	Excessive Heat
01/06/2018	Cold/Wind Chill	08/29/2018	Heat
01/13/2018	Cold/Wind Chill	09/03/2018	Heat
11/22/2018	Cold/Wind Chill	07/19/2020	Heat
01/20–01/21/2019	Extreme Cold/Wind Chill	07/27/2020	Heat
01/30/2019	Extreme Cold/Wind Chill	06/28/2021	Heat
02/01/2019	Cold/Wind Chill	08/11/2021	Heat
12/18/2019	Cold/Wind Chill	08/26/2021	Heat
01/28–01/29/2021	Extreme Cold/Wind Chill	08/04/2022	Heat
03/02/2021	Cold/Wind Chill	08/08/2022	Heat
01/11/2022	Cold/Wind Chill		
01/14/2022	Extreme Cold/Wind Chill		
01/20/2022	Cold/Wind Chill		
01/29/2022	Cold/Wind Chill		
12/23/2022	Cold/Wind Chill		
02/3–02/04/2023	Extreme Cold/Wind Chill*		

Source: NOAA NCDC Storm Events Database;

Table 1-6. Select Wildfire Incidents 1957- 2021

Date	Description
May 1957	One of the largest wildfires on record was in Plymouth. This catastrophic fire burned 15,000 acres and destroyed about 40 structures.
1964	Another large fire in the Plymouth area burned 5,500 acres and destroyed cottages on Charge Pond.
July 5-7, 2002	Smoke from wildfires across the Nemiscau region of northern Quebec became trapped under a subsidence inversion and was transported south across western Massachusetts. The fires were started by hot and dry weather conditions over that region of Canada, followed by an unusual amount of thunderstorm activity. The smoke obscured the sky and reduced surface visibility to as low as one mile. Advisories were issued in the Commonwealth, warning people with respiratory issues to remain indoors and all individuals to limit their outside activities.
April 4-5, 2012	Dry conditions, combined with wind gusts between 25 and 30 mph, produced ideal conditions for fire spread. A brush fire in Brimfield moved into an area of blown down debris from a tornado and became difficult to control. Due to a thunderstorm, firefighters had to stop until the storm passed. This brush fire burned approximately 50 acres. No structures were destroyed; however, many homes were threatened.
April 19, 2012	Dry conditions, along with gusty winds, caused a fire in the meadowlands to spread in Dedham. The fire burned approximately one acre just off Route 56 on the Leicester-Paxton line. One firefighter was injured.
April 19-20, 2012	Dry conditions, along with gusty winds, caused a fire to spread near Route 128 on the Dedham-Boston line. Almost 100 acres of meadowlands burned.
March 8-9, 2016	A brush fire on Tekoa Mountain near Westfield, Massachusetts started on March 8, 2016 and spread quickly as a result of very dry weather in the previous days and weeks. The weather on March 8th and 9th was favorable for fire fighters with light winds and relative humidity values around 50%. Despite this, the fire spread to about 60 acres before fire fighters were able to contain it. One of the reasons for the quick-fire spread was the lack of hydrants or water lines in the vicinity, requiring fire fighters to carry in water on their backs. By 2pm on March 9, fire fighters deemed the fire 90 percent contained. The area of the fire was very remote and no structures were in the area of the fire.
July 22-24, 2016	Lightning started a fire on Joint Base Cape Cod on July 22nd. The fire was discovered early Saturday (July 23) but burned through the night and into the following day (July 24). The fire was contained to 125 acres after 36 hours of fighting the fire. Dry conditions throughout southern New England contributed to the spread of the fire through dry brush and trees. Four helicopters from the Massachusetts State Police and the Army National Guard shuttled back and forth between Snake Pond in Sandwich and the areas on the base that were inaccessible to firefighters.
May 14-18, 2021	On the evening of May 14th, a wildfire started in Clarksburg State Forest on East Mountain. About 120 professional and volunteer firefighters responded to the fire

Date	Description
	and it was contained 4 days later on May 18th after burning 947 acres. No structures were impacted but several hiking trails were closed in area, including the Appalachian Trail. One firefighter was hospitalized.

Source for data before 2018: 2013 SHMP, Boston Globe

Source for data after 2018:, NCEI Storm Events Database, 2022. Starting in 2017, the Department of Conservation and Recreation (DCR) launched an effort to standardize data collection for wildfires in the state. A table summarizing the number of fire events since the effort began is included below. For more information, please refer to the Wildfire section of the 2023 Risk Assessment.

Table 1-7. Wildfire Occurrences in Massachusetts 2017-2022 by County.

County	2017	2018	2019	2020	2021	2022a
Barnstable	144	187	23	121	171	185
Berkshire	49	23	10	10	56	26
Bristol	45	26	--	65	38	57
Dukes	1	12	2	11	12	7
Essex	52	47	37	147	103	207
Franklin	39	30	13	71	56	48
Hampden	128	139	--	147	43	103
Hampshire	28	27	11	41	13	15
Middlesex	35	87	69	293	265	96
Nantucket	3	--	1	5	--	4--
Norfolk	106	35	--	44	28	63
Plymouth	391	291	--	168	153	163
Suffolk	--	6	--	--	--	1
Worcester	168	98	53	230	196	156
Total	**1,242**	**1,008**	**281**	**1,353**	**1,134**	**1,196**

Source: Developed by ERG with data from DCR, 2018; DCR, 2019; DCR, 2020, DCR, 2021; DCR, 2022.
[a] 2022 data represents fires from January 2022 through December 31, 2022.

Table 1-8. Winter Storm 1958-2022

Year	Date	NESIS Score
1958	Feb 14-17	6.25
1960	Mar 02-05	8.77
1960	Dec 11-13	4.53
1961	Jan 18-21	4.04
1961	Feb 02-05	7.06
1964	Jan 11-14	6.91
1966	Jan 29-31	5.93
1969	Feb 22-28	4.29
1969	Dec 25-28	6.29
1972	Feb 18-20	4.77
1978	Jan 19-21	6.53
1978	Feb 05-07	5.78
1979	Feb 17-19	4.77
1983	Feb 10-12	6.25
1987	Jan 21-23	5.4
1993	Mar 12-14	13.2
1994	Feb 08-12	5.39
1996	Jan 06-08	11.78
2003	Feb 15-18	8.91
2005	Jan 21-24	6.8
2006	Feb 12-13	4.1
2007	Feb 12-15	5.63
2009	Dec 18-21	4.03
2010	Feb 9-11	4.1
2010	Feb 23-28	5.46
2010	Dec 24-28	4.92
2011	Jan 9-13	5.31
2011	Feb 1-3	5.3
2013	Feb 7-10	4.35
2014	Jan 29-Feb 4	4.08
2014	Feb 11-14	5.28

Year	Date	NESIS Score
2015	Jan 29-Feb 3	5.42
2016	Jan 22-24	7.66
2017	Mar 12-15	5.03
2021	Jan 30-Feb 3	4.93
2022	Dec 13-20	8.52

Source: NESIS storm database

Note: For events after 2018, the table includes a record of events rated 3 (major)

Table 1-9. Tornadoes 1951-2022

Location	Date	F/EF Scale*	Deaths/Injuries	Property Damage
Essex Co.	8/21/1951	F2	0/0	$2,500
Dukes Co.	12/18/1951	F2	0/0	$0
Worcester Co.	6/9/1953	F4	90/1228	$250,000,000
Worcester Co.	6/9/1953	F3	0/1	$2,500,000
Norfolk Co.	6/9/1953	F3	0/15	$2,500,000
Bristol Co.	6/9/1953	F3	0/1	$2,500,000
Franklin Co.	7/14/1954	F1	0/0	$2,500
Hampshire Co.	8/16/1954	F1	0/0	$2,500
Franklin Co.	7/5/1955	F2	0/0	$2,500
Berkshire Co.	7/12/1955	F2	0/0	$0
Worcester Co.	10/24/1955	F1	0/0	$2,500
Middlesex Co.	10/24/1955	F1	0/0	$2,500
Hampden Co.	6/1/1956	F1	0/0	$250,000
Hampden Co.	6/1/1956	F1	0/0	$25,000
Hampden Co.	6/1/1956	F1	0/0	$25,000
Worcester Co.	6/1/1956	F1	0/14	$25,000
Essex Co.	6/13/1956	F1	0/0	$2,500
Hampden Co.	9/12/1956	F1	0/0	$250
Worcester Co.	11/21/1956	F2	0/0	$2,500,000
Essex Co.	11/21/1956	F2	0/0	$25,000
Norfolk Co.	11/21/1956	F2	0/0	$2,500
Essex Co.	12/18/1956	F1	0/0	$250
Franklin Co.	5/10/1957		0/0	$250
Franklin Co.	5/10/1957	F1	0/0	$250

Location	Date	F/EF Scale*	Deaths/Injuries	Property Damage
Middlesex Co.	6/19/1957	F1	0/0	$25,000
Middlesex Co.	6/19/1957	F1	0/0	$250
Worcester Co.	6/19/1957	F1	0/0	$25,000
Hampshire Co.	7/5/1957	F1	0/0	$2,500
Worcester Co.	7/5/1957	F2	0/0	$2,500
Hampden Co.	6/26/1958	F1	0/0	$250
Franklin Co.	7/11/1958	F2	0/0	$2,500
Worcester Co.	7/11/1958	F1	0/0	$250
Worcester Co.	7/11/1958	F1	0/0	$2,500
Middlesex Co.	7/11/1958	F2	0/0	$250,000
Worcester Co.	7/16/1958	F1	0/1	$2,500
Worcester Co.	7/29/1958	F1	0/0	$2,500
Franklin Co.	8/13/1958	F1	0/0	$2,500
Hampshire Co.	8/14/1958	F2	0/0	$250,000
Middlesex Co.	8/25/1958	F2	0/0	$2,500
Berkshire Co.	9/7/1958	F0	0/0	$2,500
Plymouth Co.	9/7/1958	F0	1/1	$2,500
Essex Co.	7/13/1960	F0	0/0	$30
Franklin Co.	7/2/1961	F0	0/0	$25,000
Middlesex Co.	7/3/1961	F0	0/0	$25,000
Hampshire Co.	7/21/1961	F2	0/0	$25,000
Essex Co.	7/21/1962	F1	0/3	$25,000
Worcester Co.	10/12/1962	F2	0/0	$25,000
Franklin Co.	5/20/1963	F2	0/0	$25,000
Worcester Co.	5/20/1963	F2	0/0	$25,000
Worcester Co.	5/20/1963	F2	0/0	$25,000
Worcester Co.	5/20/1963	F2	0/0	$2,500
Middlesex Co.	7/18/1963	F1	0/0	$25,000
Hampden Co.	7/21/1963	F0	0/0	$2,500
Franklin Co.	9/12/1963	F1	0/0	$2,500
Berkshire Co.	10/3/1963	F1	0/0	$2,500
Essex Co.	5/19/1964	F0	0/0	$2,500
Essex Co.	5/19/1964	F1	0/0	$2,500
Plymouth Co.	7/4/1964	F1	0/0	$250,000

Location	Date	F/EF Scale*	Deaths/Injuries	Property Damage
Franklin Co.	7/29/1964	F0	0/0	$25,000
Franklin Co.	7/29/1964	F1	0/0	$25,000
Hampshire Co.	5/27/1965	F1	0/0	$250
Plymouth Co.	6/9/1965	F0	0/0	$30
Essex Co.	8/10/1965	F1	0/0	$0
Middlesex Co.	8/28/1965	F2	0/0	$250,000
Berkshire Co.	3/1/1966	F2	0/0	$25,000
Berkshire Co.	8/11/1966	F2	0/0	$25,000
Hampden Co.	8/11/1966	F2	0/0	$250,000
Worcester Co.	8/31/1966	F2	0/0	$0
Worcester Co.	8/31/1966	F0	0/1	$250
Plymouth Co.	11/18/1967	F2	0/0	$250
Essex Co.	7/1/1968	F1	0/1	$250,000
Worcester Co.	7/17/1968	F1	0/0	$2,500
Hampden Co.	7/19/1968	F0	0/0	$250
Bristol Co.	8/9/1968	F1	0/4	$25,000
Bristol Co.	8/9/1968	F1	0/0	$2,500
Barnstable Co.	8/9/1968	F1	0/0	$2,500
Worcester Co.	5/29/1969	F1	0/0	$2,500
Berkshire Co.	6/18/1970	F1	0/0	$250,000
Middlesex Co.	7/11/1970	F1	0/0	$25,000
Bristol Co.	8/2/1970	F1	0/0	$25,000
Franklin Co.	8/17/1970	F1	0/0	$250,000
Bristol Co.	8/28/1970	F2	0/0	$25,000
Hampden Co.	10/3/1970	F1	0/0	$0
Worcester Co.	10/3/1970	F3	0/0	$250,000
Middlesex Co.	10/3/1970	F3	1/0	$250,000
Middlesex Co.	7/1/1971	F1	0/1	$25,000
Worcester Co.	7/1/1971	F1	0/2	$25,000
Franklin Co.	7/17/1971	F1	0/0	$2,500
Hampshire Co.	9/13/1971	F3	0/0	$25,000
Worcester Co.	11/7/1971	F1	0/0	$2,500
Middlesex Co.	11/7/1971	F1	0/0	$250
Franklin Co.	7/3/1972	F1	0/0	$2,500

Location	Date	F/EF Scale*	Deaths/Injuries	Property Damage
Franklin Co.	7/3/1972	F1	0/0	$2,500
Middlesex Co.	7/21/1972	F2	0/4	$2,500,000
Essex Co.	7/21/1972	F1	0/0	$2,500
Hampden Co.	8/9/1972	F1	0/0	$2,500
Norfolk Co.	8/9/1972	F1	1/6	$25,000
Worcester Co.	8/9/1972	F2	0/1	$25,000
Franklin Co.	8/27/1972	F2	0/0	$25,000
Hampden Co.	9/14/1972	F1	0/0	$2,500
Bristol Co.	9/14/1972	F0	0/0	$2,500
Franklin Co.	8/2/1973	F0	0/0	$250
Berkshire Co.	8/28/1973	F4	4/36	$25,000,000
Norfolk Co.	9/6/1973	F1	0/0	$25,000
Middlesex Co.	9/29/1974	F3	0/1	$250,000
Berkshire Co.	7/13/1975	F2	0/0	$25,000
Hampden Co.	7/24/1975	F2	0/0	$25,000
Worcester Co.	5/3/1976	F1	0/0	$2,500
Hampden Co.	6/29/1977	F1	0/0	$0
Barnstable Co.	8/22/1977	F1	0/2	$25,000
Berkshire Co.	7/27/1978	F0	0/0	$250
Worcester Co.	8/10/1979	F2	2/2	$2,500,000
Hampden Co.	8/10/1979	F1	0/1	$25,000
Worcester Co.	6/22/1981	F3	0/3	$25,000
Middlesex Co.	7/18/1983	F0	0/0	$250
Franklin Co.	8/1/1983	F0	0/0	$30
Hampshire Co.	7/5/1984	F1	0/0	$2,500
Franklin Co.	7/5/1984	F1	0/0	$25,000
Berkshire Co.	7/11/1984	F1	0/0	$25,000
Middlesex Co.	9/27/1985	F1	0/0	$250
Middlesex Co.	8/7/1986	F1	0/0	$250,000
Worcester Co.	8/8/1986	F1	0/0	$2,500
Plymouth Co.	9/16/1986	F1	0/0	$250,000
Worcester Co.	7/10/1989	F1	0/0	$250,000
Worcester Co.	7/10/1989	F1	0/0	$250,000
Worcester Co.	7/10/1989	F1	0/0	$250,000

Location	Date	F/EF Scale*	Deaths/Injuries	Property Damage
Worcester Co.	7/10/1989	F1	0/0	$250,000
Norfolk Co.	7/10/1989	F0	0/0	$2,500
Plymouth Co.	7/10/1989	F1	0/1	$25,000
Plymouth Co.	7/10/1989	F0	0/0	$25,000
Norfolk Co.	5/18/1990	F0	0/0	$2,500
Norfolk Co.	5/18/1990	F0	0/0	$2,500
Worcester Co.	8/10/1990	F0	0/0	$30
Essex Co.	8/15/1991	F1	0/0	$250,000
Hampden Co.	6/24/1992	F0	0/0	$0
Franklin Co.	6/27/1992	F0	0/4	$25,000
N. Egremont	5/29/1995	F4	3/24	$250
Florida	7/3/1997	F1	0/0	$15,000
Heath	7/3/1997	F1	0/0	$50,000
Monterey	7/3/1997	F2	0/0	$1,500,000
West Otis	7/3/1997	F2	0/0	$1,500,000
Charlemont	7/3/1997	F1	0/0	$50,000
Richmond	7/3/1997	F1	0/0	$50,000
Westport	8/6/1997	F0	0/0	$0
Plymouth	8/20/1997	F0	0/0	$0
Leads	6/2/2000	F1	0/0	$0
Princeton	6/17/2001	F1	0/0	$25,000
Bellingham	6/30/2001	F0	0/0	$0
West Brookfield	7/23/2002	F1	0/0	$50,000
Pittsfield	8/20/2004	F0	0/0	$25,000
Franklin	8/21/2004	F1	0/0	$1,500,000
Great Barrington	6/29/2005	F0	0/0	$0
Wendell	7/11/2006	F2	0/0	$200,000
New Braintree	7/19/2007	EF0	0/0	$0
South Swansea	7/23/2008	EF0	0/0	$15,000
Westfield	6/1/2011	EF3	3/200	$227,600,000
Fiskdale	6/1/2011	EF3	0/0	$0
Indian Orchard	6/1/2011	EF1	0/0	$0
Brimfield	6/1/2011	EF1	0/0	$0
Fiskdale	6/1/2011	EF0	0/0	$0

Location	Date	F/EF Scale*	Deaths/Injuries	Property Damage
White Horse Beach	7/24/2012	EF0	0/0	$3,000
Stoughton	5/9/2013	EF0	0/0	$20,000
Baconville	9/1/2013	EF0	0/0	$0
North Adams JCT	7/27/2014	EF1	0/0	$0
Chelsea	7/28/2014	EF2	0/2	$4,000,000
South Worcester	8/31/2014	EF0	0/0	$100,000
Wrentham	6/23/2015	EF0	0/0	$20,000
Mantyranta	6/23/2015	EF0	0/0	$25,000
Concord	8/22/2016	EF1	0/0	$1,000,000
Goshen	2/25/2017	EF1	0/0	$250,000
South Ashfield	2/25/2017	EF1	0/1	$400,000
Worcester Co.	7/26/2018	EF1	0/0	$25,000
Worcester Co.	7/26/2018	EF1	0/0	$40,000
Worcester Co.	8/4/2018	EF1	0/1	$5,000,000
Worcester Co.	10/23/2018	EF1	0/0	$0
Bristol Co.	10/23/2018	EF1	0/0	$20,000
Worcester Co.	10/23/2018	EF0	0/0	$0
Barnstable Co.	10/29/2018	EF0	0/0	$300
Barnstable Co.	7/23/2019	EF1	0/0	$1,200,000
Barnstable Co.	7/23/2019	EF1	0/0	$100,000
Barnstable Co.	7/23/2019	EF1	0/0	$3,600,000
Berkshire Co.	8/2/2020	EF0	0/0	$9,000
Hampden Co.	8/2/2020	EF0	0/0	$45,000
Norfolk Co.	10/7/2020	EF0	0/0	$6,000
Worcester Co.	8/19/2021	EF0	0/0	$10,000
Worcester Co.	8/19/2021	EF0	0/0	$12,000
Middlesex Co.	8/23/2021	EF0	0/0	$8,000
Worcester Co.	8/23/2021	EF0	0/0	$2,000
Middlesex Co.	8/23/2021	EF0	0/0	$2,000
Barnstable Co.	9/2/2021	EF0	0/0	$15,000
TOTAL:			105/1,562	$544,351,700

Source: NOAA NCDC Storm Events Database (https://www.weather.gov/oun/efscale)

*The Enhanced Fujita Scale (EF Scale) replaced the Fujita Scale (F Scale) on February 1, 2007. Both scales use a rating from 1-5 to represent estimated wind speed and related damage from a tornado, but they are not directly comparable due to calculation differences.

Table 1-10: Earthquakes 1963-March 2023

Date	Description
October 16, 1963	The earthquake caused some plaster to fall in Somerville, and a wall was reported cracked and stones fell from a building foundation (Modified Mercali intensity VI). Dishes were broken and many persons were alarmed in Amesbury, and a window was cracked in Winthrop. The other earthquakes did not exceed Modified Mercalli Intensity V. The residents of Nantucket Island were jolted by a moderate earthquake on October 24, 1965. Very slight damage, mostly to ornaments, was reported. Doors, windows, and dishes rattled, and house timbers creaked.
April 2012	A swarm of 12 or more earthquakes occurred off the New England coast on the continental shelf about 250 miles east of Boston. The largest earthquake measured Magnitude 4.4 on the Richter scale. This swarm was of particular concern because of the major earthquake on the continental shelf further north in 1929 that produced a deadly and damaging tsunami in Nova Scotia. In October 2012, a 4.6 earthquake centered in Maine was felt throughout Massachusetts, as well as other New England states.
November 8, 2020	A 3.6 magnitude earthquake occurred a few miles off the coast of New Bedford, MA. People reported feeling the jolt from around 100 miles away. No injuries were reported, and property damage was minimal, mostly due to broken chimneys. Twenty people were displaced. It was one of the largest earthquakes ever recorded in Massachusetts.

Sources: 2013 SHMP, Bucell 2020 accessed October 3, 2022
(https://www.bostonmagazine.com/news/2020/11/24/massachusetts-earthquakes/)

Appendix 5.B:
Technical Methods and Data

Contents

Tables

1. Introduction

The Risk Assessment includes a technical appendix that documents the data sources used and the geospatial analysis conducted for all hazards. The appendix gives technical audiences the background needed to understand the data used and how each analysis was conducted. The purpose of this document is to summarize the data and methods used throughout the Risk Assessment in a way that transparently summarizes data, sources, and methods used throughout the analysis. This appendix will enable readers to quickly identify data sources that they can use to replicate the analysis or conduct further research to build on the findings of the Risk Assessment. Chapters will provide additional detail on methodologies and data that is also contained in this summary appendix.

2. Data and Methods Used Across All Hazards

All sections of the Risk Assessment include some common data sources and methods to evaluate the risks posed to Environmental Justice communities, the locations of highest anticipated population growth, and the locations of planned development.

2.1 Table of sources

Table 2-1 shows the agencies that provided these data sources, and a link where the most recent data can be obtained.

Table 2-1. Data Sources to Describe Populations and Development

Name	Source Organization	Description	Dollar Value of Local Assets
Massachusetts Population Projections	University of Massachusetts Donohue Institute	Based off of 2010 census and produced by the Donohue Institute. Municipality and county level.	2021
Environmental Justice Populations in Massachusetts	Massachusetts Executive Office of Energy and Environmental Affairs (EEA)	2020 census EJ pop by census block group	2023
MassBuilds Development Data	Metropolitan Area Planning Council	Locations of construction projects throughout the Commonwealth.	2023

2.2 Description of methodology

Environmental Justice Populations

Every hazard section includes a discussion and analysis of vulnerability factors and considers social vulnerability explicitly to indicate how populations may be disproportionately impacted by a hazard and the underlying factors that drive vulnerability.

The Risk Assessment uses variables and data developed by the Executive Office of Energy and Environmental Affairs (EEA) to map communities with environmental injustice concerns. The Risk Assessment used the latest vintage of EEA Environmental Justice Population Data which was published in the Fall of 2022. Under this effort, a census block group is identified as an Environmental Justice population area if it meets one or more of the following criteria:

- The annual median household income is not more than 65 percent of the statewide annual median household income.
- Individuals who identify themselves as Latino/Hispanic, Black/African American, Asian, Indigenous people, and people who otherwise identify as non-White constitute 40 percent or more of the population.
- 25 percent or more of households lack English language proficiency.
- Individuals who identify themselves as Latino/Hispanic, Black/African American, Asian, Indigenous people, and people who otherwise identify as non-White constitute 25 percent or more of the population and the annual median household income of the municipality in which the neighborhood is located does not exceed 150 percent of the statewide annual median household income. portion of a neighborhood designated by the Secretary as an environmental justice population in accordance with the *Act Creating a Next-Generation Roadmap for Massachusetts Climate Policy*, Chapter 8 of the Acts of 2021.

Priority Communities

Priority populations are people or communities who are disproportionately affected by climate change due to life circumstances that systematically increase their exposure to climate hazards or make it harder to respond. In addition to factors that contribute to environmental justice status (i.e., income, race, and language), other factors like physical ability, access to transportation, health, and age can indicate whether someone or their community will be disproportionately affected by climate change. This is driven by underlying contributors such as racial discrimination, economic disparities, or accessibility barriers that create vulnerability. The term “priority populations” acknowledges that the needs of people with these experiences and expertise must take precedence when developing resilience solutions to reduce vulnerability to climate change. Priority populations are often exposed to pollution, impacts of climate change, and hazards while simultaneously experiencing long-term stressors.

Disadvantaged communities are communities that experience a combination of economic, health, and environmental burdens, and are referred to throughout the Risk Assessment as Environmental Justice communities. Communities from minoritized identities, also referred to as minority, including Black, Indigenous, People of Color, are often exposed to higher rates of pollution, natural hazards, and impacts of climate change (Banzhaf et al., 2019; Chakraborty et al., 2019; Hsu et al., 2021; Mohai & Saha, 2015). The following community and population characteristics were considered for each analysis and implemented depending on the relevance for the hazard:

- Low income
- Age (above 65, under five)
- Underlying health conditions
- Disabilities
- Residence in single-parent households
- Renting
- Residence in housing cost–burdened households
- Membership in an underrepresented or under-resourced community
- Transit dependency
- Linguistic isolation
- Unhoused status

Changes in Population and risk

To analyze how changes in population were influencing long-term risk in Massachusetts, we assessed the following questions:

- Are geographic areas at current or future hazard and climate risk projected to grow?
- Is risk being considered when growth happens through changing land use and increases in density? Is risk being addressed through higher standards and building codes?
- Are there trends and patterns that need to be considered and described in the Risk Assessment?

All hazards are assessed based on these population projections to determine if hazard exposure is growing or getting smaller based on growth projections.

Generally, the Boston Harbor region is expected to experience the most population growth in the Commonwealth, while population is expected to decline slightly in rural

Massachusetts, a hazard specific analysis is included in the discussion of the Human sector under the Exposure and Vulnerability section of each hazard analysis.

State- wide analysis of construction patterns

To better understand changes in development, the Risk Assessment identified one statewide resource developed by the Metropolitan Area Planning Council (MAPC). The public database, called MassBuilds, catalogues significant construction projects in Massachusetts (Metropolitan Area Planning Council, n.d.).

MassBuilds collects data from participants at regional planning and other government agencies. The dataset includes locations of projects and either the year construction was completed or the projected year of project completion. This allowed the assessment team to identify which regions are experiencing more development now and in the near term. There are significant limitations to using this dataset. MassBuilds is primarily focused on the Greater Boston area, with far less coverage for other regions in the Commonwealth. The dataset also focuses on large housing or commercial building projects, omitting other important areas of construction such as single-family homes.

The Risk Assessment used this dataset to assess which regions experienced recent development, and which locations are expected to experience further development.

- We express both rates of recent development and projected development as shares of a “base rate”, or the number of construction projects completed per year between 2013 and 2017.
- To show the rate of recent development, we show the number of projects completed per year between 2018 and 2022 as share of the base rate.
- To show the rate of expected further development, we take the number of projects either in planning, projected, or in construction between 2023 and 2030 as a share of the base rate. Only municipalities with construction during the base period are included.

3. Sector-Level Data and Methods

In this section, we describe data and methods used throughout the Risk Assessment to describe risks and impacts in each sector. While the methods used to evaluate risk vary, we rely on sector-level data of several key features to identify impacts and vulnerabilities.

3.1 Table of sources

The following table lists all sources used for sector-level data. For most sources, we provide a link to the dataset. For Division of Capital Asset Management and Maintenance (DCAMM) data, these locations were provided directly by DCAMM staff.

Sector	Name	Source Organization	Description	Year Published or Updated
Human	[Demographics]	Bureau of the Census American Community Survey	2019 ACS 5-year estimates	2020
Human	[Affordable housing]	Bureau of the Census American Community Survey Property and Structure Value	Used 'tidycensus' package to obtain American Community Survey Data for Variable " B25077_001 = Median Value (Dollars)":	2010
Human	[Health Risk Factors]	Massachusetts Environmental Public Health Tracking	Community-level rates of health risk factors associated with mortality from extreme temperatures: asthma (including childhood asthma), heat stress, and cardiac arrest.	2022
Governance	Government owned and operated buildings	DCAMM		2022
Governance	Critical facilities	DCAMM	Subset of government buildings	2022
Infrastructure	[MassDOT Roads]	MassGIS	Official state-maintained street transportation dataset available from MassGIS. It represents all the public and many of the private roadways in Massachusetts and includes designations for Interstate, U.S. and State routes.	2022
Infrastructure	[Railways]	MassGIS	Rail linework and station points for passenger, freight, and Amtrak and MBTA Commuter Rail trains.	2022
Infrastructure	[Wastewater treatment plants]	MassDEP	List of Municipal wastewater treatment plants in Massachusetts, geolocated by address provided.	2022

Sector	Name	Source Organization	Description	Year Published or Updated
Infrastructure	Electric Power Transmission lines	Homeland Infrastructure Foundation-Level Data (HIFLD)	Locations of electric power transmissions lines.	2018
Infrastructure	Electric Substations	Homeland Infrastructure Foundation-Level Data (HIFLD)	Locations of electric substations.	2018
Infrastructure	Seaports	MassDOT/MassGIS	This point data layer contains the locations of passenger and freight seaport locations in Massachusetts.	2020
Infrastructure	Airports	MassDOT	Airports in the state of Massachusetts generated from tabular data provided by the MassDOT Aeronautics Division.	2019
Infrastructure	Acute Care Hospitals	MassGIS	Acute care hospitals contain a majority of medical-surgical, pediatric, obstetric, and maternity beds. All hospitals in the state that have a 24-hour emergency department are included in this layer, but not all facilities in this layer have an emergency department (the ER_STATUS field stores this data).	2018
Natural Environment	BioMap	MassWildlife	Geospatial information on ecosystem types and the natural environment.	2022
Natural Environment	Protected and Recreational OpenSpace	MassGIS	The protected and recreational open space datalayer contains the boundaries of conservation lands and outdoor recreational facilities in Massachusetts.	2023

3.2 Description of methodology

The primary method of analysis for these datasets is overlay analysis, where the map of locations of assets, populations, or ecosystems is overlaid with the projected extent of the natural hazard. To conduct this overlay analysis, we convert data from all sources into consistent shape files; this requires extracting point locations from some sources, and converting mapping projections to use a uniform projection. Then, software such as ArcMap, R, or Python is used to count the number of assets, or the share of populations overlaid with the extent of the natural hazard.

When the geographic level of sector data does not match the geographic level of hazard estimates, we estimate the total number of people exposed to a hazard by making one of two assumptions. As a conservative upper bound, we assume that the entire county or census block is affected by the hazard. In some other estimates (including coastal flooding and flooding from precipitation), we assume that the sector data is uniformly distributed within its region and approximate the extent of that region exposed to the hazard. For example, if 50 percent of a census block of 1,000 people was located within a floodplain, the estimated population exposed to the hazard would be 500.

4. Hazard-Level Data and Methods

In this section, we provide details on the data sources and methods required for analysis of individual hazards.

4.1 Table of sources

The following table lists primary sources used to assess the impacts of various hazards. When the Risk Assessment team conducted original data analysis, we include a citation and link to the dataset. When hazard information was developed for the 2022 Climate Assessment, we cite the report.

Hazard	Name	Source Organization	Description	Year Published or Updated
Average/Extreme Temperatures	Declines in Fishery Landings due to Temperature	Shared from 2022 MA Climate Change Assessment.	Estimated decline in fishery landings, at the community level. Developed for 2022 MA Climate Change Assessment.	2022
Average/Extreme Temperatures	Mortality Impacts from Extreme Temperatures	Shared from 2022 MA Climate Change Assessment.	Mortality impacts from extreme temperature, at the county level. Developed for 2022 MA Climate Change Assessment.	2022
Average/Extreme Temperatures	Daily Temperature Records from Weather Stations	NOAA Global Historical Climatological Network	Daily time series of temperature observations at various weather stations. Used to plot counts of heat waves at various stations.	2022
Average/Extreme Temperatures	Temperature Impacts to Rail by Block Group	Shared from 2022 MA Climate Change Assessment.	Block-group level analysis of costs to MA rail resources. Developed for 2022 MA Climate Change Assessment.	2022
Average/Extreme Temperatures	Temperature Impacts to Roads by Block Group	Shared from 2022 MA Climate Change Assessment.	Block-group level analysis of costs to MA road resources. Developed for 2022 MA Climate Change Assessment.	2022
Average/Extreme Temperatures	CMIP6 Temperature Projections	NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6)	Gridded downscaled climate projections of daily maximum and minimum temperature from a range of climate models.	2021
Average/Extreme Temperatures	GridMET Historical Temperature	Climatology Lab	Gridded historical climate data, including daily temperature	2022

Hazard	Name	Source Organization	Description	Year Published or Updated
Changes in Groundwater	National Water Dashboard	USGS	Provides water level and quality indicators for groundwater resources, streams, lakes, reservoirs, and other water resources throughout the United States.	2023
Coastal Erosion	Massachusetts Shoreline Change Project	Massachusetts Office of Coastal Zone Management (CZM)	Through the Shoreline Change Project, the ocean-facing shorelines of Massachusetts have been delineated and statistically analyzed to demonstrate trends from the mid-1800s to 2018.	2021
Coastal Flooding, Flooding from Precipitation	Repetitive Loss and Severe Repetitive Loss Properties in Massachusetts	National Flood Insurance Program (NFIP)	Locations of repetitive loss properties and severe repetitive loss properties, based on records from NFIP.	2022
Coastal Flooding, Flooding from Precipitation	MassGIS Data: FEMA Q3 Flood Zones from Paper FIRMs	MassGIS	A subset of the data available on the FIRM map, from FEMA. All counties except Franklin are available for MA.	2005
Coastal Flooding	The Massachusetts Coast Flood Risk Model (MC-FRM)	MassDOT/Woods Hole Group	MC-FRM dynamically includes the impacts of tides, waves, wave run-up and overtopping, storm surge, winds, and currents over a range of storm conditions and at high spatial resolution to model SLR and storm surge	2017
Drought	Days without Precipitation	Analysis from 2022 MA Climate Assessment, based on LOCA Statistical Downscaling	Annual number of dry days (ascii raster files at 1/16th degree) derived from LOCA downscaled GCM projections. Has historical data	2016

Hazard	Name	Source Organization	Description	Year Published or Updated
			through 2005 and projections for 2030, 2050, 2070, 2090	
Drought	Percent of MA in Drought	U.S. Drought Monitor	The Drought Severity and Coverage Index (DSCI) is an experimental method for converting drought levels from the U.S. Drought Monitor map to a single value for an area. Data tells us the percent of the state covered by each severity type. Used to calculate the number of weeks drought conditions were present in MA.	2022
Drought	MA Drought Status History	Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency	Drought status history of different regions in MA. Data starts in 2001, when the Massachusetts Drought Management Plan (the Plan) was first developed.	2022
Earthquakes	Seismic Site Class Map	Research by Marshall Pontrelli, Stephen B. Mabee and William P. Clement	Soil classification map used with Hazus 6.0	2023
Flooding from Precipitation	FEMA 100-year Flood Plain	FEMA	The National Flood Hazard Layer (NFHL) dataset represents the current effective flood risk data for those parts of the country where maps have been	2012

Hazard	Name	Source Organization	Description	Year Published or Updated
			modernized by the Federal Emergency Management Agency (FEMA).	
Flooding from Precipitation	Massachusetts Dams	MassGIS	The Massachusetts Dams data layer contains points derived from a dam safety database maintained by the Massachusetts Office of Dam Safety (ODS).	2017
Hurricanes/Tropical Cyclones	Sea, Lake and Overland Surges from Hurricanes (SLOSH) model	NOAA	Estimates storm surge heights resulting from historical, hypothetical, or predicted hurricanes based on atmospheric pressure, size, forward speed, and track data. Used the Maximum of Maximum Enveleope of Water (MOM) flavor of SLOSH model for this analysis.	2021
Invasive Species	Early Detection and Distribution Mapping System	University of Georgia Center for Invasive Species and Ecosystem Health	Website that tracks user reports of locations of invasive species.	2023
Landslides/Mudflows	Slope Stability	UMass Amherst	A map showing the location of areas where slope movements have occurred or may possibly occur in the future under the right conditions of prolonged antecedent moisture and high intensity rainfall	2013
Other Severe Weather	Wind zones	American Society of Civil Engineers	ASCE/SEI 7-22 Risk Category IV wind loads. Georeferenced from an image of the data by Michael Enko	2022

Hazard	Name	Source Organization	Description	Year Published or Updated
Other Severe Weather	Stochastic Weather Generator	EEA, from Cornell University	Projections of temperature and precipitation variables, for four future eras (2030, 2050, 2070, and 2090) for the 10th, 90th, and median percentile results from among 20 Global Climate Models (GCMs) for the Representative Concentration Pathway (RCP) 8.5 scenario.	2021
Severe Winter Storms	High Snow Areas	Northeast States Emergency Consortium	As part of a study funded by the FEMA Hazard Mitigation Grant Program, in 2010 the Northeast States Emergency Consortium developed regional hazard maps for snowfall for the Northeast. Using their GIS data, a map was created to show which areas experience high snow levels (defined as greater than 5 inches) with a given frequency.	2010
Tornadoes	Tornado touchdowns	NOAA's NWS Storm Prediction Center	1950-2021 tornado touchdowns	2022
Tsunamis	Tsunami Inundation zone	NESEC using data from the University of Delaware	Simulated tsunami inundation zones.	2020
Wildfires	Wildfire Hazard Potential	Northeast-Midwest State Foresters Alliance	An index that quantifies the relative potential for wildfire that may be difficult to control. Can be used as a measure to help prioritize where fuel treatments may be needed.	2022

Hazard	Name	Source Organization	Description	Year Published or Updated
Wildfires	Conditional Risk to Potential Structures	Northeast-Midwest State Foresters Alliance	Potential consequences of fire to a home at a given location, if a fire occurs there and if a home were located there. It is a measure that integrates wildfire intensity with generalized consequences to a home on every pixel but doesn't account for the actual probability of fire occurrence.	2022
Wildfires	Wildland Urban Interface	University of Wisconsin-Madison Silvis Lab	The Wildland-Urban Interface (WUI) is the area where houses meet or intermingle with undeveloped wildland vegetation. Used the 2020 WUI shape.	2020

4.2 Description of methodology

We used two primary methodologies to assess locations and populations at risk from each hazard: overlay analysis and Hazus modeling. Overlay analysis requires generating geospatial datasets of the anticipated hazard extent. The methods to construct these datasets vary by hazard. Hazus is a modeling software developed by FEMA that is used to project the expected costs of various hazards, given key input files. We use Hazus to assess the risks from earthquakes, flooding from precipitation, and hurricanes. Below, we provide a compilation of methodologies used in each hazard chapter. Note, we conducted a literature review for groundwater and invasive species in lieu of data analysis, as comprehensive data for the Commonwealth was not available. For drought, we also conducted a literature review and generated figures based on existing data.

Coastal Erosion

To evaluate exposure to impacts from coastal erosion, we identified whether state-owned assets and critical facilities were located fifty feet from the shoreline, and whether critical assets were located 50 ft from the shoreline. We then found projected cost of replacing these assets based on the replacement value in the DCAMM survey of state-owned assets. In maps using shoreline transect rate of erosion, we omitted transects that had an uncertainty range larger than the rate of erosion.

Coastal Flooding

Current and future flood depths were derived from the MassGIS Q3 Flood Zones covering the entire coast of Massachusetts at a 2-meter grid resolution for six extreme flooding events: 5 percent annual chance (20-year return period), 2 percent annual chance (50-year), 1 percent annual chance (100-year), 0.5 percent annual chance (200-year), 0.2 percent annual chance (500-year), and 0.1 percent annual chance (1,000-year). Coastal flood damages to buildings from these events were estimated using differentiated depth-damage functions by residential, industrial, and commercial categories; estimated property values from readily available sources (noted below); and relevant building characteristics for residential, industrial, and commercial structures.

Economic vulnerability of properties to coastal flooding was assessed using a customized variant of the National Coastal Property model (Neumann et al., 2021). The model incorporates site- and property-class specific U.S. Army Corps of Engineers and FEMA compiled depth-damage functions, and an inventory of structure value from a database of assessed value. The model incorporates public assessment data on structure value at a 150-meter by 150-meter grid resolution, which is updated with 2017 Zillow adjustments at zip code level. The full version of the model considers both episodic flooding from the combined effects of storm surge, tides, and sea level rise; and the possibility of property inundation as a result of gradual sea level rise. To better match the format of the MC-FRM outputs, only the former component of the model was applied here. Additional details are in the cited studies.

Note: The MC-FRM does not currently provide estimates for 2090. Estimates based on flood risk from MC-FRM and loss estimation methods from Neumann et al. (2021), see text for details. Annual expected flood damage to coastal properties in millions from sea level rise and changes in coastal storms. This includes impacts on residential, commercial, and industrial properties. Future impacts presented for four time periods identified in the table by their central year: 2030 (near-term, 2020-2039); 2050 (mid-century, 2040-2059); and 2070 (mid-late century, 2060-2079). Values may not sum due to rounding.

Earthquakes

The assessment team conducted an exposure and vulnerability earthquake analysis using Hazus 6.0, FEMA's risk modeling software, which has improved long-term seismic hazard model data, updated US Census data, and updated structural valuation data to provide better damage estimates compared to previous versions.

The Hazus analysis also incorporates the updated seismic site classification map. This map was developed in 2023 based on the state's surficial geology map, and calculations that consider the average overburden velocity, depth to bedrock, and bedrock velocity (Pontrelli et al., 2023). This updated soil characterization map improves upon previous versions by incorporating better geologic data, especially shear wave velocity and depth to bedrock; this improved soils map is used in the Hazus analysis that generated the exposure and vulnerability results for each county in the Commonwealth.

To estimate the earthquake damage that could occur in Massachusetts, a probabilistic Level 2 analysis was conducted in Hazus. The 100-, 500-, 1,000-, and 2,500-year MRP events based on USGS probabilistic seismic hazard maps. The results of this analysis demonstrate which counties in Massachusetts may experience greater damages from these modelled events. Earthquake vulnerability varies due to local conditions; criteria such as geology, population, land use, and infrastructure which are incorporated in the Hazus analysis. Additional localized impacts in liquefaction-susceptible areas are not considered in the Hazus analysis, and damages in these areas would likely be greater than our estimates show.

Hazus estimates the economic loss associated with each earthquake return period assessed, which includes building and lifeline-related losses (transportation and utility losses) based on the available inventory (facility [or GIS point] data only). Given that Massachusetts, especially Greater Boston, is a national economic, financial, and transportation hub, any local impacts could have cascading consequences throughout New England, as well as the country.

Direct building-related loss estimates include the costs to repair or replace the damage caused to a building, as well as business interruption losses associated with the inability to operate a business because of damage sustained in an earthquake. Business interruption losses also include the temporary living expenses of those people displaced from their homes because of the earthquake. Hazus considers these as capital stock losses (structural damage, non-structural damage, contents damage, inventory loss) as well as income losses (relocation loss, capital related loss, wages losses, and rental income loss).

Hazus estimates the number of people that may be injured or killed by an earthquake depending on the time of day the event occurs. Estimates are provided for three times of day representing periods when different sectors of the community are at their peak: peak residential occupancy at 2:00 a.m.; peak educational, commercial, and industrial occupancy at 2:00 p.m.; and peak commuter traffic at 5:00 p.m.

The number of people requiring temporary shelter is generally less than the number displaced, as some who are displaced use hotels or stay with family or friends following a disaster event. Impacts on people and households in the planning area were estimated for the 100-, 500-, 1,000-, and 2,500-year MRP earthquakes through the probabilistic Hazus analysis. Shelter estimates from Hazus are intended for general planning purposes and should not be assumed to be exact. It should also be noted that, in Massachusetts, the season in which an earthquake occurs could significantly impact the number of residents requiring shelter. For example, if an earthquake occurred during a winter weather event, more people might need shelter if utility infrastructure damage resulted in a loss of heat in their homes. These numbers should be considered as general, year-round average estimates. Depending on the level of damage, some residents may be permanently displaced from their homes, requiring long-term housing replacement after an earthquake. This is a particularly challenging problem due to the high cost of living in Massachusetts, and especially in Boston. Ensuring earthquake-resilient design in new residential developments and infrastructure will help mitigate the need for long-term housing replacement.

Flooding from Precipitation

To estimate the population exposed to the 1 percent and 0.2 percent annual chance flood events, flood hazard boundaries were overlaid on the 2020 U.S. Census block population data. Because census blocks do not follow the boundaries of the floodplain, the portion of the census block within the floodplain was used to approximate the population contained. Specifically, this portion is the area of the intersection of the flood zones and the block groups for census population data. For example, if 50 percent of a census block of 1,000 people was located within a floodplain, the estimated population exposed to the hazard would be 500.

The underlying data considers flooding for return intervals of two years (an event with a 50 percent chance of occurring each year) through 500 years (an event with a 0.2 percent chance of occurring each year). Study authors calculate a damage function known as a "frequency-loss curve" – which expresses structural damage for each type of flood event – for each property. From this curve the EAD can be calculated. Data are not reported at the property level but are available at the block group level. The data do not address flooding events associated with poor or inadequate drainage, quantifying only riverine floods. As a result, the quantified results in this impact category are limited to riverine floods, and other types of flooding events such as stormwater drainage flooding in urban areas, in particular, are considered qualitatively.

The methodology estimates the baseline annual EAD using current structure characteristics (e.g., ground level floor elevation, replacement cost, market value), the flood depths associated with baseline conditions for varying return periods, and depth-damage functions available from FEMA's Hazus documentation (FEMA, 2022; First Street Foundation, 2020; Wobus et al., 2021). Impacts are projected under a "no additional adaptation" scenario.

Overlay analysis was also used to identify solar panels within the FEMA 100-year floodplain. This used the Solar Photovoltaic Report (as of February 2022); and a GIS file developed by Clark University professor John Rogan that documents the physical outlines of solar installations in the Commonwealth. Note that the method is based on flooding at ground level, not at the level of the solar panel installation. The assessment of at risk assumes that ground level flooding can damage the ground level components of the installation, such as connections to the grid.

Populations potentially at risk were examined near 128 High Hazard Potential (Class 1) dams for which location and other information is available through Mass GIS (2012). The extent of the exposure due to a dam breach was estimated based on a sample of five High Hazard dam Emergency Action Plans which were publicly available and included a summary of dam breach flood risk modeling.

The impacts of dam failures are calculated by estimating baseline economic costs of repair and replacement of dams, and an estimate of the likelihood of a damaging dam failure, adjusted for the economic value of surrounding homes and infrastructure. Estimates of the probability of future flood events and damages from those events are used to calculate damages associated with dam overtopping and failure projected into the future, which are compared to the baseline economic costs.

Historical records from the Stanford National Performance of Dams Program (NPDP) and the Association of State Dam Safety Officials' Dam Incident Database (DID) are used to guide reasonable assumptions about the engineering standards that could apply to the set of dams analyzed here to estimate the future likelihood of dam overtopping and breach events. Impacts are analyzed for 1,075 high and significant hazard dams, as identified by DCR. Site-analyses for flood damage, which in many instances have been conducted for Massachusetts dams, are not publicly available for a comprehensive sample of Commonwealth dams. This analysis instead uses a downscaled version of projected streamflow results of the Hydrologic and Water Quality System, as outlined in Fant et al. (2017) to simulate future hydrologic conditions at each dam site and assess the frequency of potential dam failure modes (Fant et al., 2017).

Economic impacts representing flood damages to nearby buildings and infrastructure are based on four elements of data for each dam site: (1) an average estimated area of influence for flooding associated with an overtopping event; (2) the average county level building value per acre in the area surrounding each dam in Massachusetts; (3) standard U.S. Army Corps of Engineers depth damage functions for Massachusetts that are used to estimate building damages associated with a certain freshwater flood height, and (4) estimates of the cost of dam repairs necessary after an overtopping or breach event. Dams may fail for reasons other than high precipitation or river flow events, such as poor maintenance and construction. However, according to the broader dam event databases examined in this analysis, high flow events tend to be triggering events which reveal or exacerbate underlying maintenance and construction deficiencies.

Estimates of the cost of dam repairs necessary after an overtopping or breach event are developed based on NPDP and DID reports of dam safety incidents, characteristics, and estimated economic damage. Fifty-six and five incidents were reported in the NPDP and DID databases, respectively, from Massachusetts. Incidents recorded occurred between 1848 and 2015, with a majority occurring before the year 2000. Only two incidents in DID have occurred since Office of Dam Safety regulation (302 CMR 10: Dam safety) came into effect in 2017. The DID does not have estimates of economic damages, and only one entry from the NPDP had an economic damage estimate of one million dollars.

Hurricanes

An analysis of several storm surge inundation scenarios was conducted using the “maximum of maximums” outputs of the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model. These represent the worst-case storm surge scenarios for each hurricane category (Categories 1 through 4). To assess the Commonwealth’s exposure to storm surge from hurricanes and tropical storms, a spatial analysis was conducted using the SLOSH inundation layers intersected with updated population, facilities, and habitat datasets. It is important to note that the SLOSH model does not incorporate any future estimates of sea level rise and cannot be used to estimate exposure to inland flooding.

This SLOSH analysis assumes that if any portion of the block group is inundated by storm surge, the entire population of the block group may be affected. Similarly, the environmental justice (EJ) populations data reported are the total number of people living in an EJ-designated community.

To assess the broader exposure of government facilities to the surge inundation from a hurricane event, the digital SLOSH zones were overlaid upon the state facility data. A dollar value of these resources comes from the replacement value, as reported by DCAMM. Any state assets that serve as lifelines to the community will also have additional impacts that are not as easily quantified with a dollar value.

The Risk Assessment team also assessed the exposure to critical facilities and natural habitats, using the SLOSH zone inundation through four hurricane categories by facility type and county, respectively. The locations of critical facilities are provided by DCAMM. For natural habitats, we use the exposure of Core Habitat and Critical Natural Landscape areas, as defined by MassWildlife and The Nature Conservancy's BioMap3, to hurricane storm surge inundation. The "percent total" refers to the number of acres exposed to the SLOSH zone compared to the total acres of the habitat or landscape type within the coastal counties included in this analysis.

To supplement the SLOSH model, additional hurricane analysis was conducted using FEMA's Hazus hurricane risk modeling software. The Hazus Hurricane Model estimates damages from peak wind gusts under several probabilistic scenarios for all counties in the Commonwealth. The Risk Assessment team used this analysis to estimate displaced households and building-related economic losses.

The Hazus hurricane model estimates direct economic losses to buildings that could be expected from hurricane winds over a range of probabilistic scenarios. This includes capital stock losses (building damage, contents damage, inventory loss) as well as income losses (relocation loss, capital related loss, wages loss, and rental income loss).

Landslides

To assess the exposure of the state-owned facilities identified by DCAMM and the Office of Leasing, an analysis was conducted with the approximate landslide hazard areas. Using GIS software, the Slope Stability Map was overlaid with state-owned facilities data.

Other severe weather:

Using data analysis of Global Climate Models, downscaled using the Localized Constructed Analog (LOCA) approach, extreme precipitation event intensity is also expected to increase across the state (Pierce et al., 2014).

Using ArcMap GIS software, the wind zones for Risk Category IV were overlaid with the 2022 DCAMM facility data; the appropriate wind load zone determination was assigned to each DCAMM facility. Risk category IV buildings are designated as essential facilities, including emergency preparedness, communications and operations centers, designated emergency shelters, buildings with critical national defense functions, water storage facilities, air traffic control centers and occupancies with emergency or surgery treatment facilities. Not all government buildings are likely to be classified as risk category IV. However, some facilities will perform one or more of the category IV functions.

Winter storms

Using the Northeast States Emergency Consortium data of high snow areas, the map below was created to show how many days each area experiences high snow levels (defined as greater than five inches). The data were overlaid with the DCAMM facility data, to identify state assets and critical facilities in high-snow areas. The total replacement value is calculated from DCAMM facility data. A surge inundation zone does not exist to estimate the number of government facilities exposed to this severe winter storm risk. However, the storm surge areas generated by SLOSH provide a useful proxy; we show the buildings exposed to storm surge by both hurricanes and nor'easters in SLOSH zones by county.

Temperature

Geospatial data analysis was used to produce historical summaries and to process global climate forecasts. To generate historical county-level or state-level temperature records, gridded daily historical temperature observations from GridMET were used. This is a daily historical dataset that uses satellite and weather station observations (Abatzoglou, 2013). Daily weather station records from the National Oceanographic and Atmospheric Association (NOAA)'s Global Historical Climatological Network were also used for the analysis (Menne et al., 2012).

To project the impacts of future climate change, the team relied on two sources: A Stochastic Weather Generator (SWG) developed using methods from a team at Cornell University (Steinschneider et al., 2019), and downscaled daily climate projections from the Coupled Model Intercomparison Project Phase 6 (CMIP6) produced by the National Air and Space Administration (Thrasher et al., 2022). The area-weighted average of basin-level estimates from SWG or grid-level estimates from CMIP6 is used to generate state-wide averages. SWG is the preferred source of long-range climate forecasts and was developed for the 2022 Massachusetts Climate Change Assessment (MA Climate Assessment). However, SWG does not include some variables (such as daily temperature forecasts) – CMIP6 is used for these. CMIP6 estimates are the most current climate projections from the global climate scientific community but may still contain biases or errors relative to the local climate in Massachusetts. CMIP6 forecasts are from the high-emissions scenario SSP 5-8.5; while not exactly comparable to an emissions scenario from SWG, this is most similar to the RCP 8.5 scenario used throughout the MA Climate Assessment.

Overlay analysis was used to identify critical transportation infrastructure (including rail and predominant highways) that overlay with high land surface temperature regions.

Tornadoes

To analyze how tornadoes could impact state facilities, DCAMM data were overlaid with zones of historic tornado tensity.

Tsunami

All elements of the built environment within the tsunami inundation zones are at risk from a tsunami event. Assets such as hospitals, elder care facilities, prisons, animal care facilities, and schools are most vulnerable during a tsunami as they require special level of care and coordination. To analyze how tsunamis could impact state facilities, the tsunami inundation zones were overlaid with the state-owned critical facilities.

Wildfire:

To analyze how wildfire may impact state facilities, we identify the number of state-owned buildings located in wildfire hazard areas within each county and provides the total replacement value according to the Division of Capital Asset Management and Maintenance (DCAMM). This figure assumes 100 percent loss to each structure and its contents. This estimate is considered high because structure and content losses generally do not occur to the entire inventory exposed.

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Appendix 5.C:
Detailed Risk Assessment and Hazard Analysis for 15 Hazards Assessed in the 2023 MA SHMCAP

Chapter 5. Risk Assessment and Hazard Analysis

Average/Extreme Temperatures

Contents

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5.2 Average/Extreme Temperatures

5.2.1 Average/Extreme Temperatures Problem Statement

Average and extreme temperatures can affect the entire Commonwealth; however, extreme temperature events occur more often and with greater severity inland, especially in urban settings where the urban heat island (UHI) effect can amplify temperatures. UHIs disproportionately affect underrepresented races and ethnicities, low-income populations, and linguistically isolated populations.

Extreme temperatures are the leading cause of weather-related mortality in the U.S. In Massachusetts, studies find that 19 annual premature deaths could be attributed to extreme temperatures. Climate change could lead to an additional 400 annual premature deaths by the end of the century if no adaptation action is taken. People with certain health conditions (such as asthma and heart disease) are at higher risk of heat-related health impacts. Extreme temperatures also have mental health impacts, including increasing the risk of suicide and decreasing students' ability to learn.

Rising average temperatures have severe consequences for the natural environment throughout the Commonwealth. Warmer waters in typically cold-water, coastal wetland and marine ecosystems and warmer surface temperatures in terrestrial ecosystems (particularly boreal forests) have already led to changes in the range and behaviors of key native species. As the climate warms, the severity of these impacts is expected to increase.

Extreme temperatures also affect other state assets and critical facilities. Existing stormwater drainage systems may be undersized to safely convey greater rainfall intensity associated with extreme temperature away from roads and highways. Extreme temperatures can degrade materials for roads, rails, bridges, and airports, and are projected to increase annual maintenance costs of transportation infrastructure by over $140 million by the end of the century.

5.2.2 Average/Extreme Temperatures Risk Assessment

5.2.2.1 General Background

There is no universal definition of "extreme heat," "extreme cold," or "extreme temperatures": these terms are relative terms whose meaning depends on the normal average temperatures and climatic highs and lows in a region.

- Extreme heat can be defined as a period of excessively hot weather—usually defined as a daily high temperature above 90 degrees Fahrenheit (°F) in Massachusetts—which may be accompanied by high humidity.
- Extreme cold is defined as a period of excessively low temperatures, especially with additional wind chill. In Boston, the National Weather Service (NWS) issues a wind chill advisory when the Wind Chill Temperature index (defined below in Figure 5.2-1) drops below −15°F.
- Extreme temperatures can be defined as those that are far outside the normal seasonal ranges for Massachusetts. The average highs and lows of the hottest and coolest months in Massachusetts are provided in Table 5.2-1.

Table 5.2-1. Annual Average High and Low Temperatures in Massachusetts

	July (Hottest Month)	January (Coldest Month)
Average high (°F)	81.5°	34.3°
Average low (°F)	61.1°	16.9°

Source: Average 2000–2020 daily gridded temperature records from GridMET.

Methodology

Geospatial data analysis was used to produce historical summaries and to process global climate forecasts. To generate historical county-level or state-level temperature records, the Risk Assessment team used gridded daily historical temperature observations from GridMET. This daily historical data set uses satellite and weather station observations (Abatzoglou, 2013). Daily weather station records from the National Oceanographic and Atmospheric Association's (NOAA's) Global Historical Climatological Network were also used for the analysis (Menne et al., 2012).

To project the impacts of future climate change, the team relied on two sources: a Stochastic Weather Generator (SWG) developed using methods from a team at Cornell University (Steinschneider et al., 2019) and downscaled daily climate projections from the Coupled Model Intercomparison Project Phase 6 (CMIP6) produced by the National Air and Space Administration (Thrasher et al., 2022). The area-weighted average of basin-level estimates from SWG or grid-level estimates from CMIP6 is used to generate statewide averages. SWG is the preferred source of long-range climate forecasts and was developed for the 2022 Massachusetts Climate Change Assessment (MA Climate Assessment). However, SWG does not include some variables (such as daily temperature forecasts)—CMIP6 is used for these. CMIP6 estimates are the most current climate projections from the global climate scientific community, though they may still contain biases or errors relative to the local climate in Massachusetts. CMIP6 forecasts are from the high-emissions scenario SSP 5-8.5; while not exactly comparable to an emissions scenario from

SWG, this is most similar to the RCP 8.5 scenario used throughout the MA Climate Assessment.

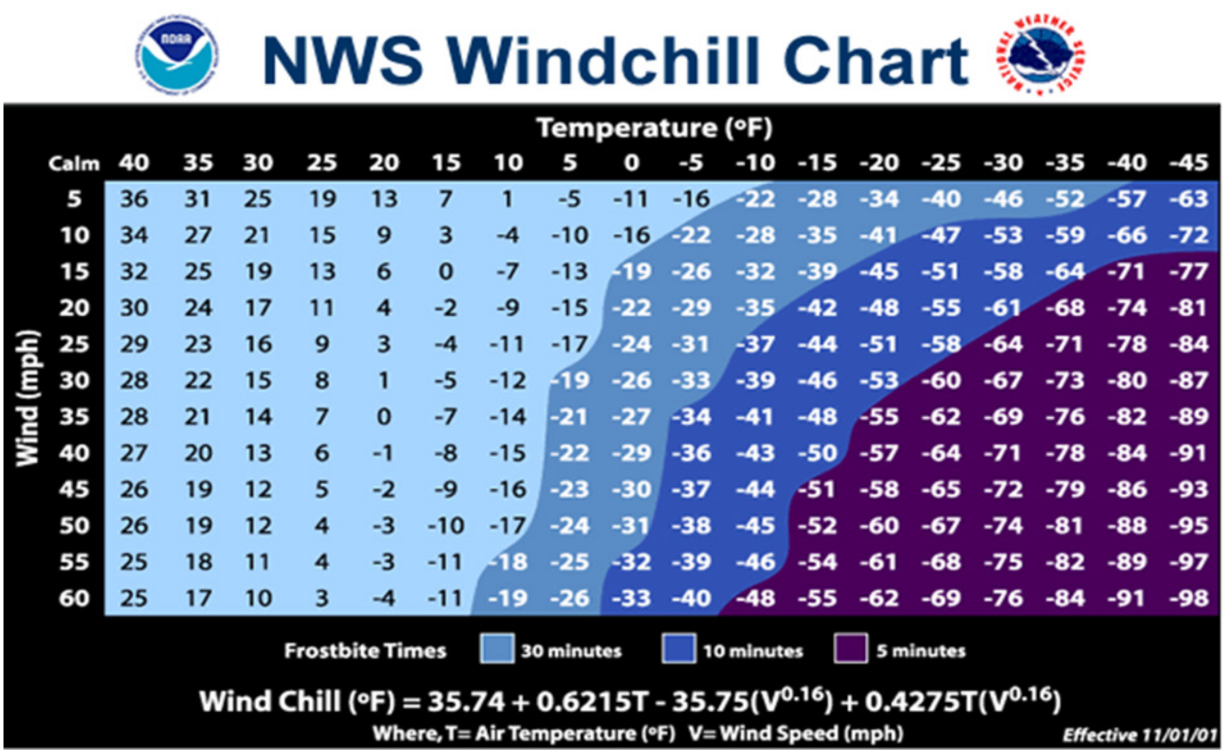
5.2.2.2 Hazard Description

Average/Extreme Temperatures includes extreme cold, extreme heat, and the change over time of average temperatures experienced throughout the year in Massachusetts. While much of the risk is associated with changes to the extremes, changes in average temperatures can impact growing seasons, native species, and resource demands.

Extreme Cold

The extent (severity or magnitude) of extreme cold temperatures is generally measured in terms of wind chill temperature: the temperature that people and animals feel outside, based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body loses heat at a faster rate, causing the skin's temperature to drop.

On November 1, 2001, NWS implemented a Wind Chill Temperature index designed to more accurately calculate how cold air feels on human skin. NWS issues a Wind Chill Advisory if this index is forecast to dip to −15°F to −24°F for at least three hours, based on sustained winds, and a Wind Chill Warning if the index is forecast to fall to −25°F or colder for at least three hours (NWS, n.d.-b). Figure 5.2-1 shows the Wind Chill Temperature Index.



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

Source: NWS (2001).

Figure 5.2-1. Wind Chill Temperature index and frostbite risk.

Extreme cold is dangerous and can result in health emergencies for susceptible people, such as those who are without shelter, are stranded, or live in homes that are poorly insulated or without heat. Extended exposure to low temperatures can cause frostbite or hypothermia and can even lead to death in particularly severe cases.

When winter temperatures drop significantly below normal, staying warm and safe can become a challenge. Extremely cold temperatures often accompany winter storms, which may also disrupt infrastructure and utilities, such as power failures and icy roads. During cold months, carbon monoxide may be high in some areas because the colder weather makes it difficult for car emission control systems to operate effectively, and temperature inversions can trap the resulting pollutants closer to the ground. Another hazard of extended cold temperatures in Massachusetts is saltwater freezing in coastal bays and harbors. Coastal freezing can interfere with ports and other water transportation and can also inhibit fishing and other maritime industries.

Staying indoors as much as possible can help reduce many of the risks associated with extreme temperatures, but cold weather also can present hazards indoors. Many homes will be too cold, due to a power failure, substandard construction or maintenance, or lack of a working (or adequate) heating system. Exposure to cold temperatures, whether indoors or outside, can cause other serious or life-threatening health problems. Power outages may also result in inappropriate use of combustion heaters, cooking appliances, and generators in poorly ventilated areas, leading to increased risk of carbon monoxide poisoning, explosions, and/or fires.

Extreme Heat

NWS issues a Heat Advisory when heat indices are between 95°F and 99°F for two or more hours over two consecutive days, or 100°F–104°F for two or more hours over one day; it issues an Excessive Heat Warning if the heat index is forecast to reach or exceed 105°F for two or more hours (NWS, n.d.-b). The NWS heat index is based on temperature and relative humidity and describes a temperature equivalent to what a person would feel at a baseline humidity level. The relationship between these variables and the levels at which NWS considers various health hazards to become relevant are shown in Figure 5.2-2. Heat index values are devised for shady and light wind conditions. Exposure to full sunshine can increase heat index values by up to 15°F. Also, strong winds, particularly with very hot, dry air, can increase the risk of heat-related impacts.

NWS Heat Index

Temperature (°F)

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

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Source: NWS (n.d.-a).

Figure 5.2-2. Heat index.

The Commonwealth of Massachusetts defines a heat wave as three or more consecutive days of temperatures of 90°F or above. A heat wave is an extended period of unusually high atmosphere-related heat stress, which causes temporary modifications in lifestyle, outdoor work and other activities, and which may have adverse health consequences for the affected population.

Extreme heat is dangerous for human health, particularly for those without shelter, those without air conditioning, occupations that require outdoor work, and those with underlying health risks such as asthma or heart disease. Extreme heat can lead to dehydration, heat exhaustion, or heat stroke, and even death in particularly severe cases. Heat waves cause more fatalities in the U.S. than the total of all other meteorological events combined. Between 600 and 1,300 Americans die from heat-related ailments every year (U.S. EPA, 2021).

Heat impacts can be particularly significant in urban areas. Over 91 percent of the Massachusetts population lives in urban areas (U.S. Census Bureau, 2022). As these areas develop and change, so does the landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and able to absorb and retain water are now impermeable and dry. Dark-colored asphalt and roofs also absorb more of the sun's energy than vegetated areas, trees, and lighter-colored surfaces. These changes cause urban areas to become warmer than the surrounding areas. This forms "islands" of higher temperatures—the UHIs mentioned earlier in this section.

A UHI is an urbanized area that, due to the density, land uses, and ground conditions, is hotter than nearby rural, natural, vegetated, or shaded areas. A city with more than 1 million people can be 1.8°F to 5.4°F warmer, in terms of annual mean air temperature, than its surrounding areas. In the evening, the difference in air temperatures can be as high as 22°F. The difference in temperatures can be even more dramatic for exposed surfaces. On a sunny day with air temperatures above 95°F, the sun can heat roof materials to temperatures as high as 60°F hotter than the air (U.S. EPA, 2022). Section 5.2.2.4.1 below includes details on factors contributing to the UHI effect.

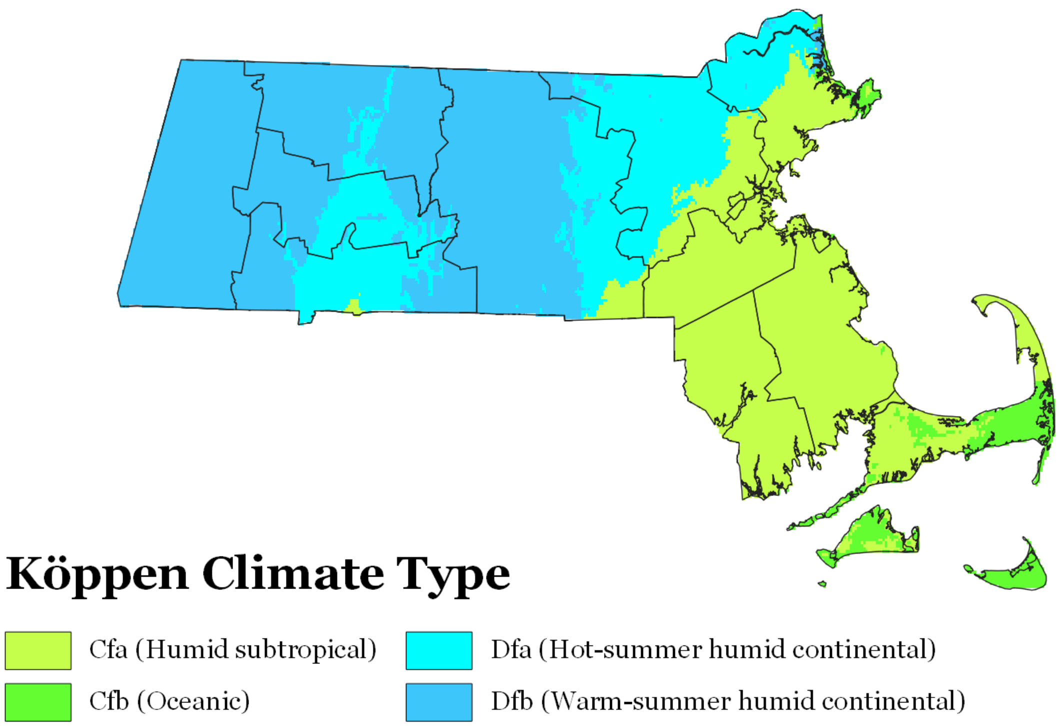
Extreme heat events can also affect air quality. High temperatures can increase the formation of ozone from volatile organic compounds and other aerosols. Weather patterns that bring high temperatures can also transport airborne particulate matter from other areas of the continent. Additionally, atmospheric inversions and low wind speeds allow polluted air to remain in one place for a prolonged period (Schnell & Prather, 2017). This can exacerbate health impacts of UHIs, as many of them are also home to high traffic that can lead to increased ozone and particulate matter during inversions.

Potential Effects of Climate Change on Average/Extreme Temperatures

Climate change has already change average and extreme temperatures in Massachusetts. Described in much more detail below, climate change is projected to reduce the number of extreme cold events, increase the number of extreme heat events, and shift the average temperature in the Commonwealth higher and shift the seasons the warm seasons forward and lengthen their duration. The effects of these changes, also described in more detail in this section, will include changes in growing seasons and crops, shifts in habitat and vegetation, warming surface waters, degradation of air quality, impacts on public health, and increased demand for energy and water resources. Risks such as wildfire, drought, flooding, and invasive species are also projected to increase as Massachusetts becomes warmer throughout the year, precipitation falls as rain rather than snow, and extreme heat events increase.

5.2.2.2.1 Location

Average temperature varies across Massachusetts, with annual averages generally higher in coastal regions and Greater Boston. The Islands and Cape Cod have the highest average winter temperatures, but experience more moderate summer temperatures. Greater Boston experiences higher summer temperatures. Central and western Massachusetts has lower average winter and summer temperatures. Massachusetts has regions with four Köppen climate types (a classification of the average expected temperature range), as shown in Figure 5.2-3. Much of inland Massachusetts, including the cities of Springfield and Worcester, is classified as continental: at least one month averaging below 32ºF and one month averaging above 50ºF. The coastal region is classified as temperate: between 32ºF and 50ºF in the coldest month and at least one month averaging above 50ºF.



Source: 1991–2020 climate normal from PRISM group at Oregon State University (PRISM Climate Group, 2020).

Figure 5.2-3. Climate types in Massachusetts.

Extreme temperature events (both extreme heat and extreme cold) occur more often and vary more in the inland regions, where temperatures are not moderated by the Atlantic Ocean. Due to the UHI effect, extreme heat impacts are more severe in densely developed urban areas like Boston, Worcester, or Springfield than in suburban and rural areas.

5.2.2.2.2 Previous Occurrences and Frequency

Previous Occurences

Since 1995, there have been 120 cold weather events within the Commonwealth, ranging from cold/wind chill to extreme cold/wind chill events (NOAA, 2022c).

In the past several years, extreme cold events have continued to break records throughout the state. A cold blast in February 2023 resulted in record cold across the state, including the coldest February 3rd on record in Boston and Worcester. In an arctic blast in January 2018, Boston experienced seven days below 20°F, tying a 1918 record for the longest time at or below 20°F. The 2018 Boston Marathon was the coldest recorded since the marathon began in 1897. A January 2019 winter storm broke daily cold records throughout the state, including one of the 10 lowest temperatures recorded in Worcester. A more comprehensive list of historic cold weather events is provided in Appendix 5.A.

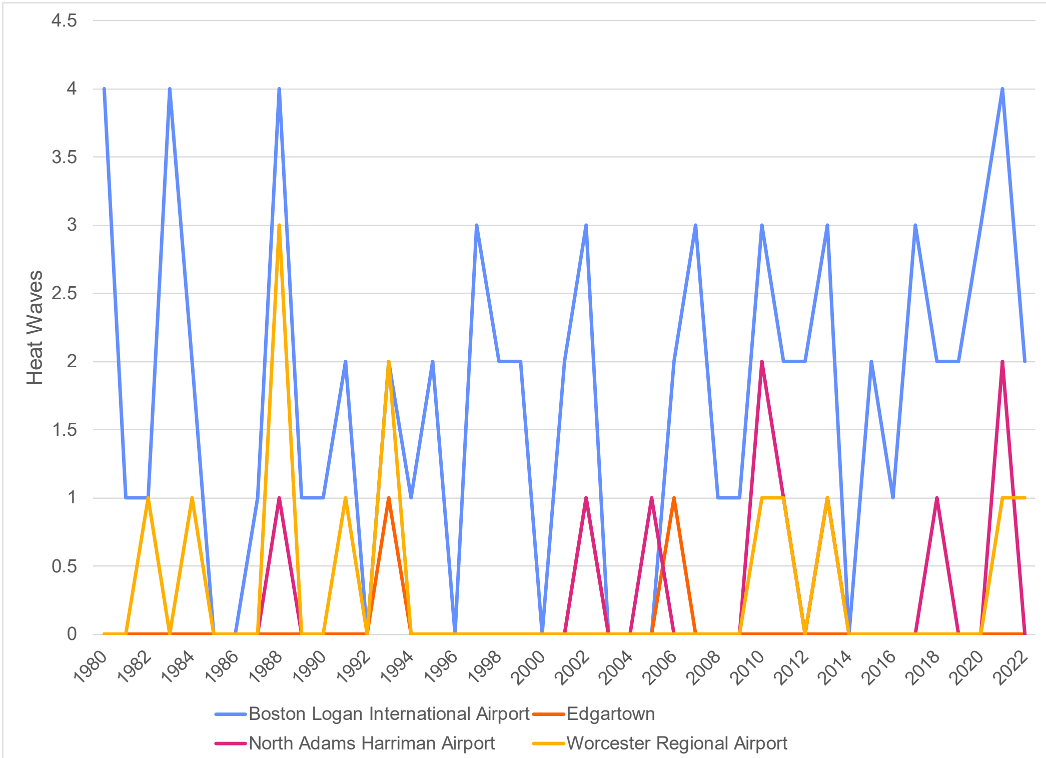
There have been 118 warm weather events (heat and excessive heat events) between 1995 and 2022 (NOAA, 2022c). In Massachusetts, 2010–2022 had seven of the 10 warmest summers on record. The hottest two summers on record for the Commonwealth were 2020 and 2022 (NOAA, 2022b). August 2022 was the hottest August recorded in the Commonwealth, with temperatures more than 6°F greater than the 20th century average. In 2022, Boston experienced at least 17 days above 90 degrees and two six-day heat waves.

In 2012, Massachusetts temperatures broke 27 heat records. Most of these records were broken between June 20 and June 22, 2012, during the first major heat wave of the summer to hit Massachusetts and the East Coast. In July 2013, a long period of hot and humid weather occurred throughout New England. One fatality occurred on July 6, when a postal worker collapsed as the heat index reached 100°F. A more comprehensive list of historic warm weather events is provided in Appendix 5.A.

Frequency of Occurrences

On average, the NOAA Storm Counter recorded three cold weather events and two extreme cold weather events annually between January 2018 and December 2022 within Massachusetts. The years 2018 and 2019 were particularly notable, with 10 cold weather events in each year, including five extreme cold/wind chill events in 2018 and six extreme cold/wind chill events in 2019.

Over this same period, the NOAA Storm Counter recorded an average of 3.6 heat events and two excessive heat events per year. Figure 5.2-4 shows the frequency of heat waves (periods of three or more consecutive 90-degree days) since 1990 recorded at weather stations throughout Massachusetts, including a range of geographic regions. Climatologists find that there are four distinct circulation patterns of heat waves in the Northeast, and two of these patterns are occurring more often due to climate change (Agel et al., 2021).



Source: NOAA (2022a).

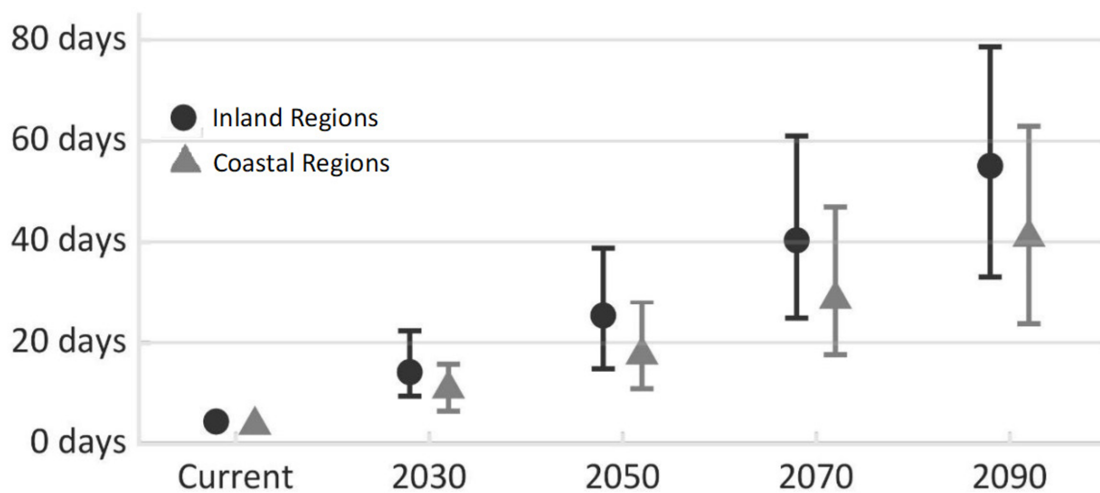
Figure 5.2-4. Historical number of heat waves throughout the Commonwealth.

There are significant long-term trends in the frequency of extreme hot and cold events. Since 2010, U.S. daily record high temperatures have occurred over 8 times as often as record lows (as compared to a nearly 1:1 ratio in the 1950s) (Climate Central, 2022). Models suggest that this ratio could climb to over 20:1 by midcentury, if greenhouse gas (GHG) emissions are not significantly reduced (Meehl et al., 2016). While many climatic phenomena determine the number of extreme weather events each year, these long-term trends are likely due to climate change. The Intergovernmental Panel on Climate Change (IPCC) finds that it is virtually certain that the frequency and intensity of heat events worldwide has increased, and that human-induced GHG forcing is the main driver of this increase (IPCC, 2021).

As the climate warms, extreme cold weather events are expected to occur less often and to be less severe. Some regions in the U.S. have experienced more frequent winter storms or extreme cold events in recent decades, although these cold waves are becoming less severe over time (van Oldenborgh et al., 2019). These trends are partially explained by warming in the Arctic (Cohen et al., 2021), and are expected to become less intense and less frequent as the Arctic warms further (Blackport et al., 2022; Gross et al., 2020). The IPCC finds that the frequency of extreme cold events is very likely to decrease in North America (IPCC, 2021).

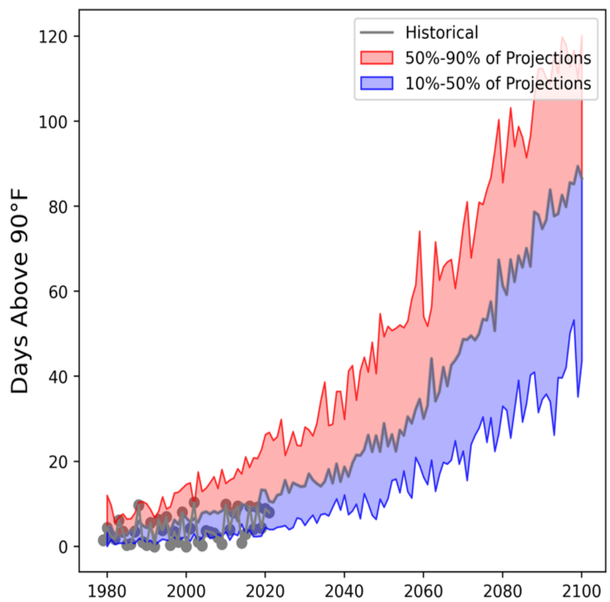
Based on these climate forecasts, the probability of future occurrence of extreme heat events is likely to increase, and the probability of future occurrences of extreme cold events is likely to decrease. Historically, extreme heat events such as heat waves occurred on average over once per year. As the climate warms and days above 90°F are virtually certain to increase, the number of heat waves is also expected to increase (IPCC, 2021). Extreme cold events also occurred multiple times per year in Massachusetts history, but due to climate change, the likelihood of extreme cold events is virtually certain to decrease toward the end of the century (IPCC, 2021).

Climate forecasts indicate increased frequency of heat events and a decreased frequency of extreme cold events. Figure 5.2-5 through Figure 5.2-7 show the projected changes in the number of days over 90°F and days below 32°F by the end of this century. By the end of the century, the number of cold days is virtually certain to decline, and the number of hot days is virtually certain to increase—all temperature projections from SWG and CMIP6 show these trends.



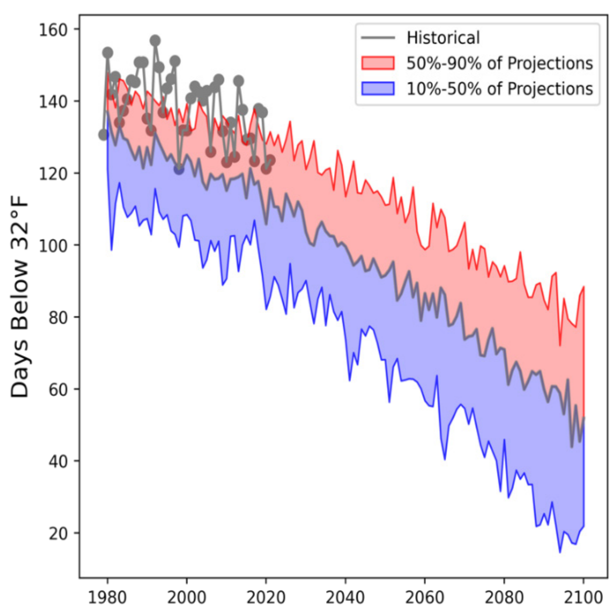
From MA Climate Assessment (Commonwealth of Massachusetts, 2022), using SWG data. Coastal region includes North and South Shore, Boston Harbor, Cape Cod, and South Coast. Inland region includes the rest of the Commonwealth.

Figure 5.2-5. Change in the number of days per year over 90°F compared to current climate.



Source: CMIP6 downscaled projections (Thrasher et al., 2022), warming scenario SSP 5-8.5, historical data from GridMET.

Figure 5.2-6. Projected annual days with temperature above 90°F.



Source: CMIP6 downscaled projections (Thrasher et al., 2022), warming scenario SSP 5-8.5, historical data from GridMET.

Figure 5.2-7. Projected annual days with temperature below 32°F.

5.2.2.2.3 Severity/Intensity

High, low, and average temperatures in Massachusetts are all virtually certain to increase over the next century due to climate change. This gradual change will put long-term stress on a variety of social and natural systems and will increase the influence of discrete events. Table 5.2-2 shows the projected statewide change in average, maximum, and minimum temperatures throughout the end of the century. While some degree of warming is expected in the entire Commonwealth, coastal regions are expected to have higher average temperatures by the end of the century. Figure 5.2-8 through Figure 5.2-11 show the locations of expected temperatures for 2030, 2050, 2070, and 2090 projections. Figure 5.2-5 and Figure 5.2-6 show the expected range of the frequency of high heat events in the Commonwealth. These increases are expected to occur throughout Massachusetts, although as Figure 5.2-5 shows, the frequency is expected to be greater in coastal regions than in inland regions.

Humidity is also projected to increase, causing hot days to feel even hotter (e.g., current hot days that feel like 81°F could feel like 91°F by 2050). The MA Climate Assessment (Commonwealth of Massachusetts, 2022) predicts that by 2050 the average summer temperature will feel like that of Maryland (average high of 94°F with about 90% humidity), and by 2090 average summer temperatures will feel like that of Georgia (average high of 95°F with 90% humidity).

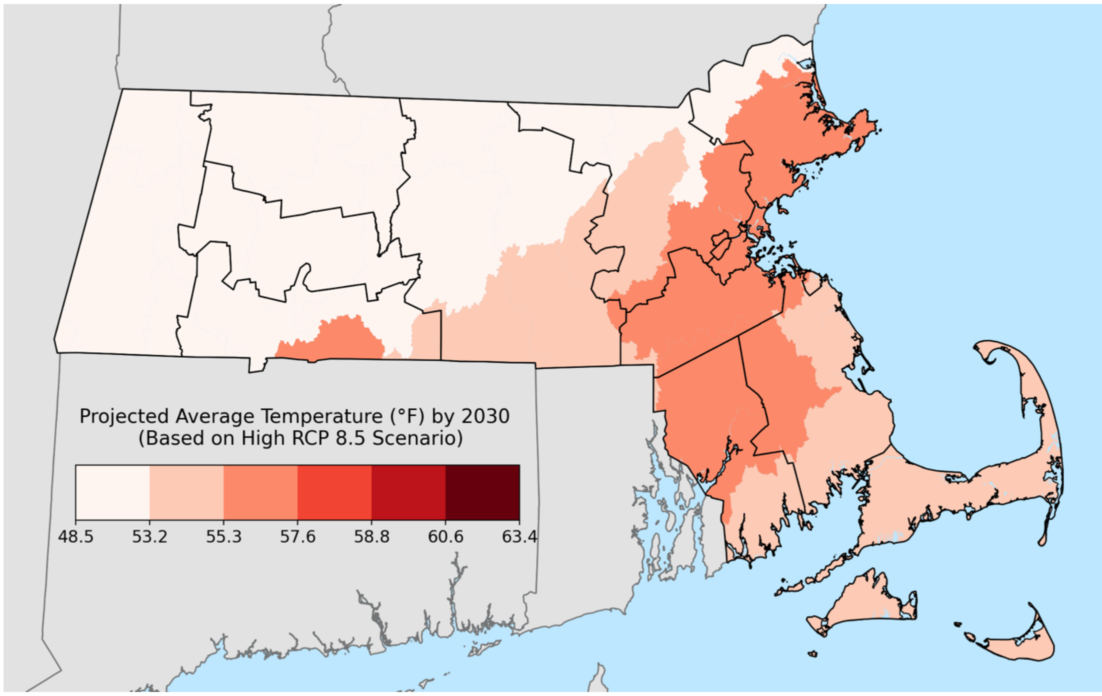
CMIP6 data provide more information on the distribution of expected temperatures. Figure 5.2-12 shows the range of annual temperature increases through the end of the century using downscaled climate projections. While there is uncertainty in the exact degree of warming, these projections universally find that average temperatures in Massachusetts will increase. Figure 5.2-13 and Figure 5.2-14 show the distribution of daily maximum and minimum temperatures from historical data, as well as median projections from CMIP6 for the 2030s (2020–2049), 2050s (2040–2069), 2070s (2060–2089), and 2090s (2080–2100). Both minimum and maximum temperatures are expected to increase, and temperatures that were once uncommonly warm (such as days above 90ºF) are expected to become more frequent.

Table 5.2-2. Projected Temperature Changes Through End of Century

Climate Indicator		Observed Value	Mid-Century	End of Century
		1985–2005 Average	Projected change in 2050s (2040–2069)	Projected change in 2090s (2080–2100)
Average temperature	Annual	48.2°F	Increase by 5.9 to 7.9°F	Increase by 10.0 to 12.9°F
	Winter	27.7°F	Increase by 6.1 to 8.2°F	Increase by 10.3 to 13.1°F
	Spring	45.4°F	Increase by 5.4 to 8.0°F	Increase by 9.2 to 12.8°F
	Summer	67.7°F	Increase by 5.9 to 7.9°F	Increase by 10.2 to 13.2°F

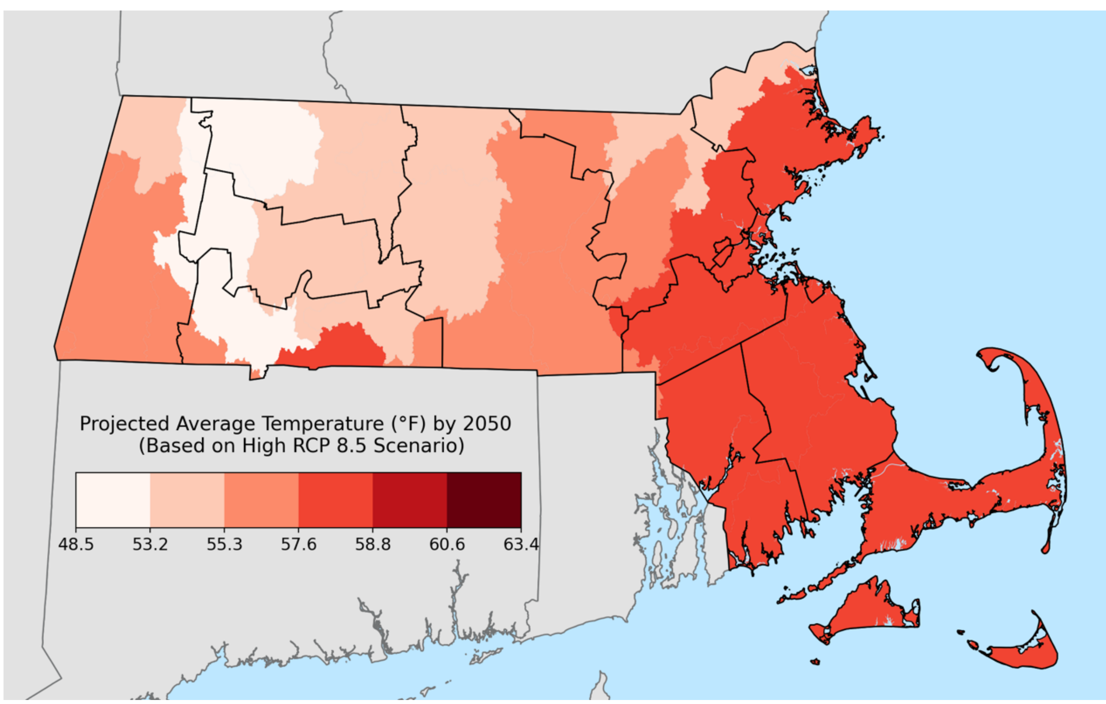
Climate Indicator		Observed Value 1985–2005 Average	Mid-Century Projected change in 2050s (2040–2069)	End of Century Projected change in 2090s (2080–2100)
	Fall	51.4°F	Increase by 5.9 to 7.2°F	Increase by 10.0 to 13.1°F
Maximum temperature	Annual	58.0°F	Increase by 5.9 to 7.9°F	Increase by 10.0 to 12.9°F
	Winter	37.0°F	Increase by 6.1 to 8.2°F	Increase by 10.3 to 13.1°F
	Spring	63.5°F	Increase by 5.4 to 8.0°F	Increase by 9.2 to 12.8°F
	Summer	78.3°F	Increase by 5.9 to 7.9°F	Increase by 10.2 to 13.2°F
	Fall	52.7°F	Increase by 5.9 to 7.2°F	Increase by 10.0 to 13.1°F
Minimum temperature	Annual	38.1°F	Increase by 5.9 to 7.9°F	Increase by 10.0 to 12.9°F
	Winter	18.6°F	Increase by 6.1 to 8.2°F	Increase by 10.3 to 13.1°F
	Spring	42.3°F	Increase by 5.4 to 8.0°F	Increase by 9.2 to 12.8°F
	Summer	57.4°F	Increase by 5.9 to 7.9°F	Increase by 10.2 to 13.2°F
	Fall	33.7°F	Increase by 5.9 to 7.2°F	Increase by 10.0 to 13.1°F

Source: SWG, from MA Climate Assessment (Commonwealth of Massachusetts, 2022). Range indicates median through 90th percentile values from RCP 8.5 climate scenario.



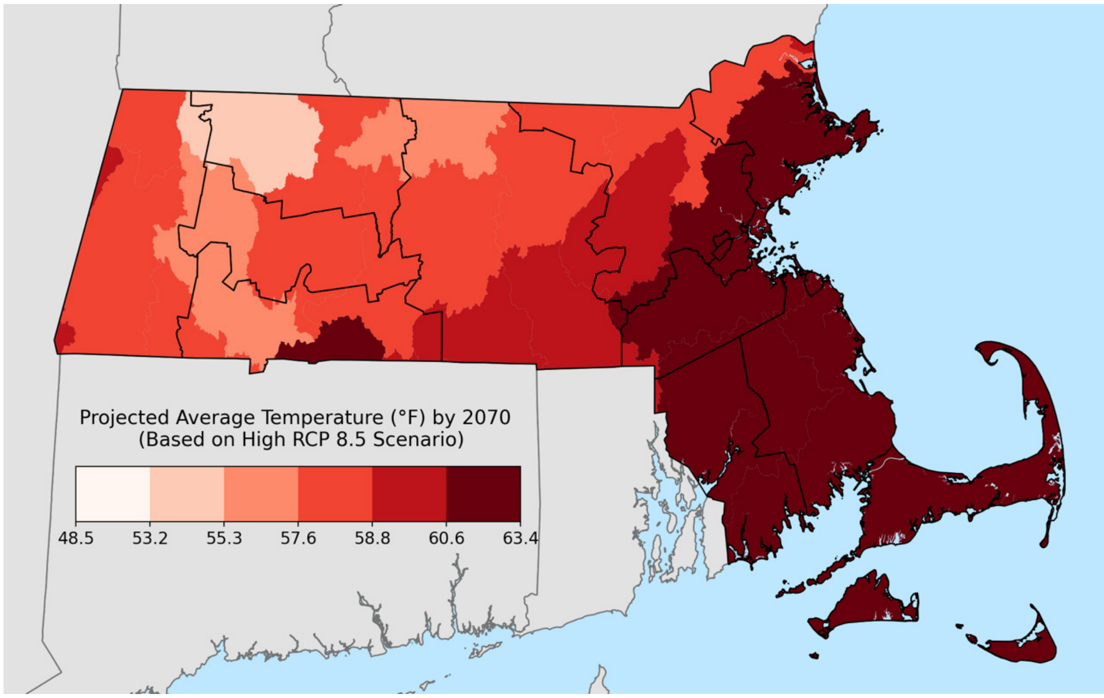
Source: SWG, from MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-8. Geospatial distribution of projected annual temperature—2030.



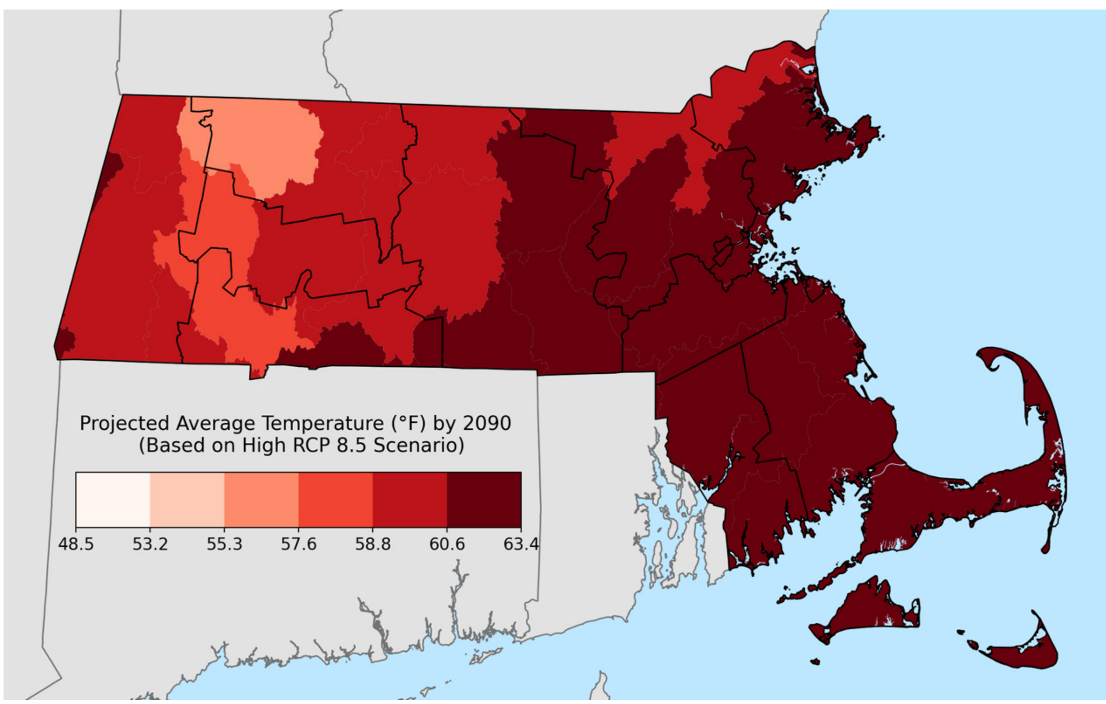
Source: SWG, from MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-9. Geospatial distribution of projected annual temperature—2050.



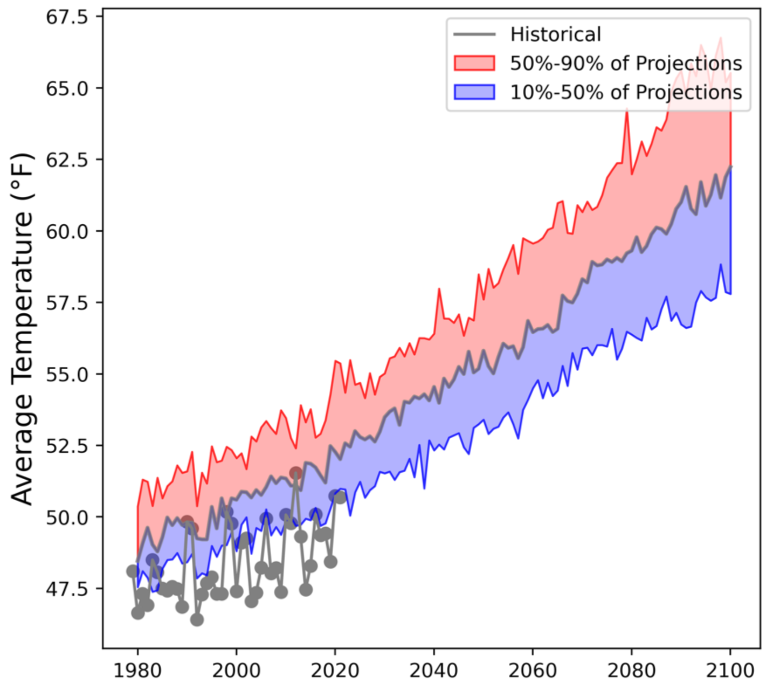
Source: SWG, from MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-10. Geospatial distribution of projected annual temperature—2070.



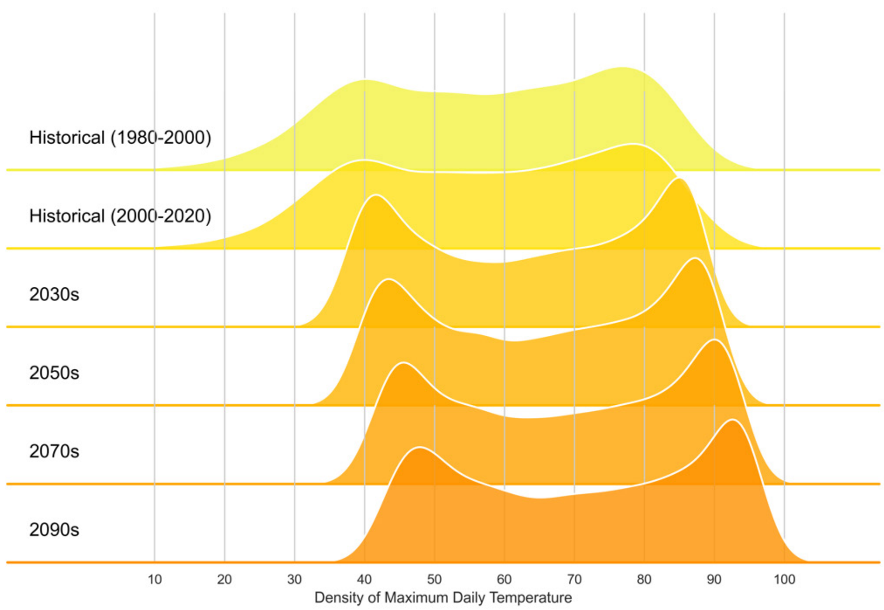
Source: SWG, from MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-11. Geospatial distribution of projected annual temperature—2090.



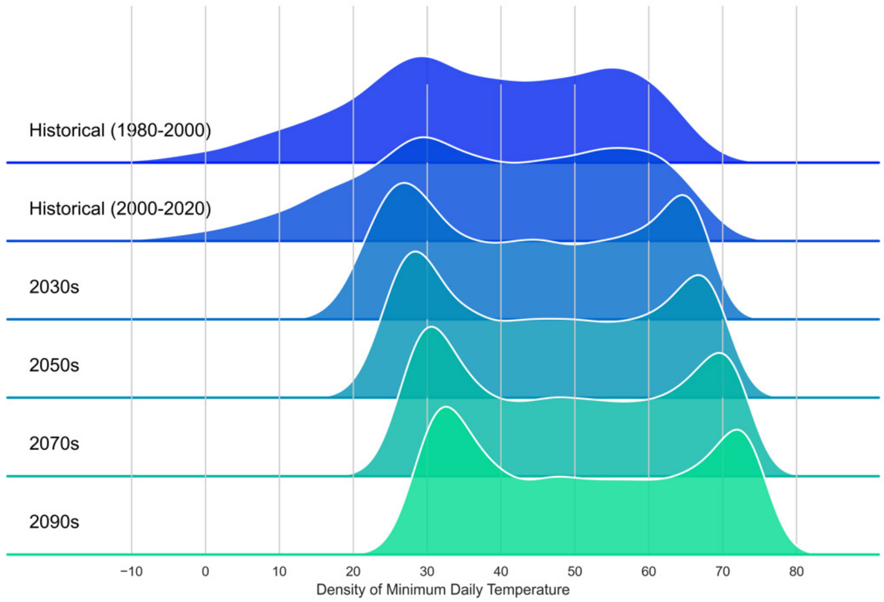
Source: CMIP6 downscaled projections (Thrasher et al., 2022), warming scenario SSP 5-8.5, historical data from GridMET.

Figure 5.2-12. Projected annual average temperature.



Source: Median SSP 5-8.5 climate scenarios from CMIP6 (Thrasher et al., 2022), historical data from GridMET.

Figure 5.2-13. Historical and projected distribution of maximum daily temperature.



Source: Median SSP 5-8.5 climate scenarios from CMIP6 (Thrasher et al., 2022), historical data from GridMET.

Figure 5.2-14. Historical and projected distribution of minimum daily temperature.

5.2.2.2.4 Warning Time

Average global temperatures are gradually rising, and will continue to rise over the coming decades, due to the increased amount of GHGs in the atmosphere. As these changes are occurring over many years, climate scientists conduct extensive simulation studies to predict the likely extent of future global temperatures. Recent advances in the downscaling of global forecasts allow predictions on a more local level, such as the watershed level (Steinschneider et al., 2019) or a fine-scaled grid (Pierce et al., 2014; Thrasher et al., 2022).

For extreme temperature events, meteorologists can accurately forecast event development and the severity of the associated conditions with several days lead time. These forecasts give public health and other officials an opportunity to notify at risk populations and prepare the Commonwealth to respond to extreme temperatures by opening shelters, deploying public safety resources to support the unhoused, and working with local hospitals to ensure availability of resources to respond to emergencies.

For extreme heat events, NWS issues excessive heat outlooks when the potential exists for an excessive heat event in the next three to seven days. Notifications such as “watches” are issued when conditions are favorable for an excessive heat event in the next 24 to 72 hours. Excessive heat warning/advisories are issued when an excessive heat event is expected in the next 36 hours.

For most extreme cold events, warning time is several days. NWS can issue a Wind Chill Advisory or Warning, or a winter weather-related Warning, Watch, or Advisory if the cold temperatures are occurring in conjunction with a winter storm event. While warning time can be several days, the resources needed to adequately prepare and respond can be significant and, in some cases, actions that are possible within the timeframe will be inadequate compared to the vulnerabilities and risks. Actions should be taken to respond to the trends and consequences of extreme weather in advance of specific, discrete events.

5.2.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

Many of the local hazard mitigation plans reviewed identified extreme heat as a significant hazard, often using the language of the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP). Some hazards included local examples of either significant historic extreme temperature events or significant local patterns, such as pronounced UHI effect. Plans for Worcester, Somerville, Boston, and other cities mention the impacts of the UHI effect on their communities (Central Massachusetts Regional Planning Commission, 2019; City of Boston, 2021; City of Somerville, 2022). Table 5.2-3 below provides examples of how extreme temperature was treated in three plans under review.

Table 5.2-3. Highlight of Local Plans and Municipal Vulnerability Preparedness Program Planning Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
2021 Natural Hazard Mitigation Plan Update, city of Boston, 2021	The UHI effect can lead to a 15°F overall temperature difference in Boston.	Severe health risks to elderly, homeless, and disabled people. Also has impacts on public transit.	N/A
North Adams Hazard Mitigation and Climate Adaptation Plan, January 2021	Projected declines in number of days below freezing in Adams, leading to changes to snow melt and increased insect populations.	Impacts on vulnerable populations, particularly in urbanized areas due to the UHI effect.	N/A
Town of Shutesbury Hazard Mitigation Plan, January 2022	Extreme temperatures are expected in over 50% of the town, with damage to several important roads due to freeze-thaw cycles.	Elderly population is most vulnerable to extreme heat and cold. Those without shelter are also at increased risk.	N/A

5.2.2.3 Secondary Hazards

High average temperatures and extreme heat are associated with a range of secondary hazards. Hot weather events increase the risk of drought, as evaporation increases with temperature. Heat is a common indicator for wildfire risk, as high temperatures dry out soil and vegetation and make environments in wildlands more flammable. Warmer weather increases the risk of invasive species success, native species extirpation, and sensitive habitat degradation. [See Section 5.10 (Invasive Species) for details.] Heat events also contribute to the formation of ground-level ozone or other respiratory irritants, which can exacerbate asthma and result in an increase in emergency department visits.

Extreme heat can also reduce indoor air quality and increase the prevalence of mold, as heat in the Commonwealth is typically accompanied by high humidity that leads to increased mold in buildings. Heat can also increase the likelihood of foodborne illness, as extreme heat can result in unsafe temperatures during transport (including grocery delivery) and disrupt refrigeration through power outages or heat waves.

Cold weather events are often associated with severe winter storms. This combination is particularly dangerous because winter weather often disrupts heat and power services, increasing the risks to the public. For example, disruptions to electrical power and heating have resulted in carbon monoxide poisoning from inappropriate use of combustion-powered generators, heaters, and cooking appliances. Risks associated with winter weather are discussed in Section 5-13 (Severe Winter Storms). Power failure leads to increased use of diesel generators for power and more wood stoves are used in extreme cold; in both situations, air pollution and health impacts increase. Extreme cold weather can also degrade the resilience of some natural environments like shallow waterbodies.

5.2.2.4 Exposure and Vulnerability

This section describes exposure and vulnerability to extreme temperatures and rising average temperatures in several important sectors. Table 5.2-4 summarizes priority impacts in each sector, as identified in the MA Climate Assessment.

Table 5.2-4. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Extreme Temperature

Sector	Priority Impacts and Vulnerabilities
Human	• Health and cognitive effects from extreme heat **(most urgent)** • Health effects from degraded air quality **(most urgent)** • Reduction in food safety and security • Increase in mental health stressors
Governance	• Increase in demand for state and municipal government services **(most urgent)** • Increase in need for state and municipal policy review and adaptation coordination • Damage to inland state and municipal buildings and land

Sector	Priority Impacts and Vulnerabilities
Infrastructure	• Damage to rails and loss of rail/transit service **(most urgent)** • Damage to electric transmission and utility distribution infrastructure **(most urgent)** • Loss of urban tree cover • Reduction in clean water supply • Damage to roads and loss of road service • Loss of energy production and resources
Natural environment	• Freshwater ecosystem degradation **(most urgent)** • Marine ecosystem degradation **(most urgent)** • Coastal wetland degradation **(most urgent)** • Forest health degradation **(most urgent)** • Shifting distribution of native and invasive species
Economy	• Reduced ability to work **(most urgent)** • Decrease in marine fisheries and aquaculture productivity **(most urgent)** • Economic losses from commercial structure damage and business interruptions • Decrease in agricultural productivity

Methodology

The methods to produce this report included geospatial analysis, literature review, and expert consultation. The Risk Assessment team conducted geospatial analysis at the most detailed level available. For some measures (such as projected mortality), this was the county level; for other information, it was the Census block group level or town level. Statistics are also summarized to the state level, especially to convey expected changes toward the end of the century.

5.2.2.4.1 Human

The entire population of the Commonwealth can be exposed to extreme temperatures and rising average temperatures, although average temperatures are expected to be highest in coastal areas and the Greater Boston area (see Section 5.2.2.2.3 for details). Extreme heat and extreme cold are the two largest sources of weather- or natural disaster–related mortality in the U.S. (Sharpe & Wolkin, 2022). Heat-related illnesses can persist for many days following a heat event (Wellenius et al., 2017). The human impacts from extreme heat will be more severe in densely developed urban areas around the Commonwealth due to the UHI effect, with especially high impacts in environmental justice and other priority populations.

The Risk Assessment team surveyed representatives from state agencies, asking them (among other things) to identify populations at risk from extreme temperature and disproportionate impacts of extreme temperature. Table 5.2-5 summarizes several top-priority concerns about populations and disproportionate impacts. State agency responses confirmed that the entire population of the Commonwealth is exposed to extreme temperatures and that agencies also identify a risk of disproportionate impacts among populations with social and health vulnerabilities.

Table 5.2-5. State Agency Responses: Primary Concerns About Extreme Temperature Impacts on Populations Served and Potential Disproportionate Impacts

Category	Primary Concerns
Populations served	• General public • Workers in executive branch and constituents • People with disabilities • Veterans, especially low-income veterans and veterans with disabilities • Mosquito control district member municipalities • Farmers and urban farmers • Users of open space • Traveling public/employees • All municipal, campus, hospital, and environmental police officers and deputy sheriffs • Insurance companies and customers • People over the age of 65 who live alone • Unhoused populations
Potential disproportionate impacts	• Environmental justice populations, especially those in urban areas • People with disabilities • People with low incomes • Disruptions to electricity service • People who depend on alternative transportation (e.g., public transit, walking, biking), including those whose jobs require them to be physically present; this may exacerbate impacts on environmental justice populations who are more likely to hold jobs that require physical presence

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Vulnerable and Priority Populations

The Centers for Disease Control and Prevention (CDC) provide a list of populations vulnerable to extreme cold and heat events (CDC, 2022):

- People over the age of 65, who are less able to withstand temperatures extremes due to their age, health conditions, and limited mobility to access shelters
- Infants and children under five years of age
- People with pre-existing medical conditions that impair heat tolerance (e.g., heart disease or kidney disease)
- People with low incomes who cannot afford proper heating and cooling

- People with respiratory conditions, such as asthma or chronic obstructive pulmonary disease
- The general public, who may overexert themselves when working or exercising during extreme heat events or who may experience hypothermia during extreme cold events
- Pregnant women, who are more likely to be dehydrated or experience heat exhaustion

Other vulnerable groups include the following:

- Unsheltered and unhoused people, who have a limited capacity to shelter from dangerous temperatures. On February 22, 2022, a count of the homeless population of Boston recorded a total of 4,439 homeless people (City of Boston, 2022). A report tracking cold-related illnesses found that between 10 and 20 percent of cold-related illnesses in Massachusetts were among people without shelter or housing (Jetter, 2020).
- People who live alone, particularly if they are elderly or have disabilities (Kafeety et al., 2020). These people are at higher risk of heat-related illness due to their isolation and reluctance to relocate to cooler environments.
- People taking medication that limits the body’s ability to regulate heat (Ebi et al., 2021).

County-level rates of key vulnerability factors are shown in Table 5.2-6.

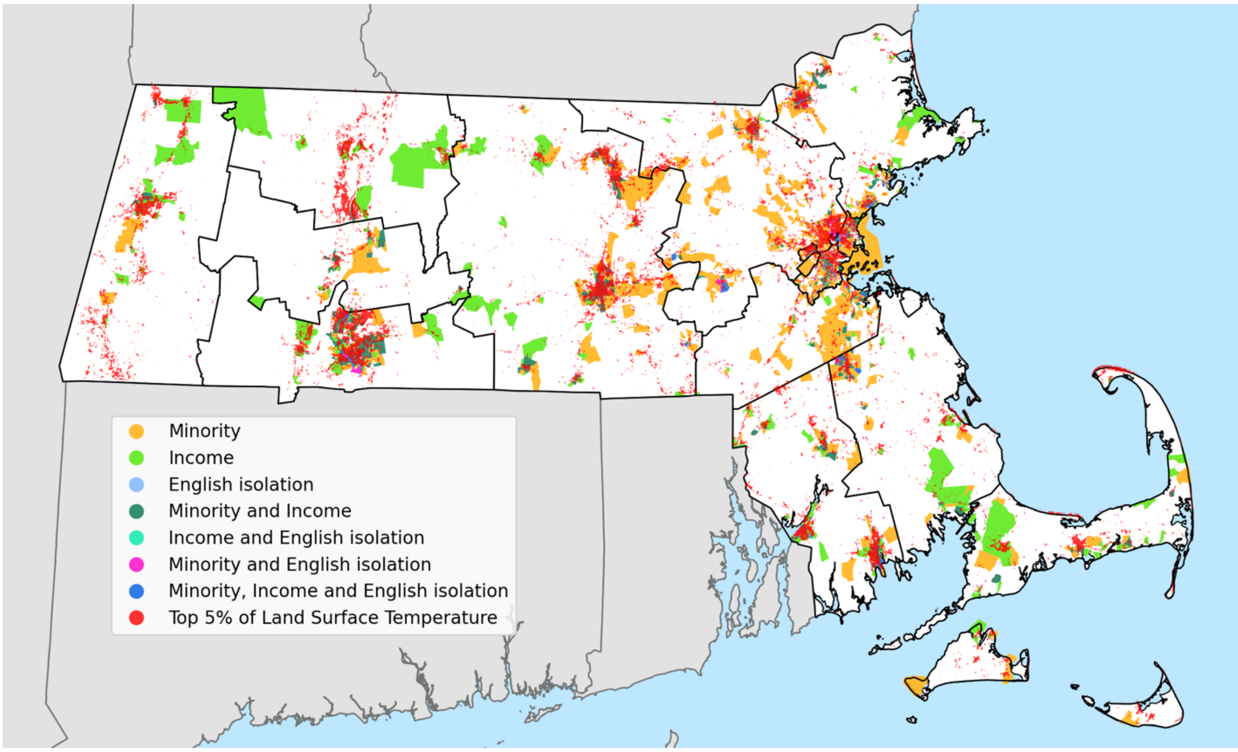
Social vulnerability is a key risk factor for heat-related health effects. The U.S. Environmental Protection Agency (EPA) finds that populations from underrepresented races and ethnicities, people in low-income neighborhoods, and people without high-school diplomas are at increased risk of temperature-related health effects (U.S. EPA, 2021). A growing body of evidence finds that heat-related deaths are higher in areas with more people from underrepresented races and ethnicities and other environmental justice and priority populations (Ho et al., 2018; Khatana et al., 2022b; Williams, Allen, Catalano, & Spengler, 2020). Figure 5.2-15 shows the location of environmental justice block groups in Massachusetts, along with areas with the highest 5 percent of land surface temperature (LST). Many areas of high surface temperature in the Commonwealth are also areas with high numbers of environmental justice block groups, such as major cities like Boston, Worcester, and Springfield. Table 5.2-6 includes the number of Census block groups per county designated as environmental justice populations by the Massachusetts Bureau of Geographic Information (MassGIS). More information on environmental justice groups is provided in Section 5.1 (Risk Assessment Introduction).

One large factor that contributes to increased and disproportionate impact of heat-related health risk among communities is the UHI effect. As discussed in Section 5.2.2.2, the UHI effect exacerbates temperatures and extreme heat in urban settings due to high concentrations of exposed surfaces such as dark roofs; pavement; impervious surfaces; and a lack of open spaces, rivers, creeks, wetlands, and trees. Nationally, this effect is larger among communities with lower average income and higher share of the population from underrepresented races and ethnicities (Benz & Burney, 2021; Hsu et al., 2021). Within the Northeast, average temperatures are higher in neighborhoods with lower average socioeconomic status, higher proportions of people from underrepresented races and ethnicities, and higher proportions of transit-dependent people (Renteria et al., 2022).

Historical discrimination can help explain the excess UHI effect among poor communities, communities exposed to environmental injustices, and communities with higher populations from underrepresented races or ethnicities. Neighborhoods that were "redlined" in 1930s maps (neighborhoods that, based largely on racial characteristics, were systematically discriminated against for loans and public infrastructure and had a disproportionate number of industrial and pollution-generating uses sited in them) have significantly higher average temperatures (Hoffman et al., 2020). In the greater Boston area and Holyoke-Chicopee, redlined districts have average temperatures over 6ºF higher than their non-redlined counterparts; in Haverhill, 4.5ºF higher; in Brockton, 2.6ºF higher (Hoffman et al., 2020).

Historical differences in land use between communities can also help explain these temperature differences. Increasing urban tree canopy can reduce daytime temperatures and limiting impervious surfaces (such as pavement, roadways, parking lots, industrial uses, and roofs) can lower both daytime and nighttime temperatures (Ziter et al., 2019). Nationally, neighborhoods with lower average income or more residents from underrepresented races and ethnicities have less green space and more exposed, impervious surfaces (Benz & Burney, 2021; Nesbitt et al., 2019). The Greater Boston Research Advisory Group Report on climate change impacts highlights the significance of land use changes that increase the exposure of disadvantaged Boston area communities to extreme heat (Douglas & Kirshen, 2022). Researchers found that Boston had among the worst racial disparity in tree cover in the U.S. (McDonald et al., 2021).

In Massachusetts, environmental justice populations are more exposed to extreme heat and are at greater risk of heat-related health effects. Figure 5.2-15 shows the spatial distribution of these populations in Massachusetts, along with areas of high LST. There is significant overlap of high-LST regions and environmental justice populations, particularly in large metropolitan areas such as Boston, Worcester, and Springfield. In fact, almost 30 percent of the area experiencing high LST in the Commonwealth is in environmental justice communities. The MA Climate Assessment found that areas with a high proportion of their population from underrepresented races or ethnicities could have 22 percent higher rates of estimated premature death from extreme heat, and areas with a high proportion of language-isolated populations could have 28 percent higher rates (Commonwealth of Massachusetts, 2022).



Sources: MA Climate Assessment (Commonwealth of Massachusetts, 2022), MassGIS.

Figure 5.2-15. LST hot spots and environmental justice populations.

Certain occupations place people at greater risk of temperature-related health impacts. Occupations where people work outside have greater risk of both extreme cold– and extreme heat–related impacts. These occupations, such as agriculture, fishing, construction, maintenance, gardening and landscaping, manufacturing, transportation, warehousing, and forest service workers, make up about 20 percent of the Commonwealth's work force (BLS, 2021). Underrepresented races and ethnicities are disproportionately represented in workplace heat-related deaths (Dong et al., 2019; Shipley et al., 2021). Indoor workplaces with limited air conditioning, such as warehouses and industrial sites, place people at greater risk of heat-related impacts. The Occupational Health and Safety Administration (OSHA) identifies bakeries, kitchens, laundries, electrical utilities, fire service, manufacturing, and warehousing as industries with potential for heat-related injuries. Additionally, schools without adequate air conditioning place teachers and staff, as well as the students, in conditions with higher risk of heat-related impacts.

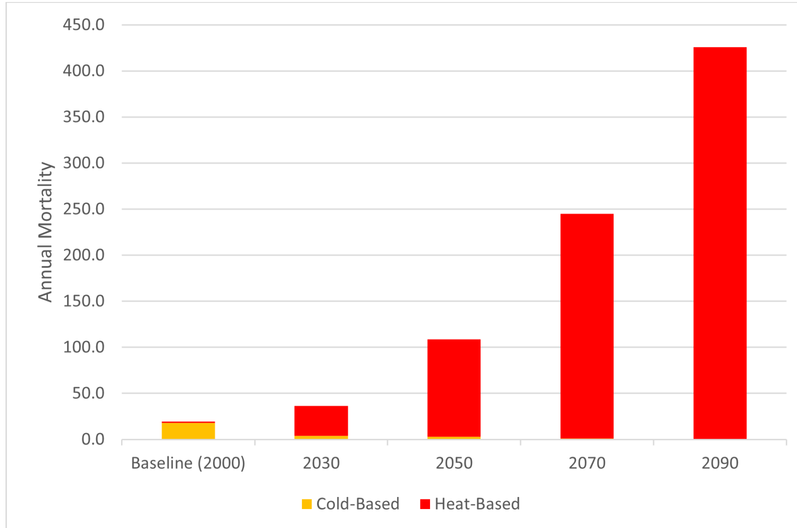
Transit-dependent people are also at increased risk of temperature-related health impacts. Transit use can expose riders to extreme heat through access and waiting time. Exposure can combine with additional heat-related hazards, such as high ozone concentration, for additional negative health effects (Braun & Fraser, 2022). Heat-moderating infrastructure such as trees, shade, or bus stop shelters can alleviate this exposure, although (as discussed above) environmental justice and other priority populations often experience a stronger UHI effect and a lack of trees and shade (Lanza & Durand, 2021). Riders are similarly exposed to extreme cold, either while accessing stations or while waiting at them. Additionally, cold weather can impose transit delays, increasing exposure to low temperatures.

Health Impacts

Both extreme heat and extreme cold can have adverse health effects, including death and significant injury that results in lifelong effects. Extreme heat and extreme cold are the first and second weather-related mortality causes in the U.S., respectively (Sharpe & Wolkin, 2022). When people are exposed to extreme heat, they can suffer from potentially deadly illnesses, such as heat exhaustion and heat stroke. Extreme heat can also have adverse effects on cognitive performance and learning. Prolonged exposure to extreme cold can lead to hypothermia or frostbite, which can lead to lifelong effects or death.

As the climate warms, heat-related mortality is very likely to surpass cold-related mortality. In Massachusetts, 19 annual premature deaths can be attributed to extreme temperature (Commonwealth of Massachusetts, 2022). Historically, Massachusetts has experienced more cold-related mortality than heat-related mortality. By the end of the century, analysis projects that the Commonwealth will experience more than 400 additional premature deaths from extreme heat per year as a result of climate change. Figure 5.2-16 shows how temperature-related mortality is expected to increase toward the end of the century, according to analysis from the MA Climate Assessment. Climate change has already increased the incidence of heat-related deaths worldwide, with 20 to 76.5 percent of heat-related deaths from 1991 to 2018 attributable to anthropogenic climate change (Vicedo-Cabrera et al., 2021).

The incidence of temperature-related mortality is projected to vary throughout the Commonwealth (Commonwealth of Massachusetts, 2022). Figure 5.2-17 shows the spatial distribution of projected temperature-related mortality in the 2090s. These projections also include estimated changes in population (U.S. EPA, 2017). Projected mortality rates are highest in the coastal regions, although all regions are projected to experience some temperature-related mortality. The UHI effect will likely exacerbate these mortality impacts in urban areas, especially areas with high proportions of environmental justice and other priority populations. The MA Climate Assessment found that environmental justice block groups are expected to have excess premature mortality rates between 22 to 28 percent higher than the statewide average (Commonwealth of Massachusetts, 2022). Additionally, extreme heat appears to be most dangerous early in the season and in areas that do not have historical experience with extreme temperatures. This could have implications for the Berkshires, areas of Cape Cod, and the Islands where temperature extremes are historically less frequent, air conditioning is less common, and the population includes high percentages of older people.

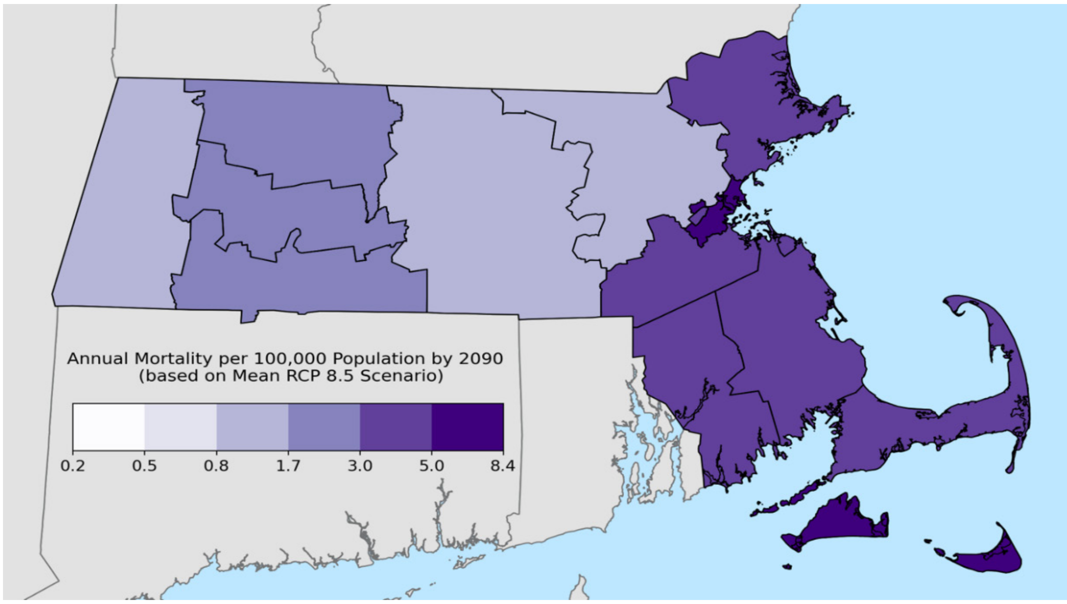


Source: Analysis from MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-16. Projected annual deaths from temperature-related mortality.

These estimates do not incorporate adaptation, which may reduce the amount of excess mortality associated with extreme heat. There is a well-documented historical decline in heat-related mortality in the U.S. (Barreca et al., 2016; Lay et al., 2021), largely due to increased use of air conditioning. However, these declines are lower for extremely high temperatures (Lay et al., 2021). Additionally, much of the reduction in heat-related mortality in the Northeast appears to be from late-season mortality (Spangler & Wellenius, 2021). The extent that adaptation measures that focus on air conditioning and individual, building-specific approaches, will be able to reduce future mortality is unclear, especially for populations that may not be able to afford air conditioning or are otherwise exposed to extreme temperatures (Cromar et al., 2022).

A growing body of evidence documents that environmental justice and other priority populations have greater risk of heat-related mortality. Nationally, non-Hispanic Black adults have higher rates of heat-related cardiac death than non-Hispanic White adults (Khatana et al., 2022a). Within Boston, heat-related mortality is greater among Census tracts with more low-income people or higher rates of linguistic isolation (Williams, Allen, Catalano, & Spengler, 2020). This may be driven by reduced access to air conditioning, as a growing body of literature documents that increasing air conditioning use can reduce deaths from extreme heat (Barreca et al., 2016; He & Tanaka, 2023; Sera et al., 2020). Cooling centers can provide air conditioning for those without adequate cooling in their homes or workplaces. Cooling centers have been shown to reduce heat-related mortality, but not to eliminate the relationship between social vulnerability and heat-related mortality (Eisenman et al., 2016). Cooling centers are an interim approach to extreme heat and may be an inadequate response as the climate warms and extreme heat becomes more frequent.



Source: Analysis from MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-17. Spatial distribution of temperature-related mortality by 2090.

Hot temperatures can contribute to deaths from dehydration, heat stroke, heart attacks, strokes, other forms of cardiovascular disease, renal disease, and respiratory diseases such as asthma and chronic obstructive pulmonary disorder. Human bodies cool themselves primarily through sweating and through increasing blood flow to body surfaces. Heat events increase stress on cardiovascular, renal, and respiratory systems, and may lead to hospitalization or death in the elderly, those with pre-existing diseases, and those taking prescribed medications that impair the body's ability to regulate its temperature or that inhibit perspiration (e.g., diuretics and some behavioral health medications).

The incidence of heat-related illness varies throughout the Commonwealth. Figure 5.2-18 shows the town-level rates of emergency room visits for heat stress. Between 2007 and 2017, the annual average age-adjusted rate of emergency room admission for heat stress was highest in Dukes and Barnstable counties (17.1 to 18.1 admissions per 100,000 residents), as listed in Table 5.2-6.

Heart disease and asthma are two medical conditions that can increase the likelihood of heat-related mortality. The interaction of heat and cardiovascular disease has caused about 25 percent of the heat-related deaths since 1999 (U.S. EPA, 2021). Figure 5.2-19 shows the town-level rates of hospital admissions for heart disease in the Commonwealth. Plymouth, Bristol, Hampden, and Berkshire counties experienced the highest annual average age-adjusted hospital admissions for heart attacks (33.7 to 35.9 per 10,000 people) during this period, as listed in Table 5.2-6.

Massachusetts has a very high prevalence of asthma—roughly one in 10 residents have it. The town-level rates are shown in Figure 5.2-20 and the county-level rates are listed in

Table 5.2-6. Nantucket and Hampden counties had the highest annual average age-adjusted rate of emergency department visits due to asthma (121.0 to 124.3 visits per 10,000 people).

In Massachusetts, poor air quality often accompanies heat events, as heat increases the conversion of ozone precursors in fossil fuel combustion emissions to ozone. Particulate pollution may also accompany hot weather, as the weather patterns that bring heat waves to the region may carry pollution from other areas of the country. Poor air quality can negatively affect respiratory and cardiovascular systems and can exacerbate asthma and trigger heart attacks. This effect can be exacerbated in UHIs, particularly those with congested highways and roadways that produce ozone or particulate matter emissions.

Recent research suggests that children may also be vulnerable to extreme heat, although heat-related mortality is historically common in older people. All-cause visits by children to emergency departments increase when daily maximum temperatures exceed 95°F (Bernstein et al., 2022).

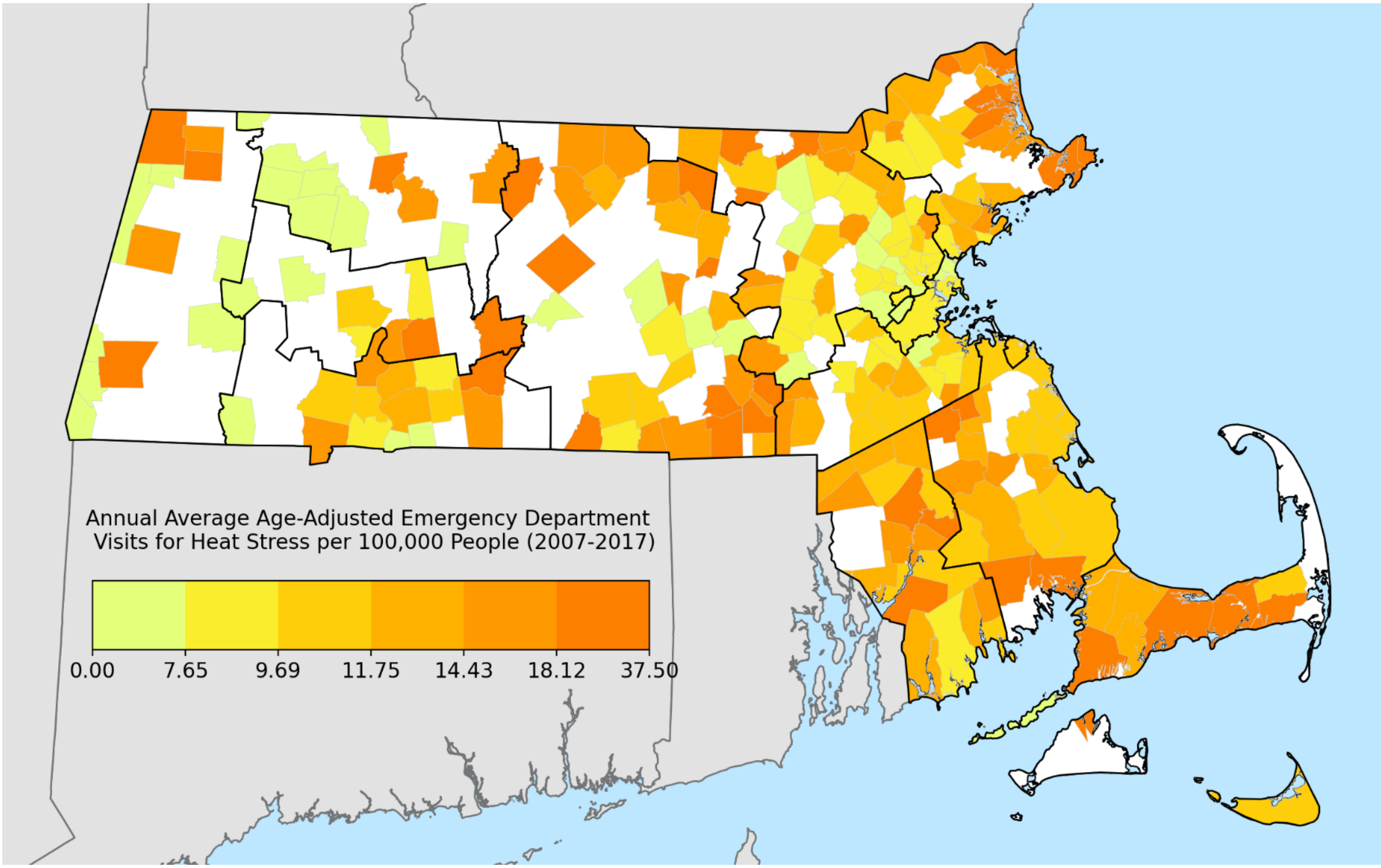
In addition to physical impacts, high temperatures can have severe impacts on mental health. Extreme heat is associated with a range of mental health impacts, including increased irritability, depression, and even suicide (American Psychiatric Association, 2021). These impacts are greatest among those with pre-existing mental health conditions, those experiencing homelessness, and those with chronic illness or substance abuse. Extreme heat is associated with an increased incidence of suicide (Belova et al., 2022; Thompson et al., 2018). A 1ºF degree increase in monthly average temperature is associated with a 0.48 percent increase in mental health emergency department visits and a 0.35 percent increase in suicides; there is no evidence of adaptation to these effects (Mullins & White, 2019). Surveys find that extreme heat worsens general mental health, and that these effects compound over prolonged exposure (Obradovich et al., 2018).

Extreme heat can also diminish cognitive ability, including students’ ability to learn. Extreme heat greatly diminishes capacity for performing complex tasks (Taylor et al., 2016). Schools without air conditioning may lose as much as 1 percent of annual learning for each additional 1°F in average school year temperature (Park et al., 2020, 2021). According to a 2015 survey of high school counselors, classrooms lacked adequate air conditioning in over 50 percent of high schools in every county except Essex County (Park et al., 2020). In Boston, only 33 out of 124 public schools have air conditioning (Boigon, 2018), and the majority of schools used during the summer do not have air conditioning (Gans, 2021). This also poses a health risk to teachers and staff in schools without adequate air conditioning. The *Town of Shutesbury Hazard Mitigation Plan* noted the impact of heat on learning as a serious concern and that local schools may need to close extreme heat events (Shutesbury Hazard Mitigation Planning Team & Franklin Regional Council of Governments, 2021). Educational facilities in Amherst, Bourne, Bridgewater, Brockton, Dartmouth, Fitchburg, Gardner, Holyoke, Lowell, North Adams, Shrewsbury, Springfield, and Worcester are all in regions with high LST.

Table 5.2-6. Heat Vulnerability Indicators

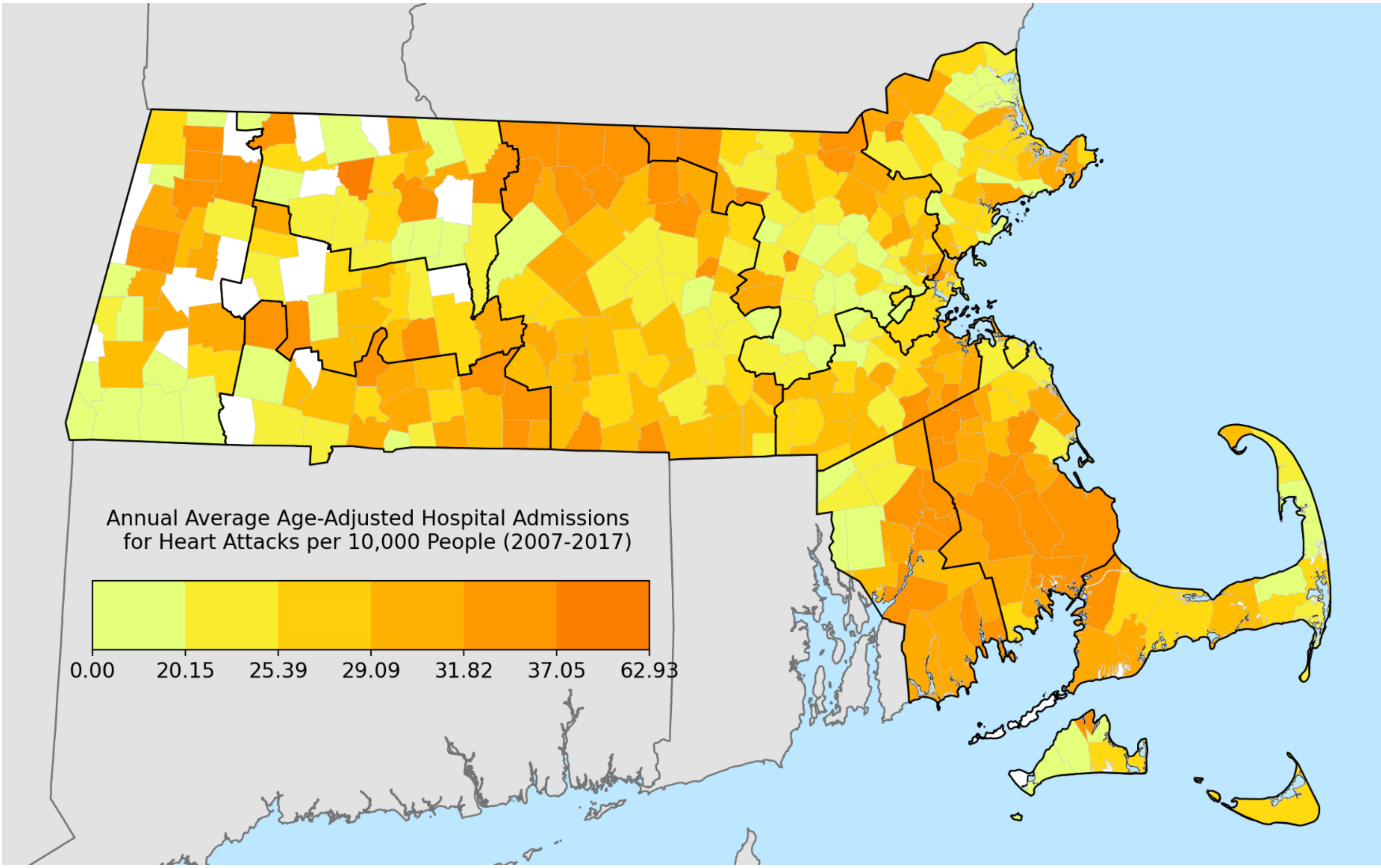
County	Census Block Groups Designated as Environmental Justice Populations	General Vulnerability Indicators			Health Vulnerability Indicators			
		Proportion of Population Aged 65 or Older	Proportion of Population Aged Younger than 5 Years	Proportion of the Population Living Below Poverty Level	Rate of Emergency Room Visits for Heat Stress (per 100,000 Residents)	Rate of Hospital Admissions for Heart Attacks (per 10,000 Residents)	Rate of Emergency Department Visits for Asthma (per 10,000 Residents)	Rate of Emergency Department Visits for Asthma for Children Under Age 15 per 10,000 Residents
Barnstable	42	32%	4%	8%	17.1	29.6	74.8	71.2
Berkshire	60	25%	4%	10%	14.6	35.4	82.4	84.2
Bristol	185	18%	5%	10%	14.4	35.9	83.5	99.3
Dukes	6	26%	5%	8%	18.8	25.9	90.6	138.5
Essex	236	18%	5%	9%	13.5	28.6	72.9	111.7
Franklin	23	24%	4%	11%	16.3	28.4	67.6	88.2
Hampden	208	18%	5%	14%	12.6	33.7	124.3	181.7
Hampshire	37	19%	3%	9%	10.6	29.0	43.9	61.6
Middlesex	485	16%	5%	7%	9.3	26.9	45.8	75.9
Nantucket	1	16%	6%	5%	10.9	28.5	121.0	139.5
Norfolk	176	17%	5%	6%	9.9	28.4	44.3	73.7
Plymouth	110	19%	5%	7%	13.8	35.8	65.8	84.3
Suffolk	496	13%	5%	17%	8.1	27.0	107.1	213.3
Worcester	251	13%	5%	19%	12.2	31.4	71.4	112.2

Sources: ERG analysis using data from MassGIS; U.S. Census Quick Facts (American Community Survey, 2021); Massachusetts Department of Public Health Environmental Public Health Tracking Program 2007–2017 averages (accessed 2022).



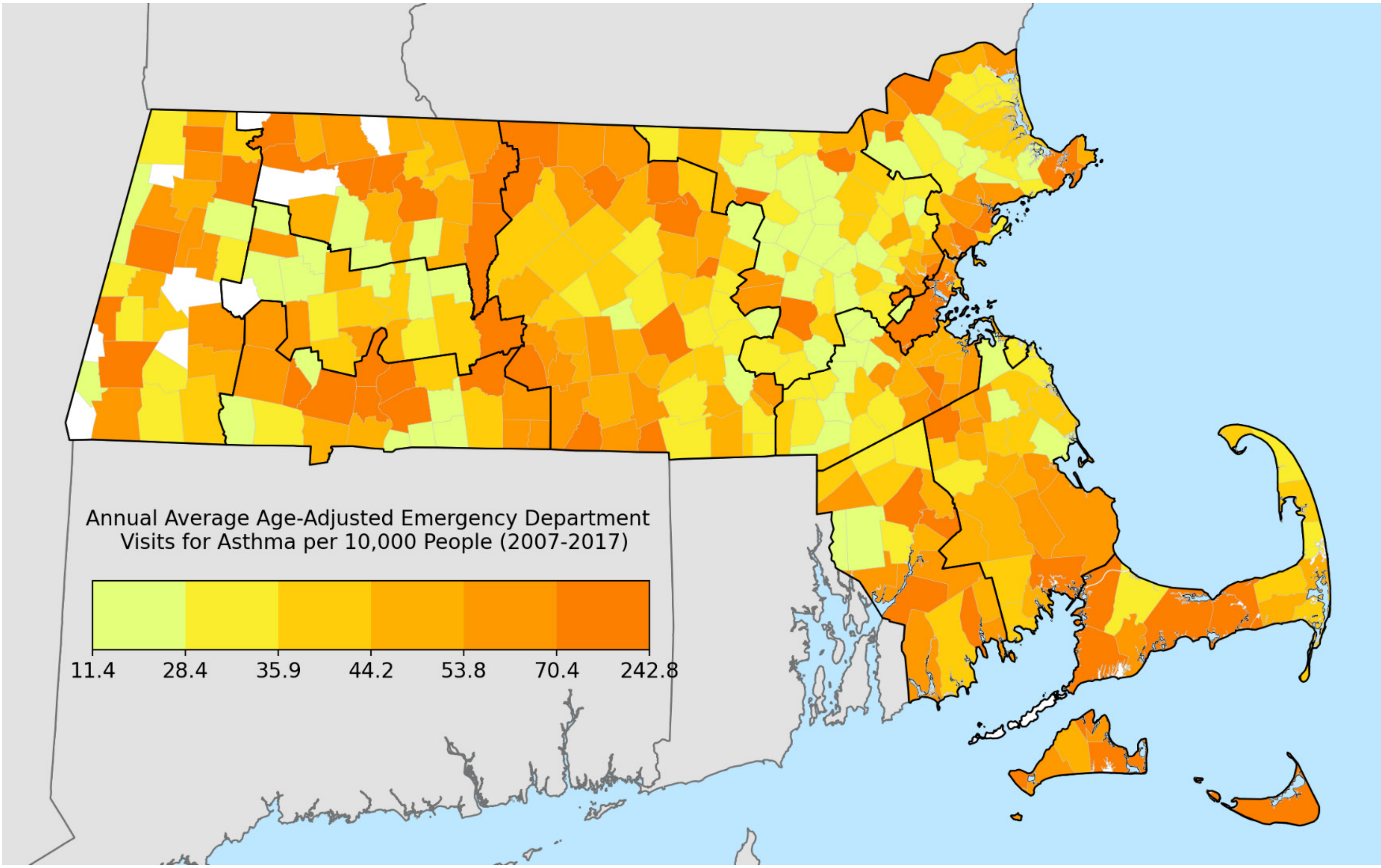
Source: Massachusetts Department of Public Health (2022).

Figure 5.2-18. Rates of heat stress–related emergency department visits by town.



Source: Massachusetts Department of Public Health (2022).

Figure 5.2-19. Rates of hospital admissions for heart attacks by town.



Source: Massachusetts Department of Public Health (2022).

Figure 5.2-20. Rate of emergency department visits due to asthma by town.

Cold weather events can also have significant health impacts, including mortality and permanent injury. The most immediate of these cold-related injuries include frostbite and hypothermia, which can become fatal if exposure to cold temperatures is prolonged. Cold weather events have disproportionate impacts, with significant effects for people experiencing homelessness, those over 65, those under five, single parent families, people in substandard housing, those living in poverty, those living on low incomes, renters, transit-dependent people, linguistically isolated people, outdoor workers, those living or working in areas without adequate heat, and people with underlying health conditions and disabilities. For example, extreme cold can increase the risk of pre-existing respiratory and cardiovascular conditions and cause these conditions to worsen.

Additionally, power outages that occur as a result of extreme temperature events can be immediately life-threatening to those dependent on electricity for life support or other medical needs. Isolation of these populations is a significant concern if extreme temperatures keep them from moving or stop systems they depend on from working. Power outages during cold weather may also result in inappropriate use of combustion heaters, cooking appliances, and generators in indoor or poorly ventilated areas, leading to increased risk of carbon monoxide poisoning.

5.2.2.4.2 Governance

All state-owned buildings are exposed to the extreme temperature hazard, as are many state employees—for example, emergency responders, park and recreation staff, maintenance workers, public transit staff, and other outdoor workers. Additionally, extreme temperatures may increase the demand for government services such as cooling or warming centers and emergency services. As part of the Risk Assessment development, state agencies were surveyed to identify concerns related to extreme temperatures and asked for suggested improvements to address these impacts. Table 5.2-7 summarizes several top-priority concerns. The survey responses make it clear that preparedness for extreme temperatures will require greater investment throughout the Commonwealth.

Extreme temperatures increase demand for heating and cooling, imposing additional costs on state and municipal governments. Manufactured buildings (trailers and mobile homes), antiquated or poorly constructed facilities, buildings with insufficient insulation, and buildings with insufficient heating or cooling systems may require additional energy expenses. Even in well-insulated buildings, extreme temperatures can increase the need for temperature regulation, increasing energy costs for state and municipal buildings.

Cold temperatures can lead to additional damage or interruptions to state facilities. Extreme cold temperature events can damage buildings through freezing or bursting pipes and freeze and thaw cycles. The heavy snowfall and ice storms associated with extreme cold temperature events can also cause power interruptions. Respondents from the Risk Assessment survey of Massachusetts state agencies recommended backup power for critical facilities and infrastructure, including IT infrastructure.

Preparing for, responding to, and recovering from extreme cold and heat events can stress government agency resources. Preparation activities include setting up and staffing heating and cooling centers, education and outreach to alert communities and businesses to the risks, plowing the streets, identifying and addressing disproportionate impacts on environmental justice and other priority populations such as unhoused or unsheltered populations, and preparing for an increase in power and energy demand. Additionally, the MA Climate Assessment finds that municipal and state governments will need to hire more staff to plan climate change adaptation and mitigation efforts, including to respond to rising average temperatures and extreme heat (Commonwealth of Massachusetts, 2022).

Extreme temperature can stress transportation infrastructure, requiring considerable expenses to repair municipal and state-owned roads as well as state-owned rail lines. The MA Climate Assessment finds that annual costs to repair state and municipal roads by the 2090s will exceed $100 million statewide. Over 90 percent of this expense will fall on municipalities, with large expenses in inland regions. This could add disproportionate stress for small municipalities, which own a high share of exposed roads relative to population and tax base. Extreme heat also affects rail infrastructure, much of which is either owned or maintained by the Massachusetts Department of Transportation. The MA Climate Assessment finds that annual rail maintenance costs due to temperature will increase by over $35 million by the 2090s (Commonwealth of Massachusetts, 2022). These vulnerabilities are discussed in more detail in the Section 5.2.2.4.3, which includes maps showing where these impacts are expected to be greatest.

Table 5.2-7. State Agency Responses: Primary Concerns About Extreme Temperature's Effects on Services, with Suggested Improvements

Category	Concerns/Improvements
Government services affected by extreme temperature	• Public education • First responder training (fire fighters, emergency medical services, police) • Emergency response, including 911 services (which might be affected by damage to public safety answering points or cell towers) • General agency operations • Transportation • IT and security infrastructure and services • Emergency services coordination at the federal, state, and local levels, including situational awareness • Disaster recovery services from the Massachusetts Emergency Management Agency • Mosquito control and potential risk of arborvirus risk • Trout stocking, recreation, and sensitive species • Services for the Commonwealth's disabled community • Aquatic habitat restoration projects

Category	Concerns/Improvements
	• Cemetery interment • Roads, bridges, and culverts
Updates, improvements, or enhancements to address concerns	• Study infrastructure/electrical grid to support increased air conditioning use • Equip all facilities (including training academies and underground stations) with adequate air conditioning and heating; maintain these systems • Plan for additional necessary resources • Use equipment that can perform in extreme temperatures • Ensure budgets support increased frequency of temperature events • Increase track inspections and monitoring during high-heat events • Increase the number of employee breaks • Increase shade for passengers • Move infrastructure to more resilient and redundant third-party facilities and cloud solutions • Install backup power generators for heating systems • Add state appropriated funding sources for statewide mosquito control • Implement habitat management, hatchery retrofits, and invasive species management • Incorporate vulnerability assessments into environmental restoration planning • Reduce impervious surfaces/heat retention • Support heat awareness through Department of Public Health programs, such as asthma or heart disease services

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Extreme heat also increases the demand for government services, such as cooling centers and emergency services. This demand is likely to be greatest in areas that experience the greatest degree of extreme heat, such as urban areas with environmental justice and other priority populations. Boston-area emergency medical services and fire department dispatches are about 10 percent more common on days when temperatures exceed 90ºF (Williams, Allen, Catalano, Buonocore, et al., 2020).

Extreme temperature–related events can sometimes cause utility failure, affecting government services. Extreme heat events can overload the electric grid, leading to outages (commonly referred to as brownouts) due to increased usage of air conditioners, appliances, and other items needing power. As the 2021 power outages in Texas demonstrated, extreme cold (and winter storms) can also lead to utility failure by reducing available electric generation and increasing demand for electric heating. The Risk

Assessment survey of state agencies identified these outages as a potential impact on government services, especially IT and security-related functions.

State agency employees that spend part of or all their time working outside are at a disproportionate risk from extreme temperatures. These include maintenance and construction staff in the Department of Transportation, park rangers, and seasonal workers from the Department of Conservation and Recreation, and inspection workers from the Department of Public Health. Field workers, security, landscape and gardening, maintenance, and construction staff of all agencies are at increased risk. Many state workers—for example, food inspectors and police officers—are exposed to high heat-related stress when their jobs are most demanding (Obradovich et al., 2018). Some indoor government workers may also be exposed to extreme temperatures when buildings lack adequate heating or cooling systems. For example, many schools in the Commonwealth lack air conditioning, and teachers and school staff may be exposed to extreme heat.

5.2.2.4.3 Infrastructure

Infrastructure, utilities, and other components of the built environment are among the assets most significantly exposed to the extreme temperature hazard. As interdependent networks and systems, infrastructure and utilities often experience cascading effects from extreme heat or extreme cold events. The impacts of extreme heat on buildings include increased thermal stresses on building materials, which leads to greater wear and tear and reduces a building’s functional lifespan; increased air-conditioning demand to maintain a comfortable temperature; overheated heating, ventilation, and air-conditioning systems; and disruptions in service associated with power outages (Nugroho et al., 2022). Extreme cold can cause materials such as plastic to become less pliable, making them more likely to break down during extreme cold events (Lstiburek, 2009). In addition to the facility-specific impacts, extreme temperatures can affect the built environment in several ways, summarized in the subsections that follow.

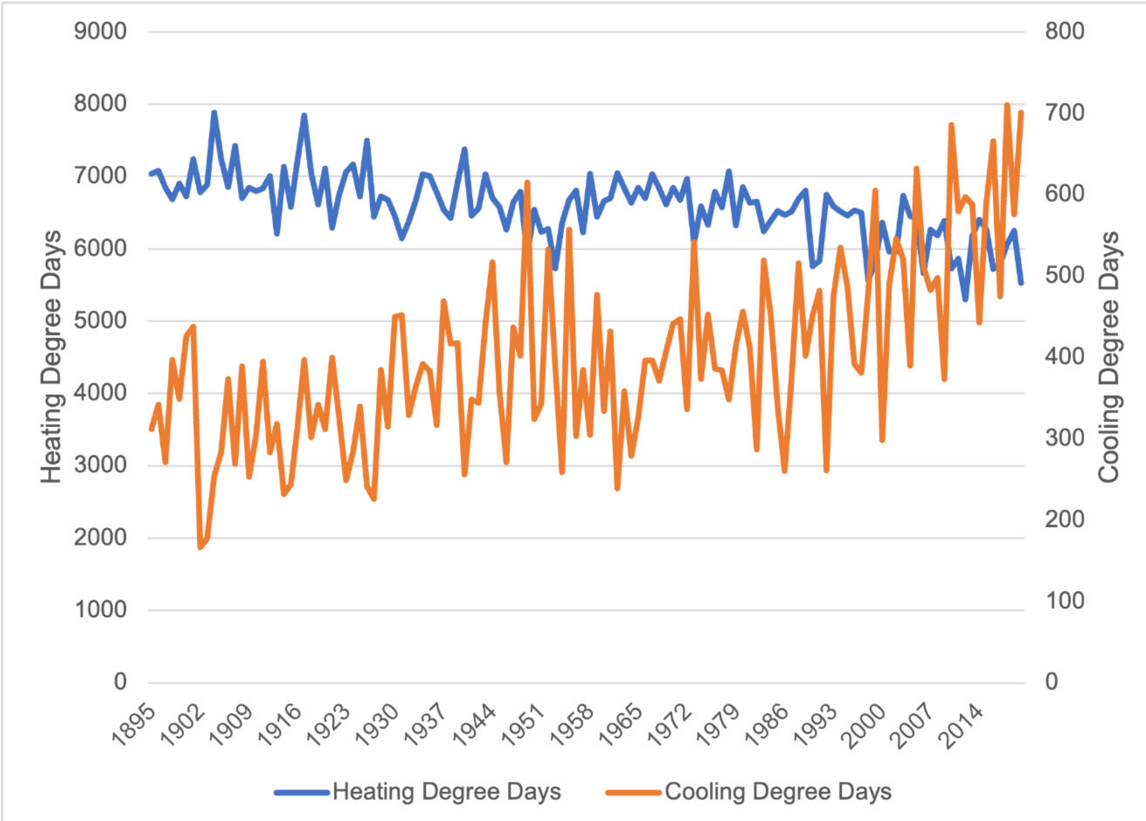
Agriculture

Exposure to extreme temperatures can cause losses or reduced productivity for Massachusetts agriculture. Certain high-value crops in the state—such as apples, cranberries, and maple syrup—rely on specific temperature regimes, which may be shifting as the climate changes (Dhaliwal & Williams, 2022; Schlenker & Roberts, 2009). Unseasonably warm temperatures in early spring that are followed by freezing temperatures can result in crop loss of fruit-bearing trees. Warmer conditions may mean that farmers could introduce new crops that are viable under these conditions and longer growing seasons; however, a transition such as this may be costly (IPCC, 2019). Extreme heat is also damaging for dairy and cattle production, and for a variety of crops including sweet field corn. Section 5.2.2.4.5 below includes more details on these economic impacts. Additionally, agricultural workers are disproportionately exposed to extreme temperatures, resulting in human health impacts as described in Section 5.2.2.4.1.

Energy

Extended-duration extreme cold can lead to energy supply concerns, as the heating sector demands a higher percentage of the natural gas pipeline capacity. When this occurs, New England transitions electricity generation from natural gas to oil and liquid natural gas. Limited on-site oil and liquid natural gas storage as well refueling challenges may cause energy supply concerns if the events are colder and longer in duration. In extreme cases, this could lead to utility failures during times of extreme need. In January 2019, a winter storm caused a prolonged natural gas outage in Rhode Island, leaving thousands without heat during a period of extreme cold. As the climate warms, the amount of heating needed in Massachusetts is gradually decreasing (see Figure 5.2-21 for an illustration of heating needs over time). The average annual number of heating degree days from 1958 to 2020 was 5 percent lower than the average from 1895 to 1967. However, to meet climate goals, Massachusetts is expected to increase the number of electric heating units to reduce reliance on gas and other fossil fuels (Massachusetts Executive Office of Energy and Environmental Affairs, 2020). This may increase electricity demand during extreme cold events, potentially exposing additional residents to extreme cold during electricity outages.

In addition to increasing demand for heating and cooling, periods of hot or cold weather can stress energy infrastructure. In 2022, heat waves caused brownouts that left thousands of Massachusetts residents without power. Summer electricity demand has been increasing historically, as the climate warms and Massachusetts residents experience greater need for cooling. Figure 5.2-21 the change in number of cooling degree days, one key measure of the demand for cooling. The average annual number of cooling degree days in Massachusetts from 1958 to 2020 was 30 percent higher than the average from 1895 to 1967. Summer electricity demand is very likely to increase as the climate warms and more air conditioning is installed throughout the Commonwealth (Auffhammer et al., 2017; van Ruijven et al., 2019). This excess demand will strain electric infrastructure. Extreme heat also lowers the efficiency of thermoelectric generation and the transmission system, exacerbating the risks of heat-based electric system failures (Bartos et al., 2016; Yalew et al., 2020).



Source: EPA heating and cooling degree days, accessed 2022 (U.S. EPA, 2016).

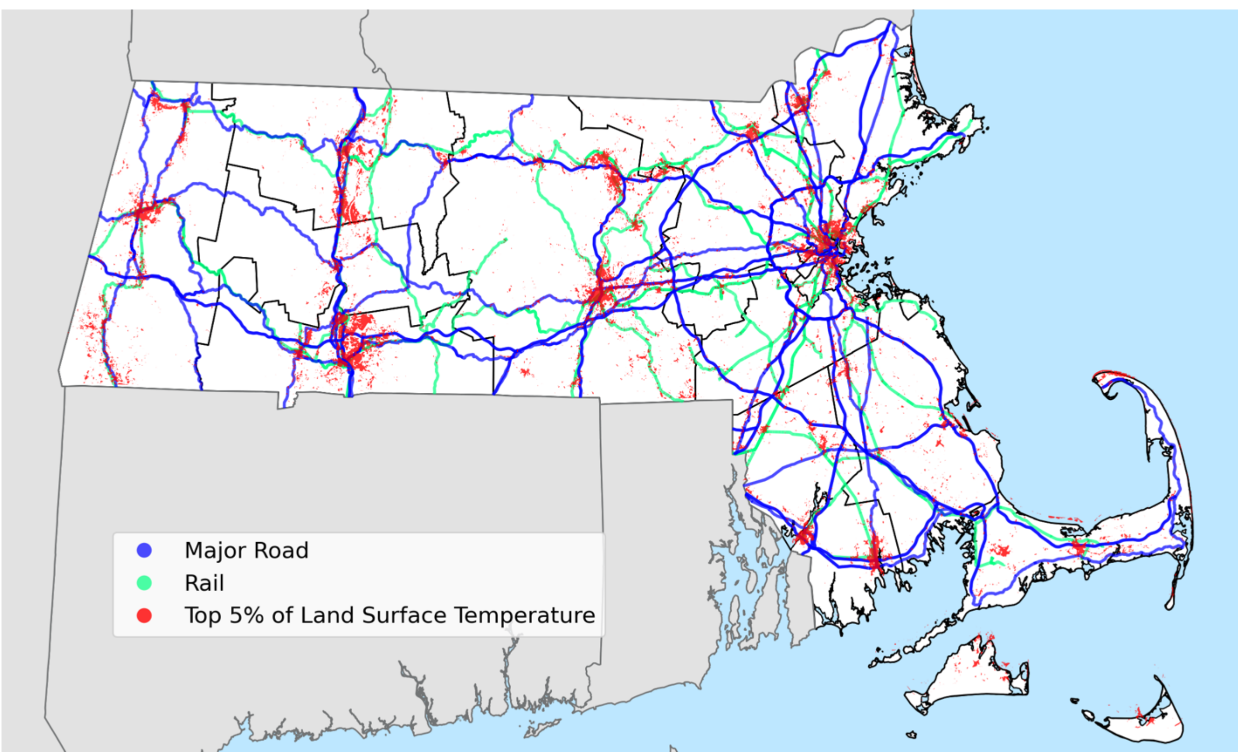
Figure 5.2-21. Heating and cooling degree days in Massachusetts, 1895–2020.

Transportation

Extreme cold can degrade transportation infrastructure and expose transit users and workers to unsafe temperatures. Extreme cold can necessitate additional delays and maintenance for transit, resulting in delays and longer exposures for workers and riders (Dolven, 2022). Extreme cold can also degrade roads and bridges through rapid freeze and thaw cycles that may damage road surfaces. An increase in freeze and thaw cycles can also damage bridge expansion joints. In extremely cold conditions, seawater can freeze (Sweeney & Staff, 2018), potentially interfering with sea ports and shipping. Some cargo is also sensitive to extreme temperature, leading to damage of goods during both extreme cold and extreme heat events in airports and seaports. This is particularly true of perishable items such as agricultural products, seafood, medications, and pharmaceuticals.

Extreme heat has potential impacts on the integrity and operation of the transportation system. High heat can cause pavement to soften and expand, creating ruts, potholes, and jarring and placing additional stress on bridge joints. Extreme heat may cause heat stress in materials such as asphalt and increase the frequency of repairs and replacements (Knott et al., 2019; Qiao et al., 2020). Figure 5.2-22 shows “hot spots” (the top 5 percent of the Commonwealth by LST) and major roads/rail infrastructure. Impacts to critical transportation infrastructure are likely to be greatest in regions with both major infrastructure and temperature hot spots. These impacts may be greatest in urban areas where the UHI effect exacerbates extreme temperatures (Wu et al., 2022). Given the disproportionate exposure of environmental justice and other priority populations to extreme urban heat (see discussion in Section 5.2.2.4.1), these impacts to roads and other infrastructure are likely to lead to greater infrastructure damage in neighborhoods with higher proportions of under resourced and underrepresented communities. Existing stormwater drainage systems may be undersized to safely convey greater rainfall intensity associated with extreme temperature away from roads and highways.

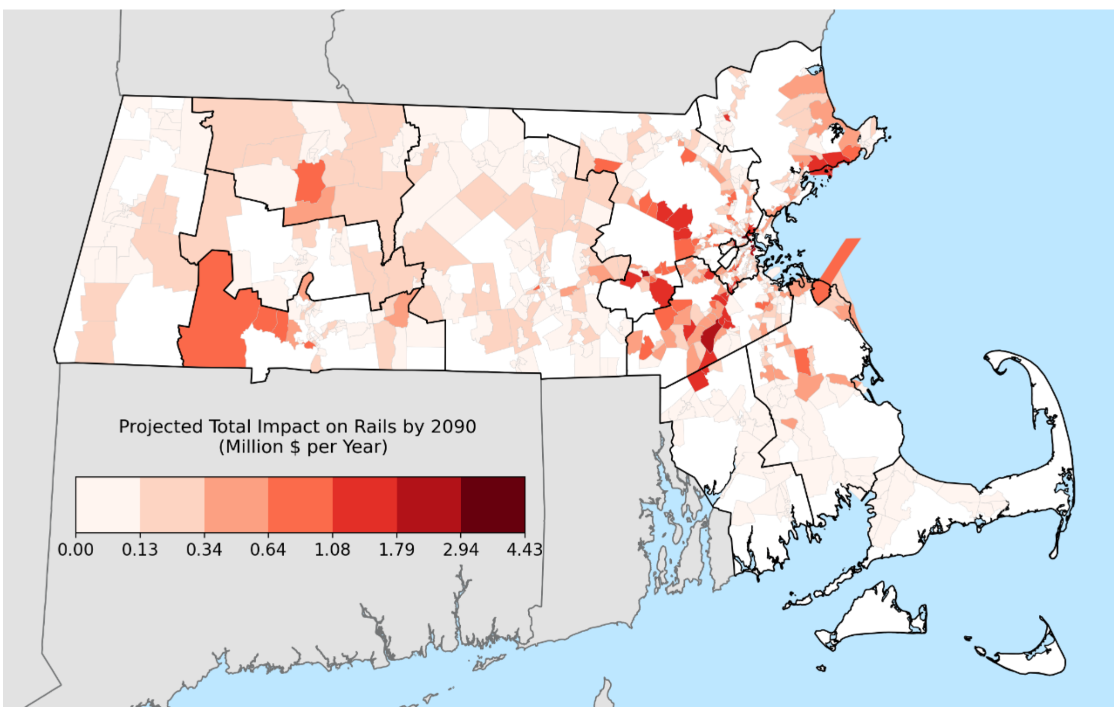
Rail and public transit operations are also affected by extreme heat, including impacts to infrastructure and essential workers. Rail and transit, maintenance, and construction workers are directly exposed to extreme temperatures. Railroad tracks, including commuter rail and exposed rail for public transit, can expand and “kink” in extreme heat, causing derailments (Chiu, 2022; Simauchi, 2022). This damage could require the use of long-distance bus bridges, with higher operating costs and longer transit times, as well as higher maintenance costs. Other rail components are also sensitive to extreme heat. Higher temperatures inside the enclosure-encased equipment, such as traffic control devices and signal control systems for rail service, can result in equipment failure.



Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022).

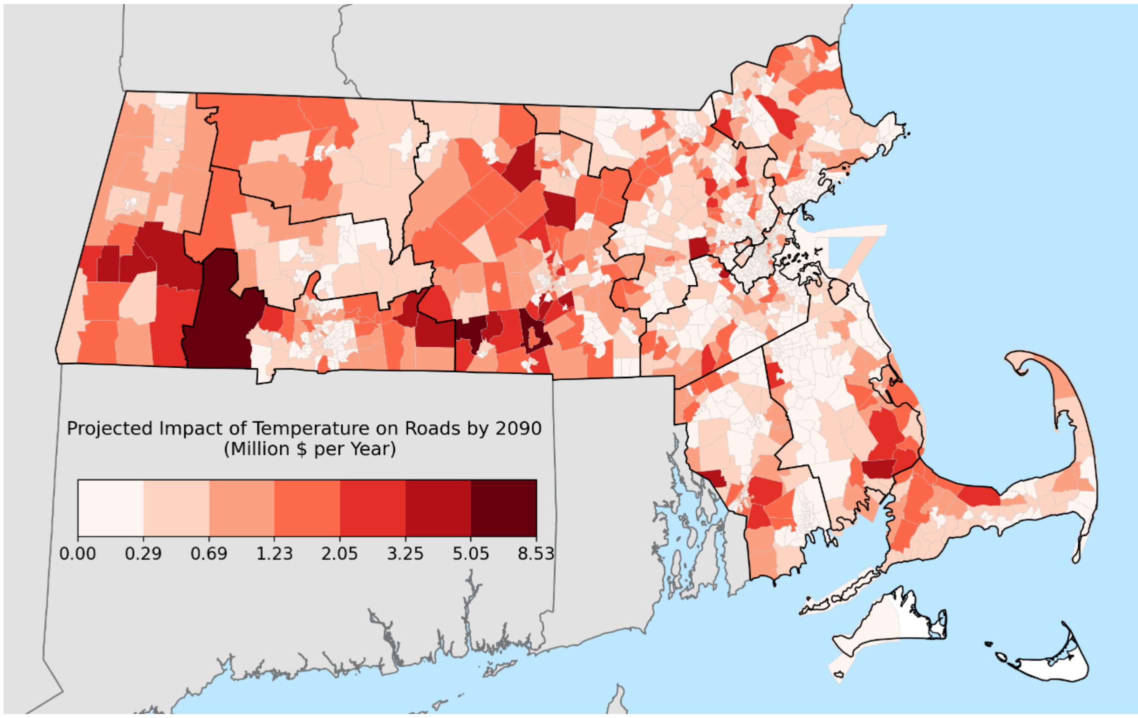
Figure 5.2-22. Hot spots and major transportation infrastructure.

As the climate warms, rising temperatures are expected to increase the costs of maintaining roads and rail infrastructure. The MA Climate Assessment finds that annual repair costs from temperature for rail in the Commonwealth will increase by $6 million by 2050 and $35 million by 2100, and for roads from all climate impacts (including precipitation and flooding) will increase costs by over $30 million by 2050 and over $100 million by 2100 (Commonwealth of Massachusetts, 2022). Figure 5.2-23 shows the spatial distribution of this expected damage to rail infrastructure by the 2090s, and Figure 5.2-24 shows the spatial distribution of expected damage to road infrastructure by the 2090s. Impacts of extreme temperature are projected throughout the state on both rail and road infrastructure. The highest rail costs are concentrated in the Eastern Inland and Boston Harbor regions. The cost associated with road maintenance are high throughout the state. Urban projects are more expensive than rural projects. However, because road costs per capita are highest in western Massachusetts, they pose the most significant financial burden for municipalities and local governments in the area. This may lead to a disproportionate government burden on these municipalities because they have relatively smaller populations.



Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-23. Projected temperature-driven increases to rail maintenance by the 2090s.



Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-24. Projected temperature-driven increases to road maintenance by the 2090s.

High temperatures also affect airplane operations and airports. High heat can stress runway materials and make it challenging for planes to take flight because airplane engines generate less lift in hot air. To adapt to increasing heat, Massachusetts airports may need to extend runways to accommodate these increasing challenges.

Operations are vulnerable to heat waves and associated power outages that affect electrical supply to rail operations and to supporting ancillary assets for highway operations, such as electronic signs. Peaks in power demand during hotter summer days could cause outages that affect electrified public transit. Increased heat also affects transportation workers, the viability of vegetation in rights-of-way, and vehicle washing or maintenance schedules through a variety of health-related impacts, as described in Section 5.2.2.4.1. Hot weather increases the likelihood that cars may overheat and increases the deterioration rate of tires, with a disproportionate impact on older, less frequently maintained cars.

Finally, extreme temperatures discourage active modes of transportation, such as bicycling and walking—common transportation modes for people without automobiles and who are transportation cost burdened. This may necessitate additional transit scheduling to reduce heat-related impacts (Rosenthal et al., 2022). It will have a secondary impact on sustainable transportation objectives and public health.

Water Infrastructure and Resources

The effects of extreme cold on water infrastructure services and resources include damage to assets and disruption to service due to freezing, as well as increased flood risk due to ice jams and broken pipes. Extreme cold can have impacts at the utility scale and the household scale (Morris & Hubbs, 2019). At the utility scale, extreme cold can affect treatment processes, treated water storage, hydraulic control systems, and raw water intakes. At the household scale, extreme cold can cause burst pipes, frozen parts for those relying on well water, or utility service interruptions.

High temperatures can have significant impacts on water infrastructure, including increased cooling requirements, equipment and structural impacts, and increased risks for employees. Extreme heat can damage aboveground infrastructure such as tanks, reservoirs, and pump stations. Water utility workers are often directly exposed to extreme heat and need workplace protections to limit exposure to extreme heat and the associated adverse health consequences (Water Utility Climate Alliance, 2020). Warmer temperatures can also lead to corrosion, water main breaks, and inflow and infiltration into water supplies. Increasing temperatures may pose additional threats to water utilities, including eutrophication or increasing algal and cyanobacteria growth in reservoirs.

Hotter temperatures may also change the demand, availability, or usability of water. Hotter temperatures will also likely result in increased outdoor water consumption for agriculture, landscaping, and human users. Combined with other climate impacts, such as an increase in surface water evapotranspiration, changing precipitation patterns, and groundwater recharge rates, increased water demand may challenge the capacity of water supplies and providers, particularly during drought conditions. Hotter temperatures can also threaten drinking water quality, with larger impacts among marginalized communities (Wang et al., 2022). Extreme heat is likely to result in increased drought conditions, and this has significant implications for water infrastructure, as discussed in Section 5.6 (Drought).

Urban Tree Cover

Extreme temperatures can threaten the health of urban forests, reducing urban tree cover. Like the natural environment in Massachusetts, urban forests are adapted to a range of climate conditions and their health may decline as the climate changes. As noted in the MA Climate Assessment, extreme temperatures affect trees' nutrient cycles, increased ambient winter temperatures allow for higher levels of pests and pathogens, and ice storms can kill unprotected urban trees. Extreme heat can also contribute to secondary hazards such as drought, wildfire, or invasive species, which can also lead to loss or damage of urban trees. This can complicate the task of introducing urban trees, making it more challenging to reduce the relative shortage of green space in under-resourced and underrepresented communities (McDonald et al., 2021). To summarize, climate change is likely to have a negative impact on street trees, although further research is needed to evaluate those impacts (Esperon-Rodriguez et al., 2022; Khan & Conway, 2020).

Lifelines

Extreme temperatures can affect lifelines, the systems of services that help preserve human life. Lifelines include safety and security systems; access to food, water, and shelter; health and medical services; energy; communications; transportation; and hazardous material management. Many of these lifelines are described in more detail in the sections on each sector.

Extreme and rising average temperatures can have negative impacts on safety and security systems. As Section 5.2.2.4.2 above describes, extreme heat events can lead to disruptions of safety and security systems such as emergency dispatch, training of emergency response officers, and the daily operations of government workers such as fire response or law enforcement.

Extreme temperatures can reduce access to food, water, and shelter. As Section 5.2.2.4.5 below describes, extreme heat can reduce the quantity and quality of food produced in the Commonwealth. Extreme heat can increase the risk of food spoilage, including during transport (e.g., grocery delivery). Fresh food that depends on a "cold chain" of temperature-controlled transport from field to grocery store is particularly vulnerable to extreme temperatures (Han et al., 2021). As described under "Water Infrastructure and Resources" above, temperatures can affect the normal function of water utilities and increase the risk of contamination such as cyanobacteria. Extreme temperature can lead to damage to residences, for example by extreme cold leading to burst pipes and associated damage. In periods of extreme temperature, shelters that lack adequate heating or cooling may not be sufficient to prevent adverse physical or mental health impacts. Additionally, extreme heat may affect the cold chain that transports temperature-sensitive vaccines and other medical equipment (Lin et al., 2020; Pambudi et al., 2022).

There are a variety of temperature-related impacts to health and medical services. As Section 5.2.2.4.1 describes, there are various temperature-related health impacts, including frostbite, hypothermia, heat exhaustion, and heat stroke. Section 5.2.2.4.2 describes some ways in which temperature can affect medical services, such as leading to high demand for emergency dispatch. Additionally, temperature may impede patient movement by limiting potential modes of transportation, as described under "Transportation" above. Hospitals throughout the Commonwealth are in regions with high LST, including Worcester State Hospital, the University of Massachusetts Chan Medical Center, Taunton State Hospital, Soldiers Home in Holyoke and Chelsea, Newton Pavilion, and the Massachusetts Mental Health Center. High LST can stress these medical facilities by increasing the rates of heat-related illness in surrounding populations, and by increasing the energy needed to cool hospital rooms and equipment.

The “Energy” section above discusses how extreme and rising average temperatures can affect energy services. Extreme temperatures can lead to outages and rising average temperatures can increase the demand for electricity.

The “Transportation” section, also above, discusses how extreme and rising average temperatures can affect transportation infrastructure. Extreme temperatures can degrade infrastructure (including roads, rails, bridges, ports, and airports) and discourage some modes of alternative transportation. This includes infrastructure critical for moving people and goods in an emergency.

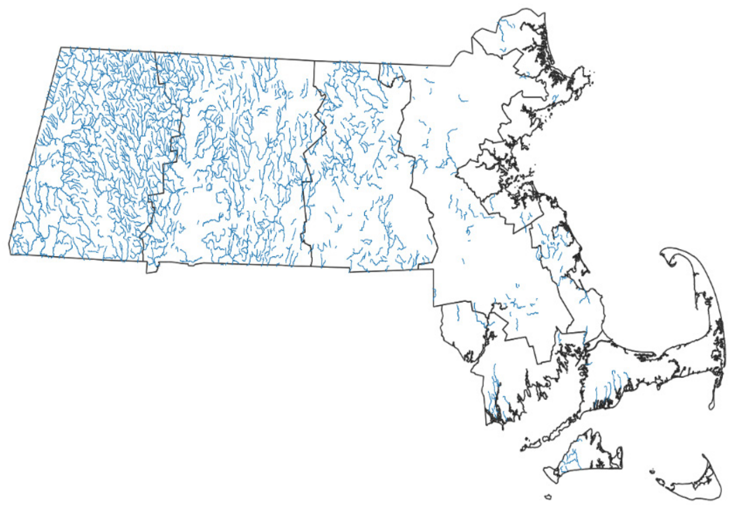
Temperature can affect communications infrastructure. Extreme temperatures can lead to electricity outages and disruptions to internet or other communications infrastructure. This is particularly true for telecommunications infrastructure such as data centers, which can require great deals of electricity for cooling. However, data centers have made impressive progress in energy efficiency, reducing their energy needs during extreme heat events (Masanet et al., 2020).

Extreme heat may also impede the ability of local emergency services to protect environmental justice and other priority populations from extreme heat. As the survey responses in Table 5.2-7 note, extreme temperatures can cause outages to emergency dispatch equipment. This may interact with limited public knowledge of sheltering options and limited alternatives for public outreach to impede the ability of the public to shelter from the hazards of extreme temperature. For example, the *Town of Shutesbury Hazard Mitigation Plan* notes that about half of the town’s households are not enrolled in their emergency temperature alert system, and that this may interact with failure of emergency communication and low public knowledge of available sheltering options to limit the number of residents who can safely shelter from extreme temperatures (Shutesbury Hazard Mitigation Planning Team & Franklin Regional Council of Governments, 2021).

Temperatures can increase exposure to some hazardous materials. Cold temperatures can lead to mold exposure (through conditions caused by burst pipes). Section 5.2.2.4.4 below includes a discussion of how increasing temperatures contribute to additional algae and cyanobacteria, another source of pollution. Additionally, temperature can interfere with rail services and could introduce the possibility of derailment of trains carrying unknown chemicals; the *North Adams Hazard Mitigation and Climate Adaptation Plan* identified this as a potential risk (City of North Adams, 2021).

5.2.2.4.4 Natural Environment

Because species are adapted to survive within a specific temperature range, extreme temperature events and rising average temperatures can place significant stress on both individual species and the ecosystems in which they function. Individual extreme weather events can have a limited long-term impact on natural systems, such as unusual frost events occurring after plants begin to bloom in the spring. However, the impact on natural resources due to changing average temperatures and the changing frequency of extreme climate events is likely to be significant and widespread (IPCC, 2022). Climate change is already having severe impacts on terrestrial, freshwater, coastal, and ocean ecosystems in New England and is expected to have further ecosystem impacts as the climate continues to warm. These changes will also have implications for human health and the economy, as discussed in Sections 5.2.2.4.1 and 5.2.2.4.5.

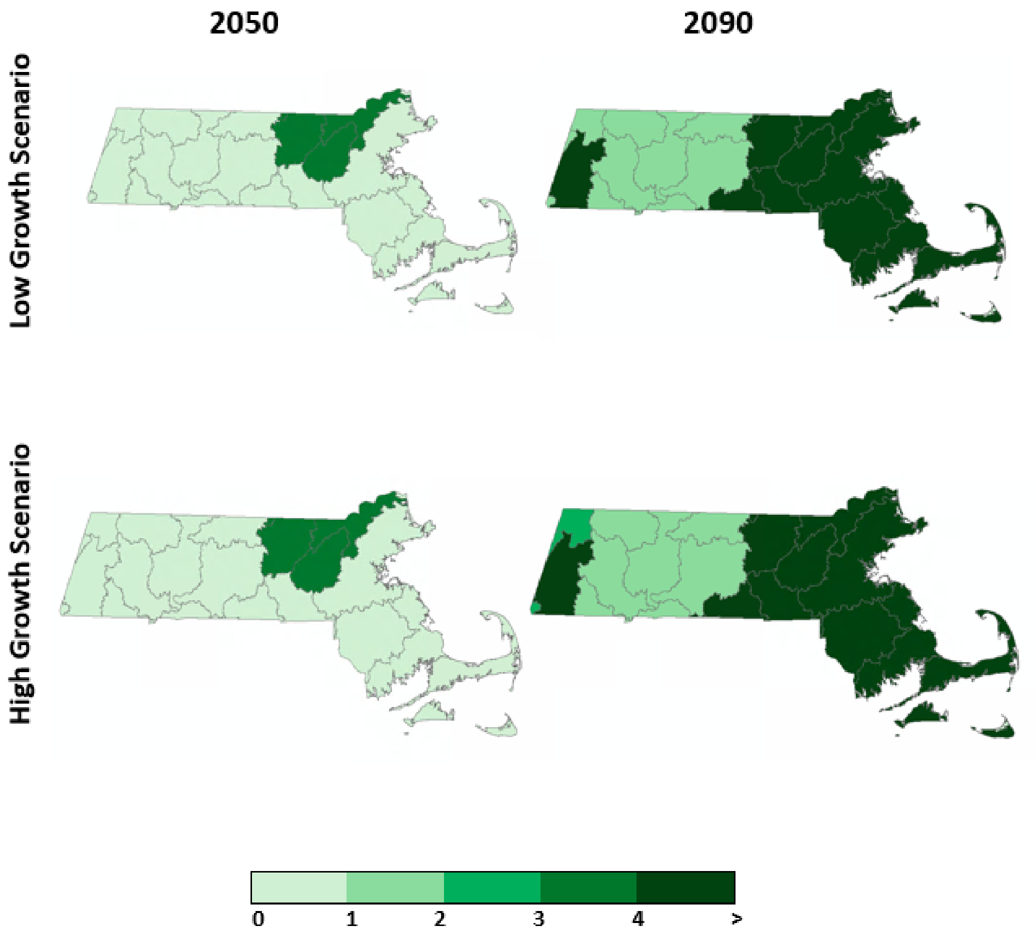


Map created using a data layer from MassGIS (2022).

Figure 5.2-25. Massachusetts cold-water fisheries resources in rivers and streams as of 2021.

The MA Climate Assessment found that warming in freshwater, coastal wetland, and marine ecosystems are the most urgent impacts to the natural environment. The Massachusetts Division of Fisheries and Wildlife developed a map of Coldwater Fisheries Resources based on the National Hydrography Dataset to illustrate the distribution of cold-water fisheries in the state (MassWildlife GIS Program, 2021). Figure 5.2-25 shows the distribution of cold-water fisheries resources in rivers and streams in the Commonwealth, which are one of the freshwater ecosystems at greatest risk from rising temperatures. For example, increases in temperatures of 2–6°C could reduce the cold-water habitat available to brook trout in summer by about 40–70 percent (Ebersole et al., 2020). Warming temperatures are also expected to degrade cool- and warm-water ecosystems, thereby potentially affecting all Massachusetts rivers, streams, lakes, and ponds. The need and demand for aquatic habitat restoration projects is expected to increase significantly in the future to improve the resilience of aquatic ecosystems to the effects of natural hazards and climate change.

Warming temperatures threaten freshwater ecosystems through reduced dissolved oxygen concentrations, increased algal and bacterial growth, and shifting habitats' characteristics away from those required by the species that inhabit them. These changes affect species including fish, reptiles, amphibians, and birds, as well as reducing ecosystem services (Commonwealth of Massachusetts, 2022). Higher temperatures increase the risk of algal blooms, including cyanobacteria. Figure 5.2-26 shows where algal blooms are expected to increase in the Commonwealth. Algal blooms are associated with a range of negative environmental, economic, and human health impacts (Zohdi & Abbaspour, 2019). In the natural environment, algal blooms negatively impact biodiversity and threaten ecosystem services, largely by threatening plankton diversity and organisms that depend on diverse plankton (Amorim & Moura, 2021).

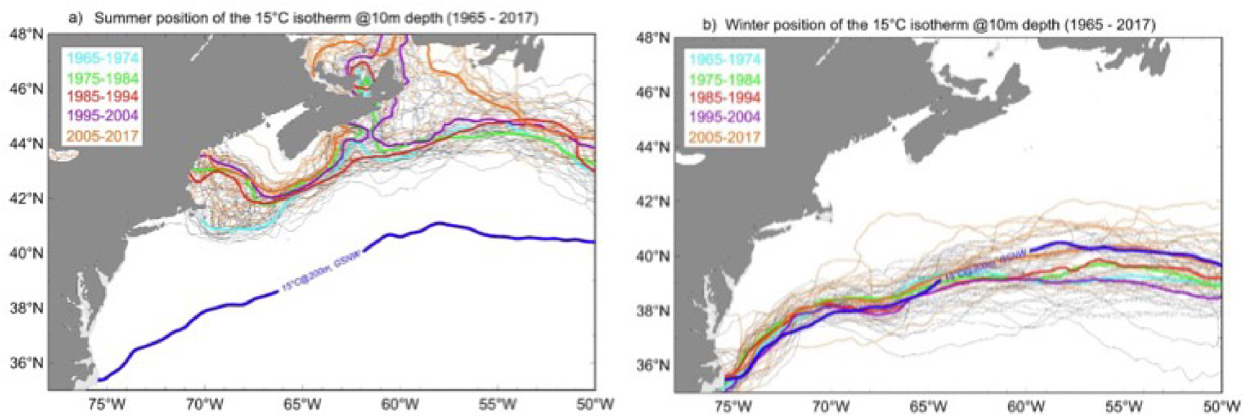


Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-26. Modeled future change in cyanobacteria concentrations (in thousand cells/milliliter).

Ocean temperatures have been rising over the past few decades, with severe consequences for marine ecosystems. Figure 5.2-27 shows the extent of warming by tracking the movement of the 15ºC isotherm (the region of water whose average summer or winter temperatures are 15ºC) over time. These rising temperatures are already causing, and are expected to further cause, marine organisms to shift from their historical ranges, with significant implications for marine and coastal ecosystems. Rising ocean temperatures also have additional effects on ocean circulation and regional climates.

Warming marine waters have already led to negative impacts on several important marine ecosystems in or near Massachusetts waters. One important temperature-sensitive marine organism is eelgrass (*Marina zostera*), a flowering plant that grows in underwater meadows along the Massachusetts coast. Eelgrass provides nurseries for juvenile fish, providing ready food sources and protection from predators, and has been shown to sequester, or store, carbon over the long term in New England waters (Novak et al., 2020). Eelgrass habitat is temperature-sensitive, however, and dies back when water temperatures reach 25°C (77°F) in the summer (Beca-Carretero et al., 2018). Marine heat waves, rising temperatures, and associated circulation changes are already affecting several important marine organisms in the North Atlantic ocean, such as kelp forests (Filbee-Dexter et al., 2020; Wright et al., 2022), cold-water corals (Morato et al., 2020), right whales (Meyer-Gutbrod et al., 2021; Record et al., 2019), and deep-sea fisheries (Bryndum-Buchholz et al., 2020; Morato et al., 2020). In Cape Cod Bay, warmer water temperatures have changed the usual mixing patterns that maintain adequate oxygen concentrations in deeper water, resulting in the death of scallops and caged lobsters in some areas (Pugh & Scully, 2022). Due to these changes, the decline in fisheries is expected to have severe economic impacts (discussed in Section 5.2.2.4.5).



Source: Seidov et al. (2021).

Figure 5.2-27. Location of the summer and winter 15°C isotherms in the Gulf of Maine.

Higher summer temperatures will also disrupt the hydrology of coastal wetlands—ecosystems that also face large threats from sea level rise and drought, as discussed in Sections 5.5 (Coastal Flooding) and 5.6 (Drought). Paired with a higher incidence and severity of droughts, high temperatures and evapotranspiration rates could lead to habitat loss and wetlands drying out (Commonwealth of Massachusetts, 2022). Impacts include shifts in water temperature resulting in species composition changes, habitat structure, and ecosystem services such as flood water storage and filtration of pollutants. Reduced wetland health (especially due to drought) may lead wetlands to become sources rather than sinks of carbon emissions (Salimi et al., 2021). As the *Great Marsh Coastal Adaptation Plan* notes, restoration projects are complicated by a confluence of other interconnected human stressors such as poor land-use planning, increased runoff, and increased water withdrawals in which climate change provides an increasing threat (Schottland et al., 2017).

Rising temperatures are also expected to affect forest health, and particularly the health of boreal forests and other cold-adapted forests (MA DCR, 2020). Extreme heat also increases the likelihood of other threats to Massachusetts forests, such as drought and wildfire. Those threats are discussed in Sections 5.6 (Drought) and 5.16 (Wildfires). The threat of rising temperatures is particularly pertinent for ecosystems that (like many in the northeastern U.S.) lie on the border between two biome types. Over time, shifting habitat may result in a geographic mismatch between the location of conservation land and the location of critical habitats and species the conserved land was designed to protect.

Forest health is essential for carbon storage and freshwater quality. Stress on forests, including stress from rising temperatures, may diminish they ecosystem services they provide, like carbon sequestration and storage and water filtration (MA DCR, 2020).

Increasing temperatures are expected to have significant impacts on the locations and behaviors of plants and animals throughout the Commonwealth. As the climate warms, some species will shift up in elevation and northward, potentially away from their historic ranges, where movements are facilitated by habitat connectivity. This can have significant impacts for the natural environment through the loss of species that play key ecosystem roles, or the introduction of invasive species that previously did not extend into these habitats. It can also create a mismatch between existing conservation regions and the species they were originally designed to protect. A body of research also documents changes in species phenology (the pattern of seasonal life events in plants and animals). As species respond to climate change, they will likely continue to shift their phenologies or ranges to track suitable habitats (Damien & Tougeron, 2019; Piao et al., 2019; Renner & Zohner, 2018). These ecosystem responses to climate change are only beginning to emerge, and further work is needed to understand and prepare for the impacts of future climate change (Jones & Driscoll, 2022).

Changing seasonal cues can lead to ecological mismatches, as plants and animals that rely on each other for ecosystem services “go out of sync.” For example, migratory birds that rely on specific food sources at specific times may reach their destinations before or after the species they feed on arrive or are in season. Additionally, invasive species tend to have more flexible phenologies than their native counterparts; therefore, shifting seasons may increase competition between existing native and introduced invasive species. This hazard is discussed in more detail in Section 5.10 (Invasive Species).

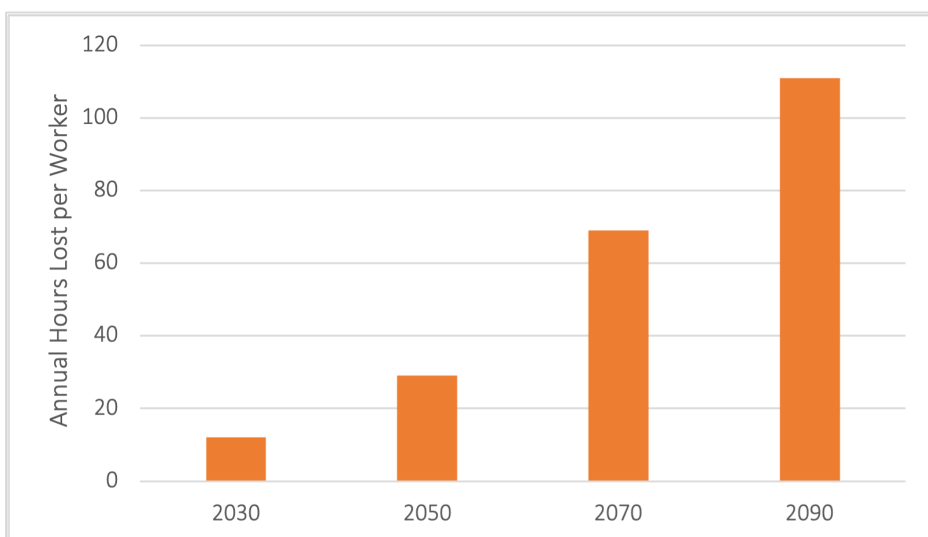
As a result, climate change will likely reduce the success of traditional wildlife and habitat management, including aquatic habitat and upland restoration, land conservation, and mitigation of non-climate stressors. Many of these restoration projects (e.g., cold water stream habitat restoration) are sensitive to temperature extremes and increasing average temperatures. The uncertainty of future changes in temperature caused by climate change may increase the complexity of restoration project design, implementation, and management. It is therefore important to plan for uncertainty, use adaptive management, and develop forward-looking strategies to increase the climate resilience of ecological restoration projects (Simonson et al., 2021; Zabin et al., 2022)

5.2.2.4.5 Economy

Extreme temperature events affect the economy through reduced ability to work, reduced fishing productivity, disruption or loss of business function, damage to inventory and buildings, and reduced agricultural productivity. The MA Climate Assessment finds that by 2090, workers in the Commonwealth could lose over 10 million hours of work and associated wages due to increased exposure to extreme heat (Commonwealth of Massachusetts, 2022). Figure 5.2-28 shows how the magnitude of disruption is expected to increase as the climate changes.

Heat-related work disruptions are likely to have greater consequences for low-income populations or workers in certain industries. Those earning lower incomes may be less able to flexibly change work hours or working conditions to avoid exposure to extreme heat. Several industries are particularly exposed to extreme heat, including agriculture, fishing, construction, manufacturing, transportation, and warehousing. Employment in these industries makes up about 20 percent of the Commonwealth's work force, and manufacturing and/or construction was flagged as a priority industry in nearly all 2020 Regional Labor Market Blueprints. In industries where people work indoors, productivity can still be affected by extreme heat due to insufficient workplace cooling systems or heat-related transportation delays (as described in Section 5.2.2.4.3).

Extreme temperatures can raise the cost of doing business through impacts to buildings, utilities, transportation, and/or inventory. Business owners may be faced with increased financial burdens due to unexpected building repairs (e.g., repairs for burst pipes in freezing temperatures), higher than normal utility bills, or business interruptions due to power failure (i.e., loss of electricity and telecommunications).



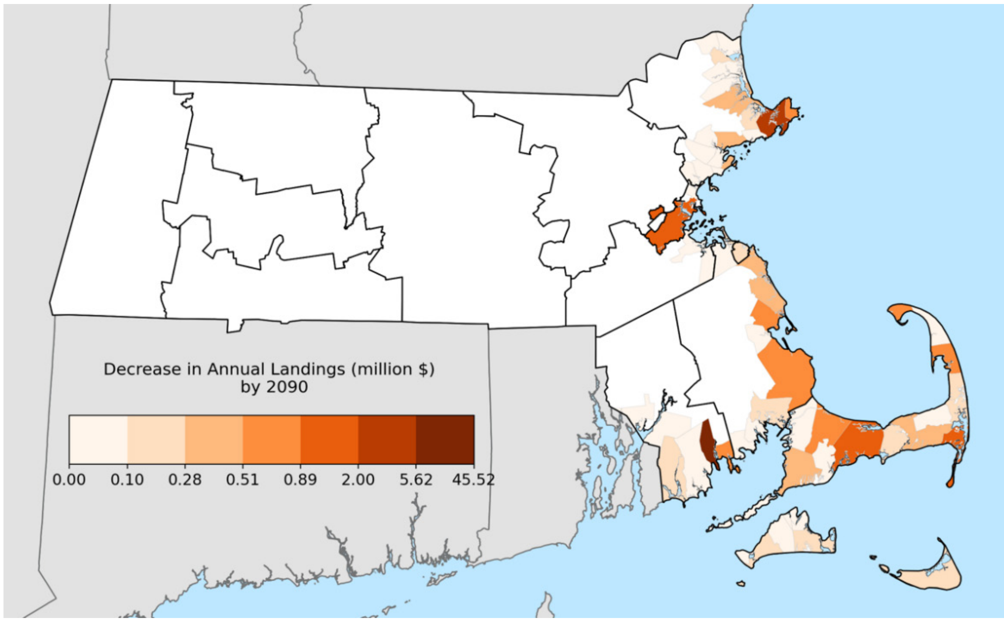
Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-28. Average annual lost hours due to extreme heat in the Commonwealth per exposed worker.

Increased demand for water and electricity may result in shortages and higher costs for these resources. Industries that rely on water for business (e.g., landscaping businesses) will also face significant impacts. Temperature-related impacts to the transportation sector can reduce productivity and income, as commodities and goods cannot reach their intended destination. Extreme temperatures can also damage inventory (e.g., if warehouses are too humid) and threaten products that depend on a “cold chain” of temperature-controlled transport such as food or vaccines (Han et al., 2021; Lin et al., 2020; Pambudi et al., 2022).

By increasing energy costs (for both heating and cooling), extreme temperatures will have an economic impact on both households and businesses. This can be a significant economic impact for low-income households. In 2020, 17 percent of American households reported reducing or forgoing basic necessities due to their home energy bills at least one month of the year (U.S. EIA, 2022). Researchers find that the impacts of extreme weather lead to larger impacts on energy consumption for low-income households, displacing spending on other essential categories such as food (Doremus et al., 2022). This is exacerbated by discrepancies in the take-up of residential energy efficiency measures: low-income households experience persistently lower energy savings than higher-income households with similar baseline levels of consumption (McCoy & Kotsch, 2021).

Increased ocean temperatures are among the major contributors to reduced marine fishery and aquaculture productivity. Fishing is a large economic activity in Massachusetts, and in 2020 New Bedford was the top port in the U.S. by value of sea food imported (NOAA Fisheries, 2022). As the climate changes, productivity is expected to decline through rising ocean temperatures and ocean acidification. The MA Climate Assessment found that catches are expected to decline by over 10 percent in value by the 2090s (Commonwealth of Massachusetts, 2022). Figure 5.2-29 shows the spatial distribution of these projected declines. This is expected to disproportionately affect low-income communities, particularly those in New Bedford.



Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Figure 5.2-29. Projected decrease in landings (in millions of dollars) in 2090.

In Massachusetts, several economically important agricultural products are at heightened risk of impacts from rising temperatures and extreme heat. As field-grown crops and livestock are directly exposed to changing temperatures, the agricultural industry is directly at risk in terms of economic impact and damage due to extreme temperature and drought events. Several economically important crops in Massachusetts are particularly vulnerable to warmer temperatures and associated drought conditions. Many fruits, such as apples and cranberries, need a certain number of cold days and may be vulnerable to sun or heat damage (Dalhaus et al., 2020; Hirabayashi et al., 2022). Rising temperatures will also affect important annual crops—for example, sweet corn yields decline from exposure to temperatures above 86ºF (Dhaliwal & Williams, 2022). Increasing average temperatures may make crops more susceptible to invasive species [see Section 5.10 (Invasive Species) for more information]. Higher temperatures that result in greater concentrations of ozone harm plants that are sensitive to ozone (Emberson, 2020). Additionally, as described in Section 5.2.2.4.4, changing temperatures can impact the phenology of plants and native species.

Livestock are also affected by extreme temperatures, as heat stress can make animals more vulnerable to disease, reduce their fertility, and decrease the rate of milk production. In cows, heat stress can increase the risk of mortality and reduce the quantity and quality of dairy products (Summer et al., 2019; Tao et al., 2020). Additionally, scientists believe the use of parasiticides and other animal treatments may increase as the threat of invasive species grows. Increased use of these treatments increases the risk of pesticides entering the food chain and could result in pesticide resistance, which could have additional economic impacts on the agricultural industry.

Chapter 5. Risk Assessment and Hazard Analysis

Changes in Groundwater

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5.3 Changes in Groundwater

5.3.1 Changes in Groundwater Problem Statements

The entire state of Massachusetts depends on groundwater resources for a variety of ecosystem services and benefits and is exposed to changes in groundwater that could present challenges to human and natural systems. Massachusetts has a range of groundwater, geologic, topographic, soil, vegetation, land use patterns that affect the complex relationship between groundwater and the hydrologic cycle.

5.3.1.1 Groundwater Rise

Flooding and damage results when groundwater rises above the current land elevation or into basements, tunnels, pipelines, water supplies, or other belowground assets. Rising groundwaters can cause flooding that can damage homes, businesses, aquifers, coastal wetlands, and other habitats and infrastructure by flooding low-lying assets and resources and creating unstable conditions in unconsolidated sediments and land made up of highly permeable sand and gravel deposits. Coastal plain ponds, wetlands, and fish hatcheries are likely to be at risk of salinity intrusion that will result from groundwater rise, which could alter their function and allow for persistence and proliferation of invasive species (e.g., *Phragmites*).

While there is a need for research and information to understand the exact impacts of sea level rise and climate change on groundwater, there is growing evidence based on modeling, observation, and monitoring that sea level rise is resulting in a higher water table in some areas of the Commonwealth. There is a need for research to identify areas that are most vulnerable to groundwater rise and factors that influence the frequency and likelihood of groundwater inundation.

Additionally, groundwater rise could result in damage to stormwater infrastructure, practices, and controls that could result in increased pollution and flooding. Areas with higher exposure to polluted water, such as locations near non-functioning septic systems, contaminated landfills, toxic sites, and overburdened sewer systems are at higher risk of exposure to contaminated water.

5.3.1.2 Groundwater Depletion

Climate change is also increasing climate variability and changing the duration and intensity of drought conditions, which places downward pressure on the water table. This depletion of groundwater supplies increases the intensity and duration of droughts, damages and disrupts ecosystems and ecosystem functions, endangers adequate water supplies, and presents risks to structures whose design depends on a stable water table.

5.3.1.3 Changes in Groundwater Characteristics

Contamination of groundwater can result from changes in precipitation patterns that increase the risk of runoff transporting pollutants. In combined sewage and rainwater systems, flooding and precipitation can result in combined sewage outflows, which can contaminate water supplies, soil, ecosystems, and groundwater quality. Saltwater intrusion contaminates drinking sources and increases the risk of damage to salt-sensitive infrastructure and species. Extreme heat events can affect shallow groundwater systems as well.

5.3.2 Changes in Groundwater Risk Assessment

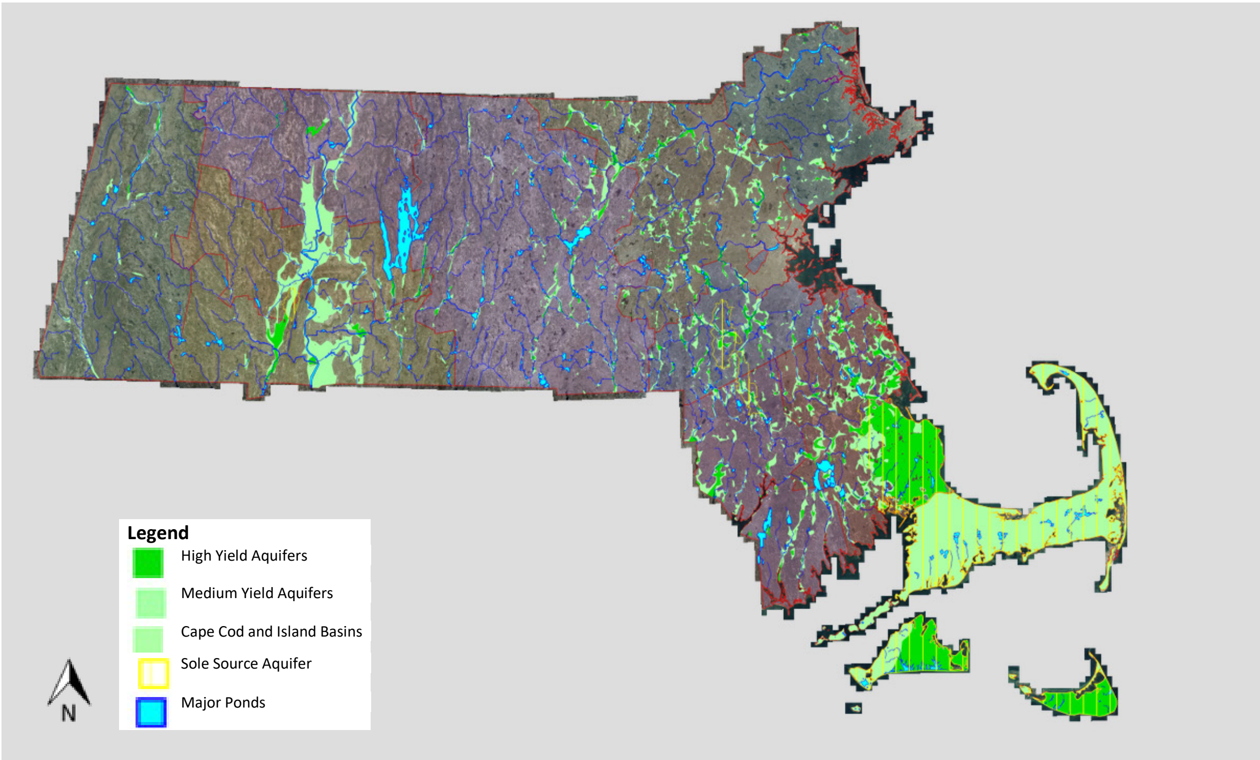
5.3.2.1 General Background

Groundwater is an important source of drinking water for many communities in the Commonwealth. It also provides fresh water for ecosystems, agriculture, and other open spaces and natural areas throughout the Commonwealth.

“Groundwater” refers to fresh water located underground in saturated zones beneath the surface and stored in pores between sediments and rock below the water table (the top of the saturated zone). Groundwater results from water on the surface moving downward through pore spaces and soil particles (the zone of aeration, or unsaturated zone) until it reaches a depth where the pore spaces are saturated with water (the saturated zone).

Groundwater is contained in formations known as aquifers that are above a layer of the saturated zone characterized by impermeable rock, soil, or clay. Several groundwater flow systems (lenses) make up the groundwater system. Confined aquifers are located between layers of impermeable material, causing the water to be under pressure and enabling it to rise when penetrated by a well. Unconfined aquifers located near the surface and at atmospheric pressure can rise and fall and are affected by surface conditions such as drought and pollution. The map in Figure 5.3-1 identifies high- and medium-yield aquifers in Massachusetts and resources that provide the sole source of drinking water for communities.

Groundwater is an essential freshwater natural resource and plays a critical role in the hydrologic cycle, providing benefits that sustain both human and natural systems. Groundwater is sensitive to the impacts of human activity and climate change (Lall et al., 2020). Water levels can change through seasons and across years. With climate change these fluctuations may result in impacts in the natural and built environment, destabilizing structures, causing flooding and increased inundation, and affecting baseflows across ecosystems. Wetlands can also respond to changes in groundwater levels, expanding as groundwater level increases and contracting as groundwater is depleted (Ameli & Creed, 2019).



Source: Developed using data from Mass Mapper using data on aquifer yields.

Map of high- and medium-yield aquifers (green) with major streams and ponds that interact with the aquifers. Yellow borders identify groundwater resources that are sole source of water for communities. Streams are depicted in Blue. County boundaries are outlined in red.

Figure 5.3-1. Map of aquifers and major surface water resources in Massachussets.

The Commonwealth's public drinking water supply depends on groundwater aquifers, directly or indirectly. Groundwater and surface water supported by groundwater provide most of the water supply for households and businesses (Boutt et al., 2010; Knott et al., 2022). These resources provide water for drinking, irrigation, and industrial uses through public water systems and private wells. These resources are also critical for ecosystem services including stormwater management (Knott et al., 2022). Groundwater can also contribute to community resilience and support adaptation to changes in precipitation and availability of surface water.

Groundwater is necessary for the natural environment and provides water supply for ponds, wetlands, and streamflow and water supplies during periods of low precipitation (Boutt et al., 2010). Discharge from aquifers is the primary supply of streamflow to support surface water levels during dry periods (Simcox, 1992). The relationships between the quantity, quality, location, and composition of groundwater are complex, and attention to these issues is growing (Knott et al., 2022) as climate change effects threaten the benefits provided by groundwater to communities and ecosystems.

5.3.2.2 Hazard Description

Groundwater is a renewable, long-term resource that depends on an adequate quantity and quality of water to replenish it. The quantity and quality of groundwater reflects the cumulative effects of extraction, recharge, and contamination (Lall et al., 2020). Groundwater challenges are caused or amplified by other hazards such as sea level rise, extreme temperatures and rising temperatures, drought, extreme precipitation, and other meteorological events.

There are three primary categories of risk associated with groundwater in Massachusetts:

- Rise in groundwater levels
- Groundwater depletion
- Changes in groundwater quality and characteristics

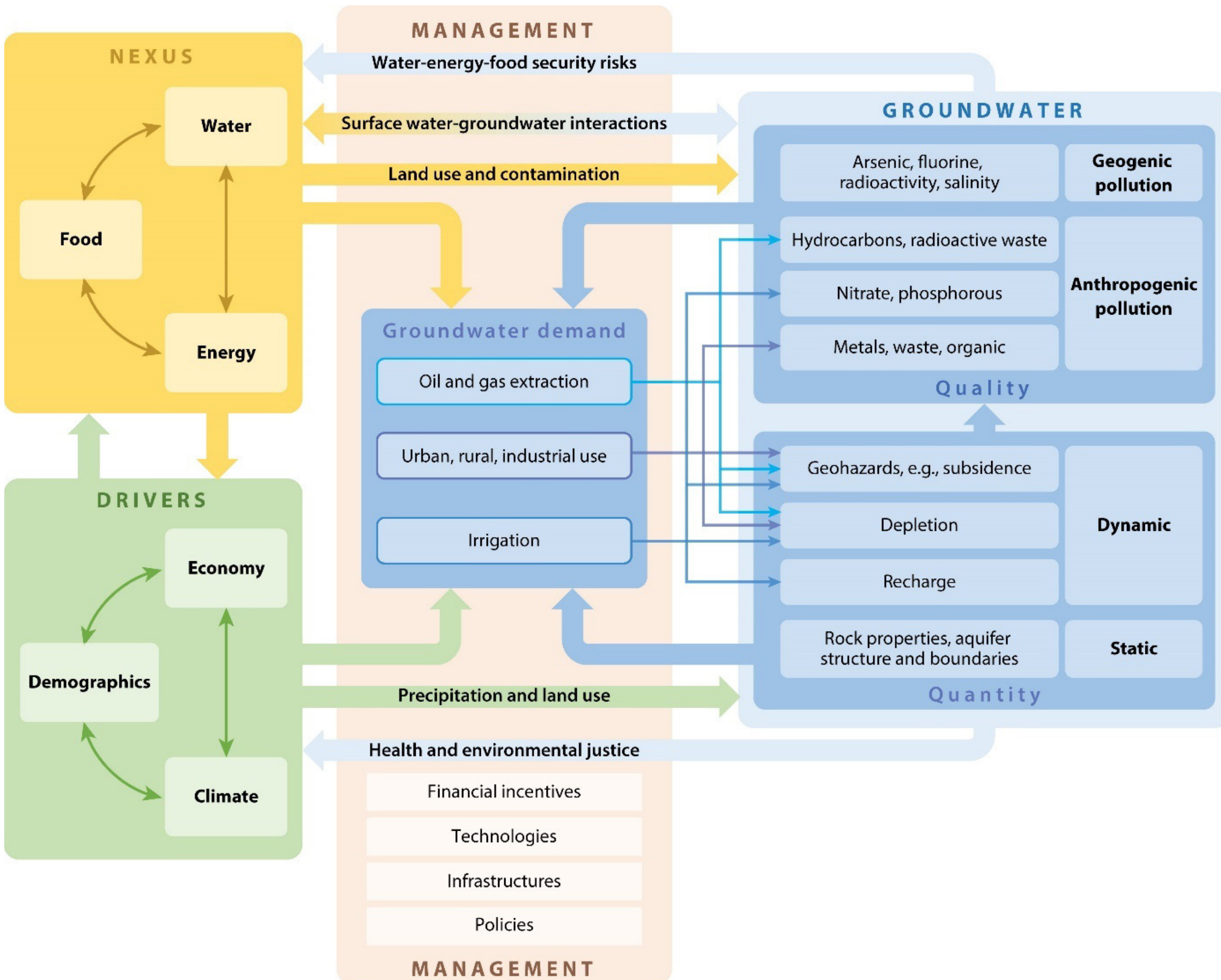
When variation of groundwater surpasses an elevation threshold or duration, changes in groundwater can affect human and natural systems. The disruption can generate long-term risk to human life and property. Changes in groundwater can result in interruption, loss, and risk due to human demands and impacts on the resource. Infrastructure is built using historical water conditions and parameters. When groundwater levels change outside historical ranges, this can affect critical infrastructure including drainage systems, septic systems, and building foundations.

The availability of groundwater resources is a result of static and dynamic changes, management decisions, and "drivers of change" as summarized in the diagram in Figure 5.3-2 (see next page). The diagram synthesizes the complex factors and interactions that contribute to the three primary categories of challenges identified for Massachusetts (Lall et al., 2020).

5.3.2.2.1 Factors Influencing Changes in Groundwater Levels

Groundwater levels are a result of the net rate of recharge and loss. Aquifer recharge is the rate at which water infiltrates the ground surface and travels through the unsaturated zone to the water table (New York Water Science Center, 2015). Aquifers in the Commonwealth are naturally recharged from surface water (infiltration from streams) and precipitation (Simcox, 1992), and can also be artificially recharged by stormwater practices or wastewater disposal. Groundwater loss can occur through groundwater discharge to surface water, a naturally occurring process, or through withdrawals for human use.

The increase of impermeable surfaces in the built environment, which is particularly significant in urban areas, reduces opportunities for precipitation and runoff to permeate into the ground and recharge groundwater systems. A higher density of vegetation is also associated with lower rates of recharge due to evapotranspiration. The concentration of pollutants on the surface can also affect groundwater quality. Storm drainage systems can also affect where water from precipitation and runoff is directed.



Lall U, et al. 2020.
Annu. Rev. Environ. Resour. 45:171–94

Source: Lall et al. (2020); released under CC BY 4.0.

As outlined by the authors, “the characterization of groundwater resources requires a detailed comprehension of the static (e.g., geologic properties) and dynamic (e.g., water fluxes) parameters to describe groundwater quantity, and the pollutants to describe the groundwater quality. The state of the groundwater resources (right column) is determined by forcings such as demographics, land use and land cover change, economics, climate variability and trends, irrigated agriculture, and access to energy (left column). Groundwater use can lead to aquifer depletion, land subsidence, and contamination of aquifers. Groundwater management mitigates, amplifies, or regulates the impacts of the overarching forcings on the groundwater resources, through subsidies and financial incentives, new technologies, infrastructure provisions, or policies and regulations.”

Figure 5.3-2. Diagram of groundwater challenges, drivers, management, and systems.

While groundwater in Massachusetts has always experienced natural and seasonal fluctuations, climate change and human activity has influenced the magnitude and duration of fluctuations as well as the long-term trends or projections for groundwater levels. Historically, groundwater recharge increases in the late fall, winter, and early spring and decreases (in some areas, to zero) in the summer and early fall. Changes in groundwater level occur naturally but are exacerbated by shifting precipitation patterns due to climate change and shifts in human withdrawals. Areas built on historical marshes or wetlands also tend to have higher water tables, which increases the sensitivity to changes in groundwater.

Groundwater changes become disruptive when levels rise, fall, or are contaminated beyond the levels human and environmental systems are used to experiencing. The speed and duration of changes and range of adaptation options affect the scale and intensity of the consequences. A faster onset, long duration, and permanent change to long-term conditions can amplify disruption. Environmental systems are similarly adjusted to natural year-to-year and seasonal variation in groundwater levels and are affected when the variation and duration in groundwater is outside the range that they can adapt to.

5.3.2.2.2 Impacts from Groundwater Rise

Rising groundwater can result in damage to homes, businesses, aquifers, coastal wetlands, and other habitats and infrastructure by flooding low-lying assets and resources and creating unstable conditions in unconsolidated sediments and land made up of highly permeable sand and gravel deposits. Hazard mitigation plans in Boston and Plymouth mention concerns about groundwater rise in connection to flooding and damage to structures and habitats (City of Boston, 2021; Horsley Witten Group, 2021). Evaluating the role of sea level rise and groundwater dynamics can contribute to improved understanding of cumulative, compound, and chronic effects from sea level rise (Bosserelle et al., 2022).

A rising water table can reduce the extent to which groundwater can buffer and reduce the impact of flooding events. It can also be a source of flooding when it interacts with below grade assets such as basements, pipelines, soils, and vegetation. For example, some basements or tree roots may not usually be exposed to groundwater, but a high precipitation event can raise the water table to their level undermining the health and stability of these assets. Groundwater rise can also result in road damage and impact the foundation of buildings and structures above ground.

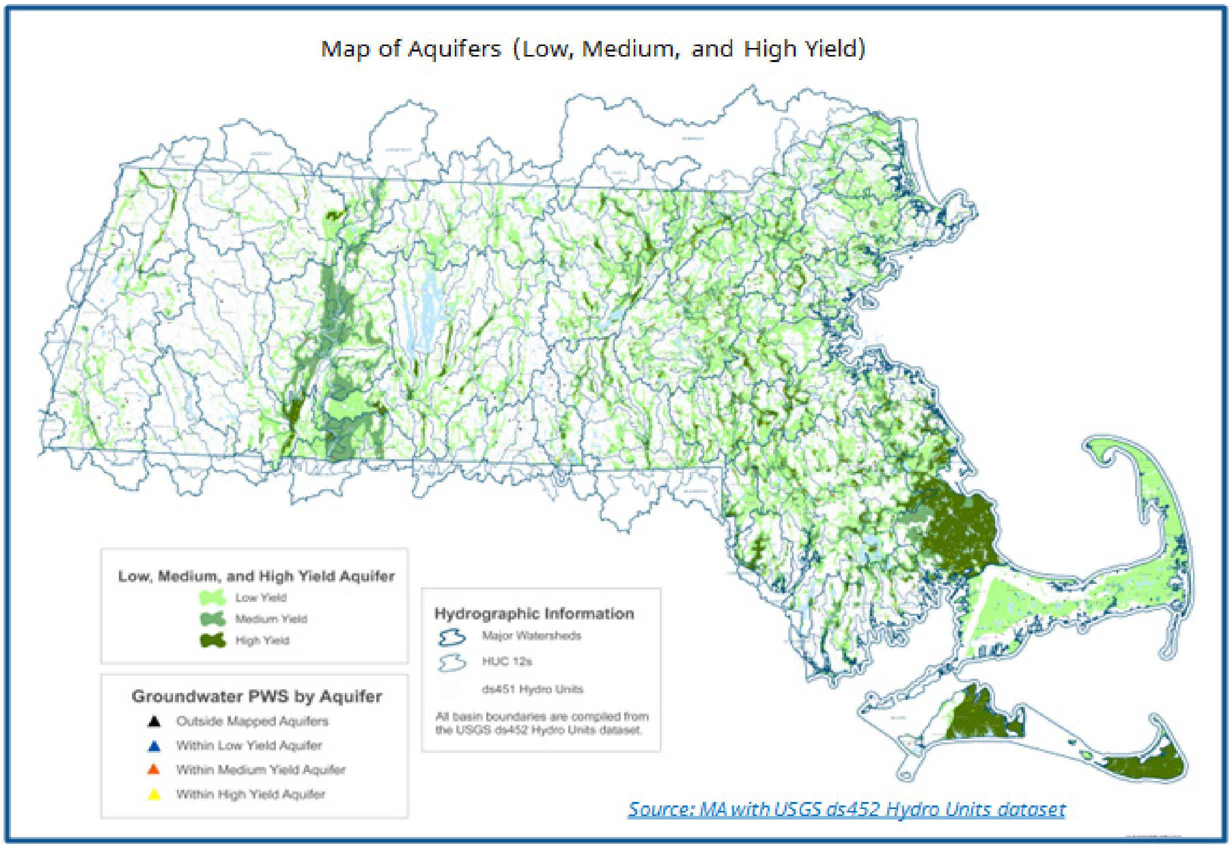
5.3.2.2.3 Groundwater Depletion

Depletion of groundwater supplies results from water table changes due to seasonal or inter-annual variability in groundwater levels and when water resources from aquifers are extracted faster than they are replenished. Depleted groundwater levels result in a reduction of freshwater sources used for human consumption and economic activities (irrigation, energy generation), environmental impacts to systems that depend on groundwater systems, and impacts to structures built on loose or unconsolidated soils and fill that depend on a constant water table for stability.

5.3.2.2.4 Challenges to Water Availability

Groundwater and surface water are part of a continuous, interconnected, complex hydrologic cycle. Groundwater withdrawals for drinking water can reduce groundwater levels, affecting baseflow (flow of groundwater) in streams. A reduction in baseflow is significant, especially in times of drought (see Section 5.6), as groundwater is often the only source of water to streams during drought conditions. In extreme situations, groundwater levels can fall below the stream channel bottom and groundwater becomes disconnected from the stream, resulting in a dry channel. In recent years, increased water withdrawals have exacerbated groundwater depletion across the state (USGS, 2019).

Other long-term factors that can reduce groundwater availability include changes in land use, and in the permeability of surfaces, that reduce the ability of the system to recharge. Many areas of the built environment—like roads, buildings, and cement surfaces—are impervious and reduce or restrict water's ability to recharge aquifers. Stormwater systems can also divert water that would have enabled groundwater recharge and route them to streams, causing additional impacts such as higher peak flows and erosion. Figure 5.3-3 illustrates the distribution of aquifers providing groundwater public water supplies in Massachusetts.



Source: MA DEP, using USGS 100k Hydro units dataset.

Aquifers are shown in bright green (low yield), teal (medium yield), and forest green (high yield). Groundwater public water supplies are marked with black, blue, red, and yellow triangles. Major watersheds are outlined in blue. A high-resolution version of this map is available at *https://www.mass.gov/doc/map-1statewideaquiferpdf/download*.

Figure 5.3-3. Map of aquifers providing groundwater public water supplies in Massachusetts.

Impacts to Structures That Depend on the Water Table for Stability

Massachusetts periodically experiences decline in groundwater elevation often associated with low precipitation or droughts. This presents risks to areas built over landfill or loose and unconsolidated soils and areas designed under the assumption that water levels would remain within the range present during construction. These areas and the structures in them are at risk when groundwater levels are lower than historical conditions and their soils and foundations become unstable.

Anthropogenic changes to the permeability of surfaces around Boston Harbor reduced opportunities for groundwater recharge. In some cases, this has resulted in lower groundwater levels in the area and presented risks to the communities and infrastructure that was built based on higher groundwater levels. In order to address these risks, municipalities like Boston invest in artificial approaches for groundwater recharge like infiltration systems and stormwater recharge practices (Michael et al., 2013; Thomas & Vogel, 2012).

Changes in Groundwater Quality and Characteristics

Aboveground conditions can affect groundwater in ways that become hazardous to human health and natural systems. Two areas of concern are changing groundwater temperatures and changes in water quality from pollution or stormwater intrusion.

Groundwater temperature: Unconfined and shallow aquifers are heavily influenced by surface conditions, including temperatures. Groundwater in urban areas has been shown to be highly susceptible to temperature changes and to influence surface conditions (Rozell, 2021; Smith & Medeiros, 2019). Impacts to aquifers can occur as rising temperatures change chemical interactions, result in thermal expansion, and affect the temperature at which groundwater enters surface water.

Water contamination: Contamination is a challenge when it interacts with structures underground that would be exposed to degradation from water or—in the case of salinity intrusion—to corrosion by saline water. During periods of drought or limited resources, contamination can reduce the availability of potable water, amplifying water stress.

- As sea levels rise along the coastline of Massachusetts, saltwater from the ocean can move into freshwater aquifers, with significant impacts to infrastructure, environments, and freshwater ecosystems. Saltwater intrusion can occur naturally but becomes a risk as sea levels rise and areas of the aquifer that experience salinity move further inland. Higher sea levels result in coastal inundation over larger areas and longer durations, both of which increase risks to infrastructure and the natural environment. In specific cases, wells near ocean shorelines that extract more water than is refreshed can cause a suction effect that can increase saltwater intrusion (Knott et al., 2022). Many aquifers in Massachusetts are shallow and unconfined, and thus more susceptible to saltwater intrusion (Knott et al., 2022). Saltwater intrusion can compromise drinking water supplies and has been cited as an area of high concern for several coastal communities, especially communities in Cape Cod. Coastal flooding events and intense rainfall events can exacerbate changes in salinity, placing stress on brackish and freshwater systems (Bosserelle et al., 2022).
- Surface water can transport pollutants into groundwater sources, so the quality of surface water affects the quality of groundwater resources. Wells can also be a source of pollution if they are not well maintained and regulated. Periods of intense precipitation can transport pollution, toxins, and contaminants to groundwater sources. Local hazard mitigation plans include actions that reduce the proximity of groundwater recharge to sources of contaminants such as industrial areas and roads.
- Aquifers near stormwater systems with combined sewer outflows are also at risk of contamination. As the intensity of precipitation events increases, so does the number of combined sewage and stormwater outflows. These events expose groundwater

recharge areas to pollutants carried by stormwater and untreated water (Horsley Witten Group, 2012). Pollution and contamination of groundwater supplies poses a health hazard when that groundwater enters aquifers used to provide drinking water.

- Contamination can also happen when the water table rises and interacts with septic systems. When the water table rises to or above the elevation of septic systems, contaminants inside these systems can filter into groundwater reserves.

5.3.2.2.5 Location

Groundwater Sources and Geological Features Across the Commonwealth

As well as being influenced by factors such as temperature, permeability, and hydrological interactions, groundwater is characterized by a region's topographical, geological, and hydrological conditions. In Massachusetts, these conditions were shaped by glaciers that left several deposits—the primary source of public water supply—in addition to shaping the landscape. Regionally extensive aquifer systems are a principal source of Massachusetts' groundwater.

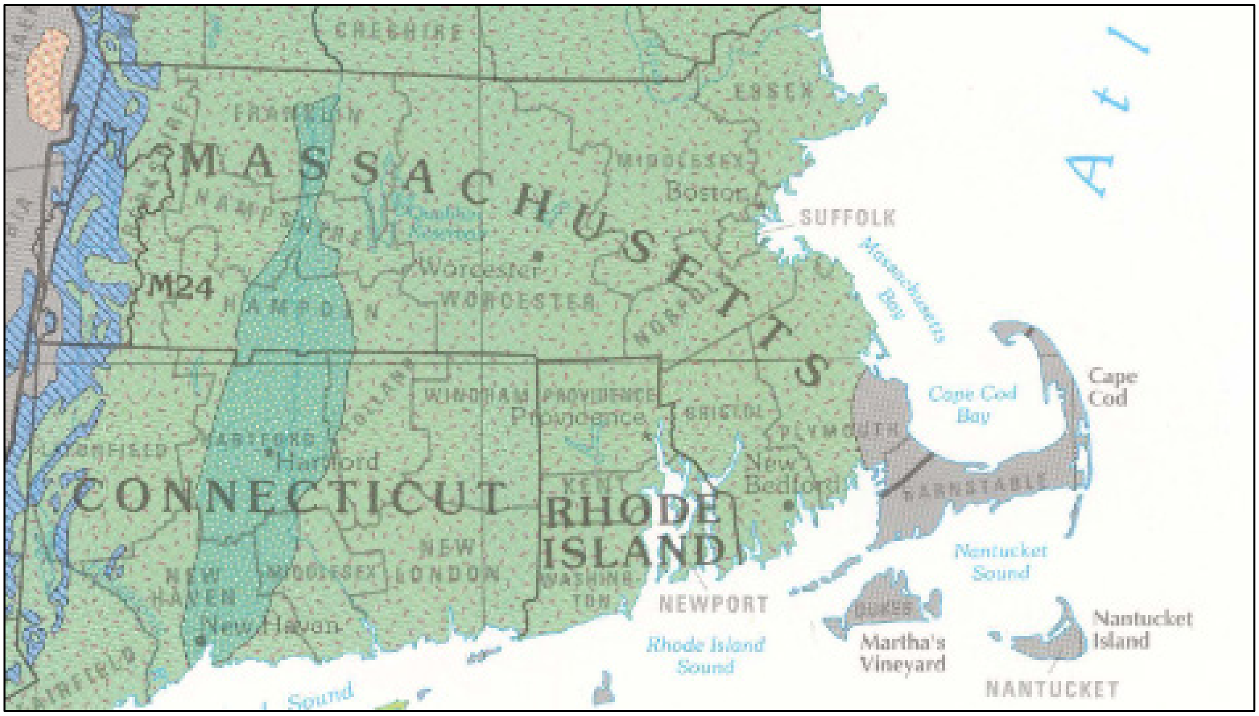
Most of the state's aquifers, especially on the eastern side, are part of the New York and New England group of crystalline-rock aquifers; they are mostly of alluvial and glacial origin (USGS, 2021). These aquifers are present in land that is not highly fractured (fractures occur around 100–150 feet below the surface, with few interconnections). They are composed of layers of sorted gravel, silt, and clay with deposit thicknesses ranging from 36 to 161 feet (Knott et al., 2022). Sediments are coarser-grained, with overlying thick layers further west (Knott et al., 2022).

There are also two principal aquifers in Massachusetts:

- One, in the Connecticut River valley, consists of sedimentary bedrock.
- Another, a carbonate-bedrock aquifer composed of limestone, dolomite, and marble (Simcox, 1992), underlies parts of Berkshire County. (Limestone is porous and can dissolve under certain conditions, forming channels that can transmit enough water for sustained yield to large wells.)

Cape Cod and Plymouth, meanwhile, receive their water source from surface aquifer systems.

These aquifers are shown in Figure 5.3-4 and described in Table 5.3-1.



Source: Olcott (1995).

Figure 5.3-4. Map of aquifers and aquifer types in Massachusetts.

Table 5.3-1. Aquifer Names and Types by Massachusetts Region

Key	Massachusetts Climate Change Assessment Region	Aquifer Name or Type
	Greater Connecticut River Valley	Early Mesozoic basin aquifers. Sandstone and basalt of the Newark Supergroup. Principal aquifer.
	Berkshires and Hilltowns, Central, Eastern Inland, Boston Harbor, Northern and South Shores	New York and New England crystalline-rock aquifers.
	Berkshires and Hilltowns	New York and New England carbonate-rock aquifers. Principal aquifer.
	Cape, Islands, and South Coast; part of South Shores; eastern extremity of Berkshires and Hilltowns	Water source from glacial sand and gravel. Primarily surficial aquifer system. Sand and gravel aquifers (glaciated regions). Extensive stratified sands bury preglacial topography.

Source: Olcott (1995).

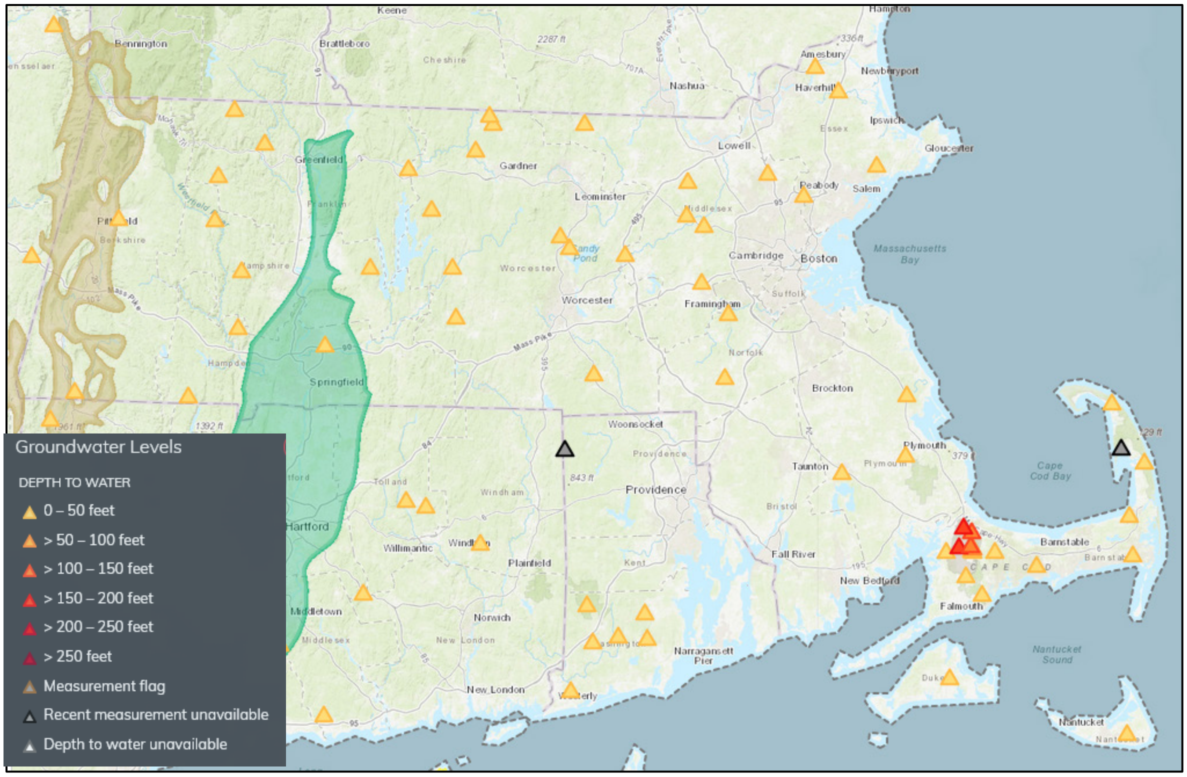
Massachusetts lies across two physiographic provinces: New England and the Coastal Plain.

- The New England province overlaps with five of the 2022 Massachusetts Climate Change Assessment regions (Berkshire and Hilltowns, Greater Connecticut River Valley, Central, and parts of Eastern Inland) and includes the counties of Berkshire, Hampshire, Franklin, Hampden, Worcester, and parts of eastern Norfolk and Middlesex. This region is characterized by north-to-south-oriented hills and valleys with elevations as high as 3,900 feet at Mount Greylock. Inland communities experience different hydrological conditions than coastal communities.
- The Coastal Plain province overlaps with four of the 2022 Massachusetts Climate Change Assessment regions (Eastern Inland, North and South Shores, Cape, Islands, and South Coast) and includes the counties of Middlesex, Essex, Norfolk, Suffolk, Norfolk, Bristol, Plymouth, Barnstable, Duke, and Nantucket. The physiographic region is composed of plains, hills, and coastline with unconsolidated sediments between 80 and 1,500 feet thick (Simcox, 1992). Cape Cod has six hydraulically distinct groundwater-flow systems with yields of about 450 million gallons of water each day (Barbaro et al., 2014). About 69 percent of the system discharges into the coast, 24 percent discharges into streams, and 7 percent is withdrawn for public water supply wells (Barbaro et al., 2014).

Water Table

The water table in Massachusetts is relatively close to the ground surface, making it a principally superficial water system (U.S. EPA, 2005). Historically, water levels fluctuated less than 6 feet in areas with stratified drift. Some of the most important sources of groundwater in Massachusetts are in unconfined stratified drift aquifers (Simcox, 1992). Water levels historically varied between 8 and 20 feet annually in areas with till and bedrock, widely used for residential supplies with large yields in some parts of Massachusetts (Simcox, 1992; U.S. EPA, 2005).

Figure 5.3-5 shows levels of groundwater in Massachusetts in January 2023. The Metropolitan Area Planning Council evaluated changes in groundwater in the 3,732 square kilometers around the greater Boston area, where they detected a slight but steady increase in groundwater levels over the last 50 years (Knott et al., 2022). Previous studies looking at decades of water table trends across New England also found significant increases to the water table throughout the region, concluding that climate change could increase flood risk in the area (Dudley & Hodgkins, 2013; Weider & Boutt, 2010). The water table is higher in areas with unconfined shallow aquifers.



Source: USGS national water dashboard (https://dashboard.waterdata.usgs.gov/app/nwd/en/?region=lower48&aoi=default), showing groundwater levels in January 2023. Data source: USGS water data for the nation (https://waterdata.usgs.gov/nwis). Depths to water are feet below land surface datums. This map also shows the areal extent of the uppermost principal aquifer at a national scale, defined by aquifer type: the green area is a sandstone aquifer, the brown area is a carbonate-rock aquifer, and blue areas consist of unconsolidated and semi-consolidated sand and gravel aquifers.

Figure 5.3-5. Map of groundwater levels and principal aquifers in Massachusetts.

Most of the state aquifers are at relatively shallow depths, less than 100 feet below the surface. Wells in certain areas of Cape Cod are deeper. Depending on soil conditions, areas at low elevation and near bodies of water could have higher water tables.

Aquifer Utilization and Groundwater Availability

Groundwater and surface water are the sources of drinking water for many communities in Massachusetts. Well yield depends on water availability and openings between bedrock (permeability). Wells with lower yields tend to be located in areas with poorly permeable sediments and areas with no saturation (Simcox, 1992). Communities in Massachussets receive water through public water providers and from private wells. The Greater Boston region receives most of its water from the Massachussets Water Resource Authority, which is supplied by surface water (70 percent) and groundwater (30 percent) (USGS, 2021). Municipalities and towns have the primary responsibility for zoning and water resource management subject to state laws.

5.3.2.2.6 Previous Occurrences and Frequency

Challenges with groundwater are experienced differently across the Commonwealth. Risks to groundwater systems vary based on the region, season, and topography, and long-term trends in precipitation and sea level rise, as well as human activity.

Seasonality

Water levels change seasonally, with lower levels occurring in the summer and late fall due to high evapotranspiration. Evapotranspiration affects the availability of water on the surface that can infiltrate and become groundwater. Groundwater recharge decreases to near zero in the summer, when transpiration from vegetation and evaporation losses from surface-water bodies and soil surface are at their highest (Knott et al., 2022).

Measuring Groundwater Levels and Quality

Groundwater data are available for Massachusetts from the USGS National Water Information System (USGS, 2023). There are, as of January 2023, 97 sites where conditions are monitored. The Boston Groundwater Trust also has more groundwater monitoring data available for the Boston area (Boston Groundwater Trust, n.d.). Groundwater monitoring data for the Boston area can be viewed in an online interactive map through the Trust's Observation Well and Building Foundation Information Center. Groundwater water levels are recorded either through discrete field-water-level measurements or as continuous time series data from automated recorders.

Data Gaps and Needs

More groundwater monitoring wells to fill in gaps throughout the Commonwealth would continue to aid analysis and research of increasing groundwater rise and decline. This increase in long-term monitoring wells would help feed into regional groundwater models to assess and predict the effects of precipitation, temperature, sea level, and land use changes on groundwater levels (Knott et al., 2022). Studies analyzing climate model outputs combined with rainfall runoff models calibrated with field studies would also aid in predicting and preparing for the effects of more extreme rainfall events on groundwater rise. Cape Cod has analyses on projected sea level rise impacts on groundwater rise (Walter et al., 2016), providing a framework for similar analyses to be produced for other coastal areas of the Commonwealth.

Previous Occurrences

Groundwater rise is often overlooked because it is slow-moving and out of sight (Knott et al., 2022). However, it can have potentially catastrophic effects, including the erosion of roadways, flooded septic systems and basements, cracked building foundations, and the backflow of sewers that could cause the leak of toxic gases into homes (Pierre-Louis, 2021). Groundwater rise can also exacerbate flooding from other hazards, such as extreme precipitation. Areas that have shallow groundwater systems, such as the land surrounding the Alewife Brook in the highly urbanized areas of Arlington, Belmont, Cambridge, and Somerville, are particularly susceptible to flooding from storms and extreme precipitation. The high groundwater levels in the Alewife area (generally within 3 feet above or below the surface) also limits the types of effective stormwater management techniques that can be used, such as biofilters or porous pavement, further exacerbating flood risk (Horsley Witten Group, 2012).

Groundwater level decreases can also have detrimental effects. Much of the city of Boston is built on infill over previous mudflats and supported by wood pilings driven into a layer of silt. These pilings support nearly all buildings constructed in the early part of the twentieth century. However, to prevent rot, they must be consistently submerged in groundwater. In 1929, the Boston Public Library's main building needed foundation repairs costing over $3 million in today's dollars due to decreased groundwater levels that resulted in rotted wood pilings. Since then, dropping groundwater levels have continued to require foundation repairs for many buildings in Boston (Boston Groundwater Trust, n.d.).

Groundwater depletion also threatens public drinking water and ecological health and the natural environment. The Ipswich River, for example, provides drinking water for about 330,000 people but was designated in 2021 as the third most endangered river in the nation by the advocacy group American Rivers. The endangered status of the river is largely due to excessive withdrawals by the pumping of water from the river and shallow groundwater reserves (Massachusetts Department of Conservation and Recreation & Ipswich River Watershed Association, 2017).

Frequency

Changes in groundwater levels can be influenced by several factors associated with human actions, climate change, and natural variations. Groundwater levels fluctuate daily, weekly, and seasonally. Recent analysis has detected long-term variation in groundwater levels over the last 50 years, but the direction of change depends on complex interactions. While there are several studies that evaluate the changes in groundwater levels in specific locations and at the regional level, there is need for a statewide understanding of factors affecting groundwater. One study estimated that annual groundwater recharge could decrease by 3 to 28 percent statewide by the year 2100 (Knott et al., 2022).

5.3.2.2.7 Severity/Intensity

The severity of groundwater rise, depletion, and contamination depends heavily on the ability of the groundwater system to recharge (i.e., the balance between extraction and recharge), the timing of the recharge, and the quality of the water. Extraction can take place through human activity and natural discharge, which can increase when surface water levels drop—particularly during droughts. Water levels can increase during periods of high precipitation, snowmelt, and coastal and inland flood events. In coastal areas, groundwater levels will be affected by coastal conditions including meteorological events, coastal storms, tides, and sea level rise. Local characteristics including topography, hydrology, vegetation, soil conditions, and human activity also have significant impacts on the severity and intensity of groundwater changes. The following environmental factors can affect the severity and intensity of changes in groundwater and have been associated with hazardous conditions and disruption to human and environmental systems.

- Groundwater rise is driven by precipitation intensity, coastal and inland storms, sea level rise, and snow melt. Groundwater rise can result in flooding, salinity intrusion, contamination and pollution of groundwater and aquifers, and increased inundation of ecosystems, below ground and at grade assets and infrastructure.
- Groundwater depletion, which results in lower a water table and strained water resources, will be more intense when conditions for groundwater recharge are low. These conditions include increasing frequency of drought (see Section 5.6), a reduced snowpack, higher rates of evapotranspiration, reduced precipitation, diversion of precipitation away from groundwater recharge areas, and pressure from human consumption and natural discharge into surface water. Development patterns and river and stream flood management infrastructure also reduce opportunities for groundwater recharge. Recharge rates can vary significantly between regions: for example, the recharge rate near the South Coastal watershed is 57 percent of total precipitation while annual recharge rates range from 37 to 44 percent of annual precipitation around the Concord watershed (Knott et al., 2022).

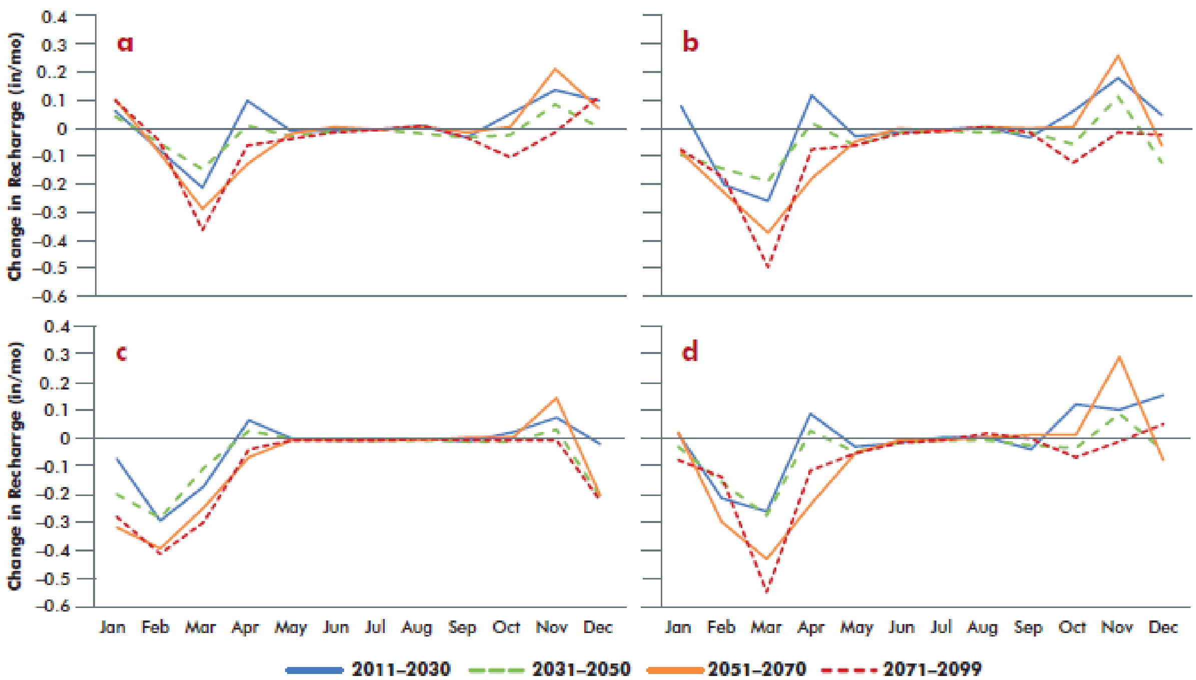
Potential Effects of Climate Change on Groundwater

Climate change can affect the severity of groundwater rise, depletion, and contamination due to the following factors: changes in precipitation, groundwater recharge, impacts from sea level rise, and changing temperatures. These factors' net impact on groundwater can be inferred and is being studied but has not been quantified.

Precipitation: Increased quantities of precipitation can elevate groundwater levels and increase recharge. However, slow steady snowmelt and rain are more likely to lead to recharge than extreme precipitation events. The timing of precipitation affects groundwater recharge depending on antecedent soil moisture. Rising temperatures are likely to lead to fewer days where the ground is frozen and increase the number of days when recharge is possible. However, recharge from snowmelt will be shifted to the winter rather than the usual springtime.

Temperature: Rising temperatures will also increase the number of days when evapotranspiration is higher. Evapotranspiration is associated with lower rates of groundwater recharge. Figure 5.3-6 shows projections for reduced groundwater recharge under climate change scenarios. Increased temperatures are also likely to extend the growing season, placing more demands on aquifer reserves via additional water use and evapotranspiration. Shallow, unconfined aquifers are also likely to experience higher temperatures.

Projected changes in monthly recharge for four 20-year periods relative to the baseline period (1981–2000) under the RCP 4.5 emissions scenario for a) Portsmouth, b) Hampton, c) Dracut, and d) Pepperrel.



Source: Knott et al. (2022).

Figure 5.3-6. Image from the GBRAG report predicting recharge rates by end of century.

Intensity of precipitation: Climate change is expected to change the intensity of precipitation events. High levels of precipitation over short periods affect the ability of the soil and groundwater system to absorb the water, which can lead to reduced recharge and increased runoff resulting in flooding.

Drought: Climate change is projected to affect the severity and duration of drought. Aquifers experience reduced recharge and increased demand for water reserves during drought periods. Research on the relationship between suburban drought and residential development found that increased developments raised sensitivity to suburban droughts and long-term planning between land use and water management was critical in reducing drought vulnerability and risks to groundwater systems that are needed for multiple ecosystem services (Hill & Polsky, 2007).

Sea level rise: Rising ocean levels are likely to increase groundwater elevation, flood risks, and salinity intrusion along the coast. The mean groundwater rise relative to sea level rise is 66 percent between 0 and 1 kilometer from the shore and 18 percent between 2 and 3 kilometers from the shore. The largest magnitude of sea level rise–induced groundwater rise was present in marine estuaries and peninsulas. Groundwater inundation is predicted to contribute to coastal tidal flooding (Knott, Jacobs, Daniel, et al., 2019). The *2021 Hazard*

Mitigation Plan: Plymouth, Massachusetts finds that groundwater pushes the water table closer to the surface and will push higher water tables further inland (Horsley Witten Group, 2021).

Contamination: Higher precipitation over shorter periods can mobilize surface contaminants that can seep into the groundwater (Amanambu, 2015). This is particularly a concern in shallow aquifers like those in Massachusetts. The Plymouth 2021 Hazard Mitigation plan mentioned above addresses the groundwater protection concerns identified in reports conducted by the State Source Water Assessment Protection program[1] by reducing contaminants through zoning enforcement and restrictions on certain development (Horsley Witten Group, 2021). Contamination may also occur from road salting (Heath & Morse, 2013). More frequent road salting necessitated by more rain on snow "mixed precipitation" events can exacerbate salt contamination.

Other Factors Affecting Groundwater Levels and Composition

Groundwater quality can also be affected by the following:

- **Land use changes.** Land use can change surface cover permanently or temporarily, and can affect the water balance (evaporation, transpiration, infiltration, and runoff). Developed lands increase compaction and impermeable surfaces, both of which decrease infiltration (Amanambu et al., 2020).
- **Changes in discharge.** During periods of extended drought or high temperatures when surface water levels decrease, wastewater discharge is less diluted, raising contaminant concentration.
- **Depleted soils.** Depleted soils remove hydrogeologic barriers like clay that protect the water table from rising seas (Horsley Witten Group, 2021). This can increase contamination from aquifer elevation change and from sea level rise.

5.3.2.2.8 Warning Time

Groundwater elevation changes happen over days, months, and years. Saturation can happen over days in connection with precipitation events and coastal storms, while depletion usually happens over a longer duration. Based on a review of available information, the following summarizes the time horizons associated with changes in groundwater:

- Long-term trends in groundwater elevations can occur over several decades and have been observed in New England throughout the end of the 20th century (Dudley & Hodgkins, 2013; Weider & Boutt, 2010). A recent study of inland and coastal communities around the Greater Boston area detected groundwater increases over

[1] The Massachusetts State Source Water Assessment and Protection program identified potential sources of contamination of water sources and provided recommendation to public water systems to support local water supply protection planning. Reports are available at https://www.mass.gov/lists/source-water-assessment-and-protection-swap-program-documents.

the last 50 years, with the magnitude of change being about 1.5 millimeters (Knott et al., 2022).

- Groundwater used as a source of public drinking water can vary seasonally and between years. Adaptive management practices are essential to the sustainability of this resource. There are artificial recharge techniques to replenish groundwater resources and many ways to conserve water to reduce withdrawals. Well yields can change over several years, especially without proper maintenance.
- Contamination of groundwater can occur over years or decades or quickly during a significant storm event or spill. Contaminants on the surface can take years or decades to permeate aquifers depending on depth and porosity. Some wells have been discontinued due to exposure to surface pollutants. If a well is not properly covered and maintained, it can also enable pollutants to enter the aquifer and contaminate the resource.
- Increased temperatures, especially in urban areas, can change the temperature of shallow groundwater. Temperature changes in shallow groundwater reserves can interact with surface temperatures. These impacts are experienced over the course of weeks and days.
- Groundwater rise associated with periods of high precipitation can have different impacts depending on characteristics of the area experiencing high precipitation. In areas with naturally occurring high water tables and high permeability, extreme precipitation events can result in flooding. These impacts can occur over a scale of days.

5.3.2.2.9 Local Context for Hazard and Vulnerability: A Review of Local Plans

Groundwater change was not featured heavily in the local hazard mitigation plans reviewed for the 2023 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP), listed below in Table 5.3-2. When mentioned, it was often discussed in the context of drought conditions and as a potential contributing factor to flooding. A few of the plans reviewed noted Groundwater Protection Districts as an existing mitigating capability for addressing groundwater influences on flooding and drought risks. None of the plans provided estimates of damage to assets or assets at risk from groundwater change.

Table 5.3-2. Highlight of Local Plans

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
2021 Hazard Mitigation Plan: Plymouth, Massachusetts, 2021	Groundwater rise and saltwater intrusion could affect all of the town.	Potential for groundwater contamination to the town’s drinking water and onsite wastewater systems.	Not provided.

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Multi-Hazard Mitigation Plan, town of Adams, April 2019	Areas along the Hoosic River corridor with higher water tables are more exposed to flooding.	Agricultural operations in the floodplain are vulnerable to flooding and drought.	Not provided.
2021 Natural Hazard Mitigation Plan Update, city of Boston, 2021	Areas in the city with high water tables are most exposed to groundwater flooding.	Boston's groundwater table is vulnerable to environmental contaminants from decades of industry.	Not provided.
Town of Erving Hazard Mitigation Plan (draft), October 2019	All of the town could be affected by depleted groundwater levels during a drought.	Residential well owners may experience dry wells or more sediments and pollutants in their water during a drought.	Not provided.

5.3.2.3 Secondary Hazards

Changes in groundwater can contribute to several secondary hazards, including the following:

- Depleted groundwater reserves can exacerbate drought.
- A lower water table can result in structural challenges to buildings and ecosystems that depend on the water table for stability, particularly in areas that consist of fill.
- Groundwater rise can lead to flooding.
- Contamination can travel from surfaces to groundwater and be mobilized during flooding events, with impacts to water supplies.
- Sea level rise can increase the water table in coastal areas, increasing the risk of flooding and coastal infrastructure damage over time.
- A saturated or high-water table can provide a lower buffer to precipitation events, increasing the risk of flooding.
- If groundwater rises to a level where it interacts with infrastructure or natural elements, it can cause flooding and deterioration.
- Shallow unconstrained aquifers are likely to interact with the surface and can experience increases in temperature. This can exacerbate heat island effects.
- Stress from changes (increase, decrease) on ecosystems can make them more susceptible to invasive species.

5.3.2.4 Exposure and Vulnerability

Groundwater rise can lead to the flooding of below-grade and at-grade utilities, infrastructure, natural environments, living spaces, and workspaces. Rising groundwater levels can also mobilize contaminants in soil and destabilize ground and soil. Groundwater rise can lead to saltwater intrusion to salt-sensitive habitats, vegetation, land uses, and infrastructure. Saltwater intrusion corrodes infrastructure and alters natural habitats. Decreases in the water table can also have an impact on ecosystems and human health by reducing the availability of freshwater sources. Long-term changes in groundwater levels can also affect structure stability, especially for buildings built on wood pilings.

Groundwater changes in salinity and height driven by sea level rise can affect drinking water supplies and have significant impacts on the natural environment. Groundwater rise can interact with precipitation, drainage, and sea level rise in complex ways that can contribute to flooding. Section 5.5 (Coastal Flooding) and Section 5.8 (Flooding from Precipitation) identify assets and estimated losses from flooding events.

Table 5.3-3 summarizes the priority impacts and high-consequence vulnerabilities in key sectors from groundwater changes identified in the 2022 Massachusetts Climate Change Assessment and this risk assessment.

Table 5.3-3. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Groundwater Changes

Sector	Priority Impacts and Vulnerabilities
Human	• Health effects from degraded air quality **(most urgent)** • Impacts from aeroallergens and mold in buildings • Reduced access and increased cost to freshwater for drinking and other uses • Septic system failure leading to water quality degradation and increased bacterial exposure
Governance	• Increased demand for state and municipal government services **(most urgent)** • Damage to coastal state and municipal buildings and land • Damage to inland state and municipal buildings and land
Infrastructure	• Damage to inland buildings **(most urgent)** • Damage to rails and loss of rail/transit service **(most urgent)** • Damage to coastal buildings and ports • Reduction in clean water supply • Damage to roads and loss of road service
Natural environment	• Freshwater ecosystem degradation **(most urgent)** • Coastal wetland degradation **(most urgent)** • Shifting distribution of native and invasive species

Sector	Priority Impacts and Vulnerabilities
Economy	• Economic losses from commercial structure damage and business interruptions • Decrease in agricultural activity • Increased costs to businesses and industries, due to reduced water supply or increased flooding

5.3.2.4.1 Human

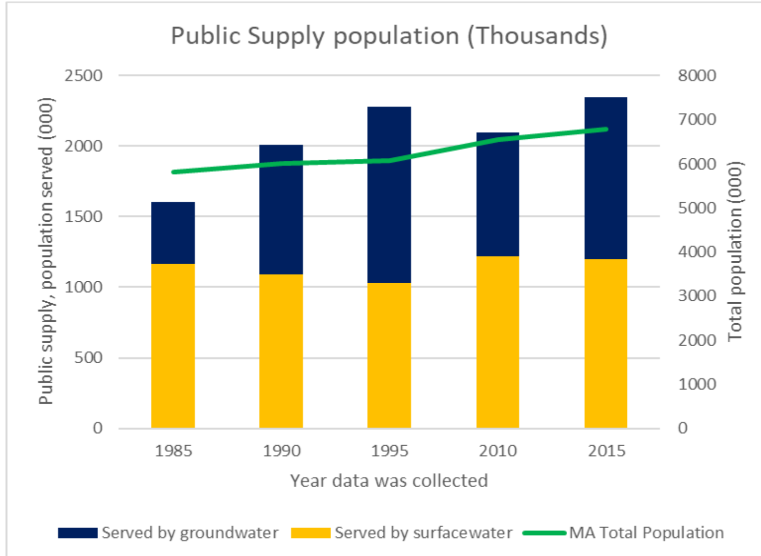
Groundwater is an important source of drinking water for many communities in the Commonwealth. Communities access groundwater through public water suppliers or private wells. Figure 5.3-7 illustrates the proportion of public water supply that is derived from groundwater and surface water as a share of the population of the Commonwealth. Groundwater and surface water are connected, and the health and sustainable management of groundwater resources is essential to the availability of sustainable, affordable, reliable, and clean sources of water. Changes to groundwater levels and groundwater recharge can have impacts on people’s health, welfare, and safety.

Groundwater contamination can result from flooding events, saltwater intrusion, displacement of pollutants or contaminants that seep into the groundwater, or contamination from a well that is not maintained. Contaminated groundwater can have significant impacts on people’s health and wellbeing. Coastal communities exposed to saltwater intrusion may face increased costs and challenges accessing reliably clean water. Increased flooding that creates damage and disruption of water, sewer, septic or power service due to below-grade utilities and infrastructure is also a significant risk.

Housing

Belowground living spaces, basements, utilities, and infrastructure are at risk from groundwater flooding. Rising groundwater levels can amplify or lead to flooding events when the water table rises to an elevation that interacts with infrastructure. Residential buildings and basements are especially susceptible to this type of flooding. Flooding from groundwater may and often does occur outside designated Federal Emergency Management Agency (FEMA) flood zones, and many community members and business owners are unaware of their flood risk. In addition to expenses associated with recovering from a flood event, residences that experience flooding are more susceptible to mold and other damage. In areas that experience repeated flooding, households incur costs to operate flood management techniques such as sump pumps and other forms of drainage. Pumps often use electricity or fuel; their use can result in additional costs to residents, and they run the risk of being non-operational or inaccessible during a hazard event.

A decrease in the water table can also affect buildings, including residential buildings. When the extraction of groundwater is greater than the rate of groundwater replenishment, the water table may drop. Groundwater levels tend to decrease during periods of drought. As noted above, buildings in Boston Harbor and other areas built over landfill were constructed over wood pilings that were placed under layers of silt about 15 to 20 feet below the ground (Boston Groundwater Trust, n.d.). The construction practice is considered of relevance for cultural heritage (Klaassen & Creemers, 2012). The wood pilings are protected by being submerged under water. When water levels are reduced below a certain level, the wood pilings become exposed and susceptible to deterioration and exposure to microbes (Boston Groundwater Trust, n.d.). The longer the duration of the groundwater level drops, the greater the potential for impact and deterioration. While pilings can be repaired and replaced, the cost for re-supporting a building can be greater than $300,000 for a three-to-four-story row house (Boston Groundwater Trust, n.d.).



Graph created with USGS data (https://water.usgs.gov/watuse).

Figure 5.3-7. Sources of public water supply.

Vulnerable Populations and Priority Populations

Changes in groundwater levels and contamination of groundwater can affect communities throughout the Commonwealth. Populations in regions with reduced water resources can face financial stress associated with changes in water costs during periods when water levels are depleted. Rising groundwater increases flood risk, which can reduce the capacity or ability of some community members to prepare for, respond to, or recover from flood events. Low-income populations, linguistically isolated populations, single parents or those living alone, underrepresented and under-resourced populations, those under five or over 65, renters, people who face housing cost burdens, and populations with underlying health conditions are more likely to experience impacts, and those impacts will be disparate. Priority populations can also be disproportionately affected by the contamination of water resources, water damage, and mold that follow flooding events due to the structural integrity, building quality, or other conditions that create hazards in substandard housing. Certain population groups are sensitive to any **changes to critical lifelines including access to emergency services, utilities, and healthcare.**

Households outside the FEMA-designated flood zone may be affected by flood events caused by elevated groundwater levels. Areas that experience repetitive flood loss might struggle to recover if their homes are not insured for flooding. Changes in groundwater can also affect rural and agricultural communities disproportionately, especially people who rely on private wells and aquifers. People who rely on private wells may be burdened if they need to address contamination or invest in improvements, decontamination, or new wells.

In low-lying areas and communities in areas with shallow groundwater, surface temperatures may interact with groundwater temperatures. Groundwater temperatures have been estimated to be more susceptible in areas that are urbanized and have low levels of permeability. The impact of surface temperature on groundwater temperature has been shown to increase heat island effect if high temperatures are prolonged (Öngen & Ergüler, 2021). As groundwater level temperatures change, there could also be impacts to vegetation and urban trees.

Health Impacts

In some urban areas, drains are connected to the sanitary system. In these areas, groundwater and precipitation are transported to wastewater treatment plants where effluent is treated and typically discharged to surface water bodies and not returned to the groundwater. Highly urbanized areas with traditional stormwater drainage systems tend to result in higher peak flood levels during rainfall events and the potential overflow of untreated sewage and stormwater. After peak flows, such areas experience a rapid decline of groundwater levels during periods of low precipitation. There is concern for increasing gastrointestinal illness due to runoff from damaged and non-functioning septic systems. These effects can disproportionately affect communities with increased vulnerability to contaminants due to age or health conditions. Areas with higher exposure to polluted water, such as locations near non-functioning septic systems, overburdened sewer systems, and combined sewer overflows are at higher risk of exposure to contaminated water.

Health impacts can also emerge when living quarters are flooded. Increases in humidity and water damage can lead to mold, which affects respiratory health. These impacts are particularly pronounced for residents with pre-existing conditions including asthma, the very young, and the elderly.

Recreation

Groundwater contributes to freshwater systems that provide recreation and wellness. Changes in groundwater can reduce the availability or quality of these recreational assets—for example, through an increased presence of toxic algae or reduced flow. They can also affect water bodies and generate health risk to people who interact with these water bodies.

Population Projections

Massachusetts' population is projected to grow by over 7 percent between 2020 and 2040. This growth will increase the demand for housing and infrastructure and likely reduce the amount of permeable surfaces that enable groundwater recharge. A growing population will also increase demand for water resources. Some areas have an abundance of high-yielding aquifers and therefore have access to groundwater resources. Regions near low-yielding aquifers or areas with disconnected and shallow aquifers may have challenges providing reliable and affordable public water supply to expanding communities. Areas in the center and eastern part of the state have a lower abundance of medium- and high-yielding aquifers (Figure 5.3-3). These communities may face more challenges in accessing groundwater supplies or may need to draw water from nearby surface sources. While counties anticipated to have the highest rates of growth, including Suffolk, Dukes, and Middlesex, are near high-yielding aquifers, sustainable management of the renewable resource is essential.

5.3.2.4.2 Governance

Municipalities and towns have the primary responsibility for zoning and water resource management subject to state laws. Additionally, there are regions where local organizations play an active role in managing groundwater resources. For example, the Boston Groundwater Trust was established in 1997 and received $1.6 million to build a comprehensive network of wells to monitor groundwater elevations. Groundwater is also extracted by private wells, which are monitored and regulated by the state and local authorities. Local planning agencies often include measures to protect groundwater from contamination. Measures to manage and protect groundwater recharge are present in the *2021 Hazard Mitigation Plan: Plymouth, Massachusetts* (Horsley Witten Group, 2021); the *Dukes County Multi-Jurisdiction Hazard Mitigation Plan Update* (Martha's Vineyard Commission, 2022) and the city of Boston's *2021 Natural Hazard Mitigation Plan Update* (City of Boston, 2021).

Several state agencies play a role in managing aspects of the groundwater systems. These agencies include, but are not limited to, the Department of Fish and Wildlife, the Department of Conservation and Recreation, the Department of Environmental Protection, the Executive Office of Energy and Environment, and the Massachusetts Emergency Management Agency.

Sustainably managing groundwater resources is essential but can be costly. In coastal communities facing rising sea levels, saltwater intrusion can affect public water wells, requiring additional cost to develop deeper wells or to treat for salinity. Government agencies also need resources to invest in groundwater quality monitoring and remediation.

Increases in groundwater levels are also of direct concern to government agencies. A rising water table can expose government assets to flooding and damage. It can also reduce the useful life of government property exposed to flooding events. In areas where saltwater intrusion is happening, groundwater flooding can also expose government buildings and infrastructure to corrosion from increased salinity.

As part of the 2023 MA SHMCAP process, Massachusetts state agencies completed a survey in which they identified their primary concerns for populations served and potential disproportionate impacts from groundwater challenges. One of their primary concerns was the danger of inland flooding to many Commonwealth buildings that are not known to be located in flood-prone areas. Water infiltration into basements containing critical equipment is already a source of repetitive loss of equipment. This is considered to be a significant risk. In areas of repetitive loss, there may be a need to relocate facilities.

As challenges from groundwater increase, there will likely be an increased demand for state and municipal government services and resources to conduct studies, run programs, develop policies, and engage locally to better understand the risks and mitigate the impacts.

Table 5.3-4 below summarizes agency responses to the 2023 MA SHMCAP survey.

Table 5.3-4. State Agency Responses: Primary Concerns About Groundwater Change Impacts on Populations Served and Potential Disproportionate Impacts

Category	Primary Concerns
Populations served	• Injured workers from maintenance activities • All residents, businesses, and municipalities • All municipal, campus, hospital, and environmental police and deputy sheriffs • General public affected by changes in water availability and quality
Potential disproportionate Impacts	• Those reliant on public transportation would have less flexibility to adjust if there are challenges to water supply and could also be most exposed to temperature changes. • Impacts could be disproportionate to priority communities and people who experience conditions heightening vulnerability, such as the elderly, young, and immunocompromised. • Infrastructure and services could be damaged or disrupted. • If utilities are affected by decreases in water availability, there could be outages resulting in potential delays in court proceedings. Delays in filing of important documentation subject to statutory timeframes.

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

5.3.2.4.3 Infrastructure

Groundwater changes can have significant impacts on the built environment. The 2023 MA SHMCAP survey that Massachusetts state agencies completed included questions related to their primary concerns for services provided and updates, improvements, or enhancements to address concerns for impacts from groundwater challenges. Table 5.3-5 below summarizes agency responses. The responses to the survey were completed by agency staff and did not go through a formal review process.

Table 5.3-5. State Agency Responses: Primary Concerns About Groundwater Changes' Effects on Services, with Suggested Improvements

Category	Concerns/Improvements
Services provided	• Damage to public safety answering points or 911 infrastructure such as cell phone towers • Adjudication of disputed workers' comp claims • Effects on transportation • Delays to emergency response
Updates, improvements, or enhancements to address concerns	• Study to mitigate flooding and determine if there are public safety answering points in a flood zone or vulnerable infrastructure that serves 911 (e.g., cell towers) • Re-engineering and reconstruction of transit stations to ensure flooding protection (groundwater leaking into some MBTA stations in Boston is saline due to tidal influence, which poses a corrosion risk) • Movement of infrastructure to more resilient and redundant third-party facilities and cloud solutions • Backup power generators to power sump pumps • Alternate locations, personnel, and equipment staged across the Commonwealth

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Lifelines

Changes in groundwater can result in risks that affect lifelines, especially the availability of critical facilities due to increased flood risk, which could delay emergency services and public safety. Decreases in groundwater can increase stress on community health and infrastructure. Electric power generation can also be affected if there are decreases in the availability of surface waters with reduced baseflows. Groundwater changes can cause damage, disruption, or loss of below grade or at grade utilities or infrastructure due to flooding or unstable soils including power, heat, water, sewer, and septic system.

Agriculture

Agricultural production of plants with deep roots may be affected by changes in salination, especially in coastal areas experiencing saltwater intrusion. Low-lying areas inland with decreased drainage and rising water tables may also be exposed to root rot. Groundwater can affect drainage and contribute to flooding in agricultural areas. The lack of groundwater supplies can have significant impacts on agricultural lands and crop yields. For water supply impacts to agriculture, see Section 5.6 (Drought).

Energy

Electric power generation requires a constant and abundant supply of freshwater resources. Decreases in availability of baseflow due to the depletion of groundwater reserves could affect electric power generation.

Infrastructure that supports the electric grid, generation, and distribution can be damaged during flooding. These impacts are particularly acute for below-grade infrastructure and coastal areas that may be exposed to the corrosive effects of saltwater. Saltwater intrusion can damage building foundations and salt-sensitive infrastructure and utilities.

Water Infrastructure

Groundwater is a significant source of public water supply. Decreases in the availability of groundwater in essential aquifers can generate significant stress on utilities and communities that rely on those freshwater resources. Flooding events that transport pollution into groundwater sources put those water supplies at great risk. In coastal areas, utilities may be strained to balance the need to extract water and the effects of well utilization on saltwater intrusion. Increasing elevations in the water table may affect existing stormwater controls—ultimately resulting in increased pollution and flooding.

Transportation

Flooding from groundwater can cause damage, disruption, or loss to below-grade buildings and foundations of buildings such as rail stations, due to flooding. Exposure to elevated water tables can reduce pavement life and result in repetitive losses to road infrastructure (Knott et al., 2022; Knott, Jacobs, Sias, et al., 2019). Transportation systems rely on electrical signals and equipment located below grade as well. Transportation infrastructure can also be damaged or disrupted if water table depletion results in unstable soils. Changing temperatures that affect shallow aquifers can amplify the effects of heat on transportation assets. Additionally, contaminants from roads (including road salt) and mobile sources of pollution can be displaced during precipitation events and pollute groundwater supplies.

Urban Forests

Changes in groundwater temperature can affect the health of urban forests. Groundwater in urban areas can influence surface temperature (Rozell, 2021; Smith & Medeiros, 2019), potentially increasing stress to urban forests. This can reduce important ecosystem services from urban forests, including moderating the urban heat island effect. This impact is discussed in more detail in Section 5.2 (Average/Extreme Temperature).

5.3.2.4.4 Natural Environment

The Commonwealth's public drinking water supply depends on groundwater aquifers or discharge from aquifers which are the primary supply of streamflow during dry periods (Simcox, 1992). The surface-water hydrology of freshwater systems relies significantly on baseflow. Significant changes in these groundwater supplies result in impacts to biological communities. Some species and even whole ecosystems may be unable to adapt to saltwater intrusion and inundation of aquifers or wetlands.

Above-average increases and decreases in the water table can create stress on wetland ecosystems. These ecosystems naturally expand and contract in relation to water availability, but changes in the magnitude or speed of these changes can place stress on sensitive habitats.

Drought and heat conditions can result from less groundwater in the ecosystem, which increases the risk of wildfire and invasive species, as well as damaging the health of native species. Depletion of groundwater sources can lead to reduced water availability, which can also damage habitats, natural areas, and wetlands due to reduced freshwater supplies from groundwater discharge.

Increases in the water table and exposure to flooding can result in the mobilization of contaminants into habitats, vegetation, and wetlands. Flooding that results in stagnant water could promote algal blooms, which further degrades the health of the ecosystem by stripping oxygen from water bodies.

Changes in the temperature of groundwater can have a negative impact on species that depend on cooler groundwater seasonally. Increases in temperature can be especially damaging for cold-water biological communities that depend on cooler groundwater as a critical climate refuge.

The salinity of groundwater can also have a significant impact on habitats and ecosystems. Freshwater and brackish wetlands near tidal wetlands may undergo species and community transitions as groundwater tables rise and average tidal flooding increases in elevation, causing salinity to intrude into new areas. These effects can affect freshwater wetlands and could, if the space is available, provide an opportunity for tidal wetlands and their associated species to migrate inland and to keep up with sea level rise.

Coastal plain ponds, wetlands, and fish hatcheries are likely to be at risk of saltwater intrusion that will result from groundwater rise, which could alter their function and allow for the persistence and proliferation of invasive species.

5.3.2.4.5 Economy

Flooding induced by groundwater rise can affect people's ability to work and make a living, due to disruption and damage to infrastructure, the natural environment, and physical and mental health. Flooding, groundwater depletion, and contamination can generate costs to businesses and industries, particularly small businesses and water-related and -dependent businesses due to increased flooding or reduced water supply. If water supplies become depleted, costs for alternative sources of water could rise. The disruption of utilities and infrastructure can generate delays and outages of **critical lifelines and essential functions** such as electric power supply. Addressing the challenges generated by changes in groundwater can also be costly and place pressures on governments, businesses, and residents. In areas experiencing a rising water table and flooding associated with the changing conditions, the cost of recovering can have negative effects on household finances. These impacts become more acute if flooding becomes repetitive.

Chapter 5. Risk Assessment and Hazard Analysis

Coastal Erosion

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5.4 Coastal Erosion

5.4.1 Coastal Erosion Problem Statement

Coastal erosion affects populations, structures, and the environment along the coastline of the Commonwealth. High-risk areas include communities and ecosystems near developed barrier beaches, dunes, coastal banks, and salt marshes.

Parts of the Commonwealth experience long-term average erosion rates of up to 10 feet per year. Some localities may experience erosion rates of up to 23 feet per year if current trends continue. This could increase damage to coastal ecosystems (including habitats for rare, beach-nesting birds); shoreline protection structures; homes; roadways; trails and parks; utilities; septic systems; pipelines; and water-dependent uses such as ports, water-related industries, commercial and recreational fisheries, and marinas. Impacts to evacuation routes and critical facilities such as sewer and water supply systems are of most concern. Small businesses and homeowners with fewer resources to address the risks posed by coastal erosion will experience greater risks and consequences from increased erosion. Communities along the coast that depend on septic systems may be disproportionately susceptible to gastrointestinal illness if those systems are damaged due to erosion. Feedback loops where coastal erosion impacts ecosystem services such as storm protection, flood control, and habitat functions are also of concern.

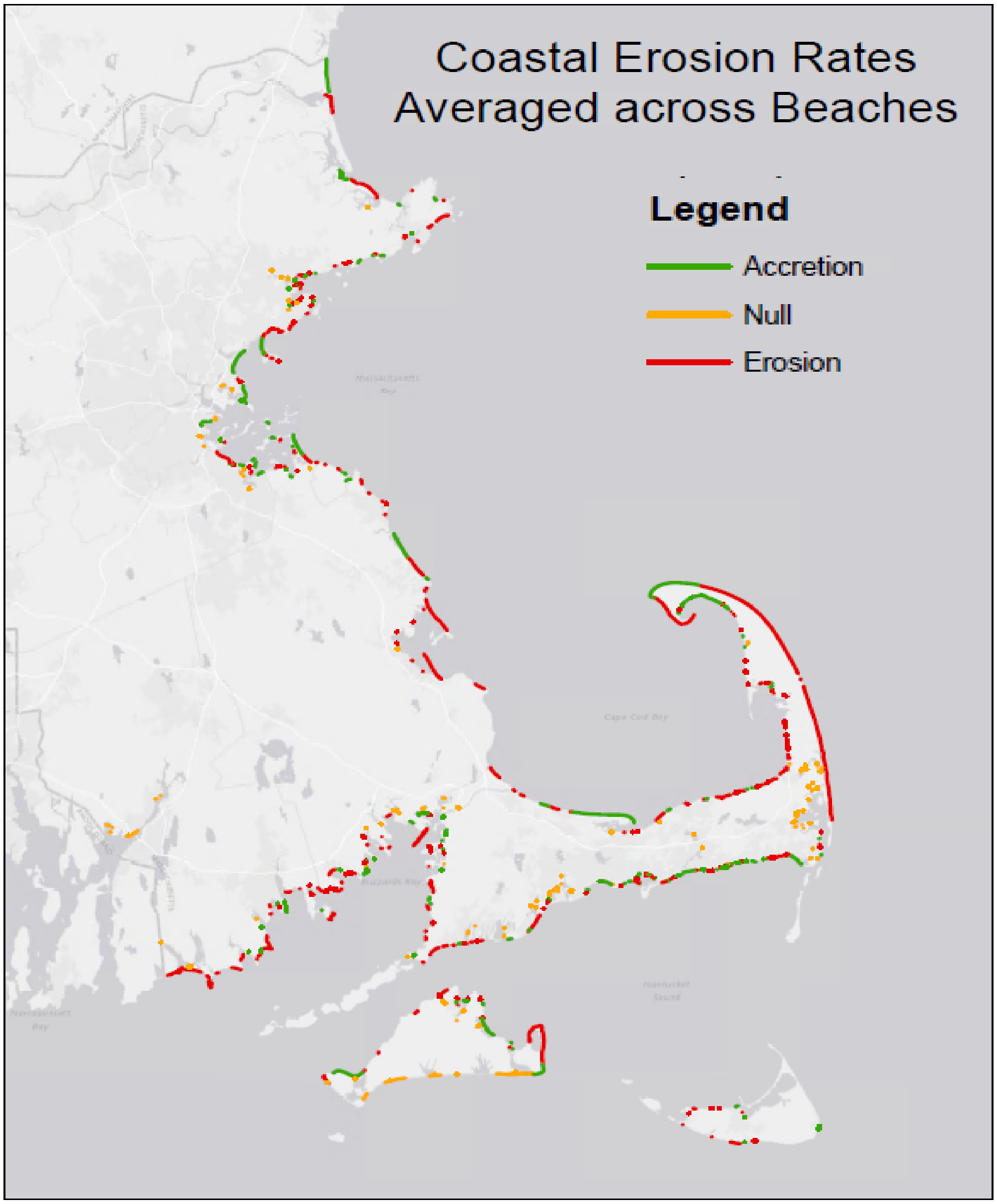
5.4.2 Coastal Erosion Risk Assessment

5.4.2.1 General Background

Coastal erosion is a process that is affected by human activities and environmental factors that are themselves influenced by climate change. Wind, waves, currents, and storms—as well as the relationship between the shoreline, nearshore environment, and uplands—influence the balance between coastal accretion (the addition of land and sediment along the shoreline and coast) and erosion (the loss of land and sediment). Human activities that can contribute to increased coastal erosion include actions to keep the shoreline in place (hardening and armoring) and changes in land use. Erosion can change and reshape the landscape significantly, thereby altering land uses and functions. Coastal erosion is described generally as the process by which local sea level rise, strong wave action, and coastal flooding wear down or carry away rocks, soils, and/or sands along the coast. Coastal erosion is of concern when land loss impacts development and ecological systems.

5.4.2.2 Hazard Description

Absent human influence, coastal erosion is a natural process with the power to shape and change shorelines. The rate at which coastal erosion occurs can have implications to humans' and ecological systems' abilities to adapt. Figure 5.4-1 identifies areas where average historical shoreline change rates are positive (accretion is occurring) or negative (erosion is occurring) between 1845–2018.



Direction of long-term rates of shoreline change from the USGS-CZM Massachusetts Shoreline Change Project, based on the historical record shoreline positions from 1845 to 2018. Map based on analysis performed for the MA Climate Assessment. Null in orange is indicative of no net erosion (shoreline change equivalent to 0 feet).

Figure 5.4-1. Coastal erosion and accretion on the Massachusetts shoreline.

Shorelines change seasonally, with accretion generally occurring in the summer when sediments are deposited by relatively low-energy waves and erosion during the winter when sediments are moved offshore by higher-energy waves. Coastal storms and sea level rise increase the rate of coastal erosion. Storms can also drive sediment into salt marsh systems (Baranes et al., 2022). Coastal erosion is of concern because it can damage structures and result in land loss. Coastal erosion can occur at sustained rates as well as episodically in connection to storm events. This is of particular concern in coastal areas with fragile ecosystems, rare species, cultural resources, economic activity, housing, and critical facilities.

Some approaches to addressing coastal erosion can exacerbate the problem. For example, efforts to maintain the shoreline via hardening and armoring (e.g., shore-parallel coastal engineering structures) can damage the natural environment, including natural buffers that protect upland infrastructure and provide essential habitat. Human activity upland and on the shore can result in increased rates of erosion. For example, certain types of shoreline protection infrastructure, like seawalls, can change erosion rates in adjacent shorelines. Land uses that affect natural sedimentation processes and increased development and infrastructure in upland areas can reduce shoreline accretion rates and contribute to increased coastal erosion. Onshore development has also significantly increased erosion rates and contributed to observed shoreline change rates in the state.

Potential Effects of Climate Change on Coastal Erosion

Climate change can impact the stability of natural landforms that protect communities from coastal erosion and flooding, such as salt marshes, beaches, dunes, and banks (Commonwealth of Massachusetts, 2022). In Massachusetts, climate change impacts such as sea level rise and increased intensity and frequency of coastal storms (including nor'easters and hurricanes) contribute to increased erosion and disrupt the balance between the natural rate of accretion and erosion, resulting in a retreat of the shoreline.

Changing intensity, frequency, duration of storms. Climate change alters the frequency, the severity, and sometimes the path of storms. Climate change impacts that result in a more vigorous hydrological cycle and more intense storms increase sediment displacement, drive coastal erosion, and can cause episodic erosion events (Borrelli et al., 2020).

Sea level rise. Sea level rise will likely increase rates of coastal erosion in several ways. First, as sea level rises, wave action occurs higher on the beaches, dunes, and banks. Sea level rise will increase the area exposed to wave and tidal action, potentially leading to destabilization and/or permanent alteration of natural buffers such as beaches, dunes, marshes, and banks. As sea level rises and shorelines erode, the inland extent of storm surge and daily tidal flooding will increase. Some interventions and protective measures can reduce these impacts, but care must be taken to ensure such measures are not counterproductive. The impacts of sea level rise on coastal erosion rates can vary widely based on local factors such as shoreline slope, beach composition, dune volume, land uses, and sediment availability in the longshore sediment transport system. More research is needed to further understand and attribute changes in the rate of coastal erosion with climate change and varying local conditions.

Human Activity That Affects Coastal Erosion Rates

Human activities have significantly altered many shoreline systems in Massachusetts. Activities such as beach nourishment can mitigate coastal erosion and help decrease erosion rates, while coastal development, infrastructure, and dredging can influence sediment availability and may exacerbate erosion. When high rates of erosion occur over short durations, structures near the shoreline or in low-lying coastal areas may experience impacts. Fact sheets developed by the Massachusetts Office of Coastal Zone Management (CZM) explain approaches to reduce coastal erosion and storm damage, including a comparison chart with relative costs of shoreline stabilization approaches.

Land use and coastal erosion. Changes to land permeability can increase the amount of runoff from precipitation events. Runoff includes rainwater, snowmelt, and water from irrigation systems that flow over the ground surface. It can cause erosion by dislodging soil and sediments, particularly when water travels across bare or sparsely vegetated areas (Massachusetts Office of Coastal Zone Management, 2018). Controlling overland runoff is one way to reduce erosion. Development patterns that reduce the permeable surfaces or displace natural areas increase runoff levels. Preserving open space, minimizing, or removing impervious surfaces, and redirecting the flow of water away from the shoreline are examples of approaches to reduce runoff and its negative consequences.

Shoreline armoring, seawalls, and hard structures. Physical structures, like seawalls, breakwaters, and riprap, have been deployed in Massachusetts to protect shorelines from erosion. Such structures are costly, provide limited protection over time, and can be counterproductive. Some structures (e.g., seawalls) reduce erosion landward of the structure but can reflect and redirect wave energy in front of the structure, increasing erosion of the fronting beach and deflecting erosion to adjacent shorelines. New coastal engineering structures are prohibited by the Massachusetts wetlands protection regulations (310 CMR 10.00) in coastal wetland resource areas for the reasons outlined above, with few exceptions.

Where certain types of engineered structures (rigid armoring) are used to stabilize shorelines, the natural supply of sediment to the littoral system is often cut off, decreasing the amount of sediment replenishment available for beaches, dunes, and salt marshes. This can also contribute to a reduction in beach elevation (lowering) over time. Structures that are perpendicular to the shore, such as groins and jetties, can interrupt the longshore flow of sediment, causing erosion to adjacent shorelines (Brucal & Lynham, 2021).

Nature-Based Shoreline Protection Measures

Naturally occurring features and processes can support natural accretion and reduce long-term sediment loss. Coastal landforms such as coastal banks are essential to maintaining a supply of sediment to beaches and dunes. Salt marsh edges, adjacent mudflats, and other marine sources of sediment, in addition to organic material produced by plants, are important for building and maintaining elevation in marshes. There are features or processes that can be mimicked to develop ecosystem-based management approaches. Nature-based shoreline protection approaches that mitigate erosion can include:

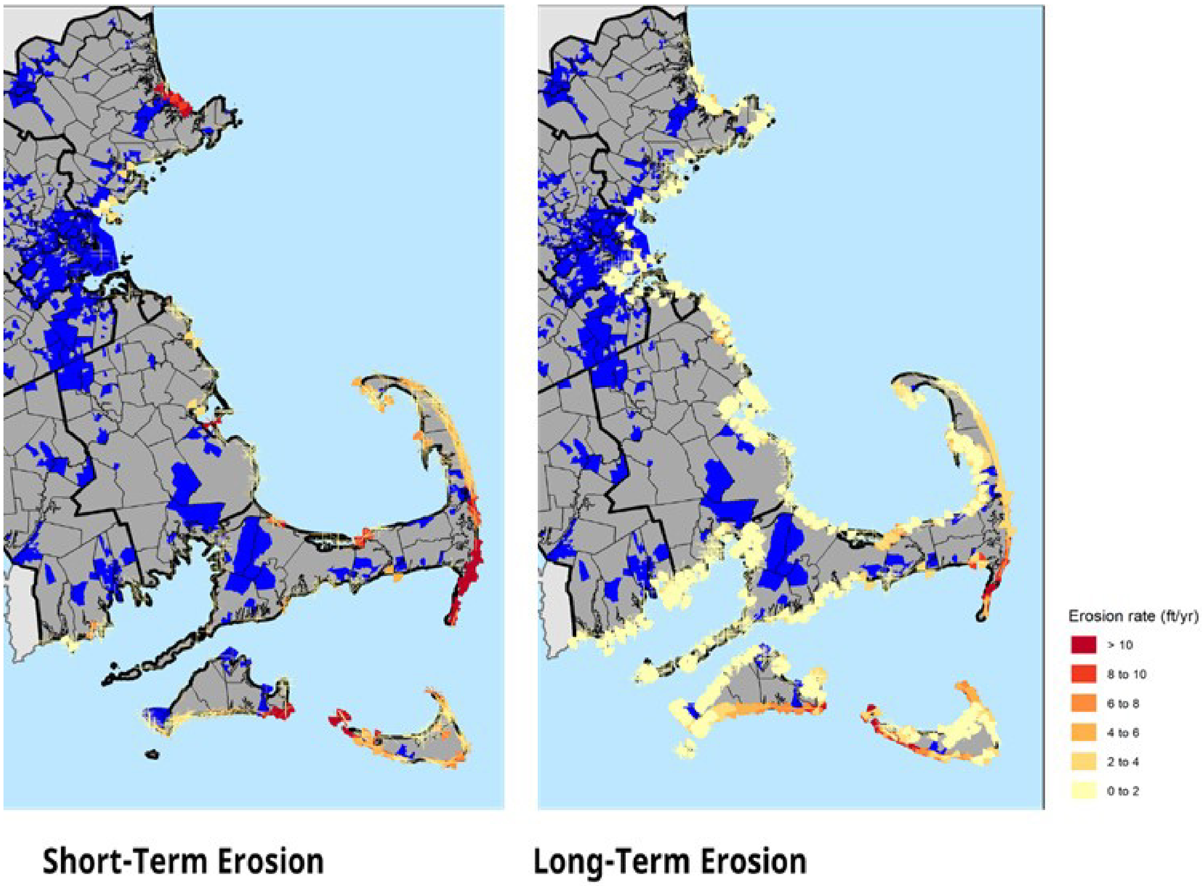
- Dune nourishment (with or without vegetation and sand fencing)
- Beach nourishment
- Cobble berms that absorb wave energy
- Bioengineering of coastal banks (with coir rolls or natural fiber blankets)
- Erosion control vegetation on landforms
- Flood control berms
- Salt marsh restoration

5.4.2.2.1 Location

Coastal erosion rates vary significantly across Massachusetts' shoreline and are influenced by various factors including local conditions (e.g., sediment type, vegetation, and exposure to wave action), land use, existing coastal erosion management measures, and exposure to episodic coastal storms. The Massachusetts coast has a mix of sand, gravel, cobble, and boulder-size sediments. The loss of coastal wetlands also contributes to coastal erosion. Higher waves, rising tides, and currents erode beaches, dunes, and banks, resulting in a landward retreat of these landforms. The damage and loss of coastal wetlands eliminates a critical buffer for existing development and natural areas.

All coastal communities and habitats are exposed to coastal erosion, but some areas of the Massachusetts coast experience higher rates of erosion than others. The *2022 Massachusetts Climate Change Assessment* (MA Climate Assessment) estimated erosion rates by region: Boston Harbor; North and South Shores; and Cape, Islands, and the South Coast. (The MA Climate Assessment's regional reports include information on these erosion rates.) The North and South Shores region, which covers a large percent of the state's shoreline, is experiencing significant erosion and is at higher risk of sediment displacement because many of its shorelines consist of fine-grained, easily transported sediments. Generally, the highest long-term rates of erosion are identified along outer Cape Cod, Nantucket, and Martha's Vineyard. The level of development also plays a role in evaluating coastal erosion risk in Massachusetts. In terms of hazard risk, urban shorelines with failing seawalls and no dry beach are more susceptible to damage from even low levels of erosion than unarmored areas of Cape Cod and the Islands that see large changes in shoreline position. Some areas of the Massachusetts coastline are experiencing accretion, as illustrated in Figure 5.4-1.

Section 5.4.2.4 further discusses risk and assets exposed to damage from coastal erosion. Figure 5.4-2 illustrates short- and long-term erosion rates along the Massachusetts coastline using transect data developed by the Massachusetts Shoreline Change Project.



Rates of erosion by transect. Analysis from the USGS-CZM Massachusetts Shoreline Change Project, based on the historical record shoreline positions between 1845 and 2018.

Figure 5.4-2. Short-term and long-term erosion rates.

5.4.2.2.2 Previous Occurrences and Frequency

Erosion rates vary significantly along the Massachusetts coastline. It is important to consider that there can be significant short-term (less than 30 years) variability and instability of the shoreline that is masked by local fluctuations between eroding and accreting shorelines over time.

Previous Occurrences

Erosion is consequential when it damages or threatens critical assets, infrastructure or utilities, or important ecological areas. Erosion can threaten human safety when events unfold rapidly and adequate precautions, such as local closures and evacuations, are not taken.

The Massachusetts Shoreline Change Project provides information about the average rates of erosion along the open ocean-facing shorelines. In addition to the ongoing erosion, there is episodic erosion caused by coastal storm events. The National Weather Service categorizes the level of storm impacts in three categories: minor, moderate, and major. Minor impacts include splashover and flooding on shore roads. Moderate impacts include damage to vulnerable structures near the high tide lines, such as piers, docks, decks, and porches. Major impacts include severe damage to or destruction of roads, homes, and businesses. The Massachusetts Coastal Erosion Commission reviewed damage from coastal storms and associated damage (Massachusetts Coastal Erosion Commission, 2015, p. 4-4). Storms that resulted in severe episodes of coastal erosion include the Blizzard of 1978 and the 1991 storms (see Table 5.4-1 below). There has not been a new assessment since the Commission's report was published in 2015. Based on reports from the Massachusetts Coastal Storm Damage Assessment Team, though, most of the coastal storms affecting Massachusetts since the Coastal Erosion Commission's last comprehensive assessment have had relatively minor impacts.

The two exceptions are the January 2015 and March 2018 storms, which received Presidentially Declared Disasters. Damage to public infrastructures in Presidential Disasters are eligible for Public Assistance from the Federal Emergency Management Agency (FEMA). It is not possible to distinguish the damage related to coastal flooding and coastal erosion. The damage eligible for the Public Assistance Program includes debris removal; emergency protective measures; and repair, restoration, or replacement of roads, bridges, water control facilities, buildings, contents and equipment, utilities, parks, recreational facilities, and other facilities.

Table 5.4-1 lists the federal disaster declarations that have occurred in Massachusetts coastal counties since 1978. This list was cross-referenced with the National Flood Insurance Program claims data to ensure that these events did result in coastal impacts (e.g., flooding and erosion). Although these federal payments include all damage (not just coastal erosion), the table shows the trend and magnitude of costs in 2023 dollars to illustrate the significant costs of the 1978 and 1991 events relative to the other events. Those costs far outweigh the cost of the more recent, more frequent, less damaging events declared in the Commonwealth.

Table 5.4-1. Public Assistance Damage from Federal Disaster Declarations Affecting Coastal Counties

Storm	Public Assistance Damage in millions (adjusted to 2023 dollars)[a]
February 1978	$238
August 1991	$301
October 1991	$25
December 1992	$25
March 2001	$13
April 2007	$16
October 2012	$13
February 2013	$16[b]
January 2015	$25[b]
March 2–3, 2018	$19[b]
March 13–14, 2018	$9[b]

a Inflation adjustments were made using the U.S. Bureau of Labor Statistics' CPI Inflation Calculator.

b These amounts are not final: FEMA is still reviewing them.

Frequency

Chronic coastal erosion affects many coastal communities. Communities experiencing high erosion rates have seen the loss of buffers and natural areas between critical assets, infrastructure, utilities, and environmental and recreation assets and the ocean. As a result, they are more exposed to consequences to storms and flooding. The rate of erosion along any given coastal area depends on several factors, including exposure to wave action and currents; frequency and severity of coastal storms; elevation of landforms providing buffers to flooding and erosion; type of shoreline and soil conditions; vegetation, ecosystem and habitat health; proximity to development; and shoreline management interventions. Several of the factors that increase the risk of high coastal erosion rates, such as geographic position in relation to wave activity and development, are unlikely to change in the near term. As a result, it is very likely that erosion will continue to occur in areas that have already experienced erosion.

The MA Climate Assessment used data from the U.S. Geological Survey (USGS)–CZM Massachusetts Shoreline Change Project to estimate and project the rates of shoreline change for regions along the Massachusetts coast. Table 5.4-2 shows estimated acres of high beach loss using average shoreline erosion rates (Commonwealth of Massachusetts, 2022).

Table 5.4-2. MA Climate Assessment Estimate of Anticipated Dry Beach Loss by Region

Region	Dry Beach Area Loss Due to Coastal Erosion (Acres)		
	2030	2050	2070
Boston Harbor	140	460	770
North & South Shores	690	2,220	3,750
Cape, Islands, and South Coast	4,800	15,470	26,140
Statewide dry beach loss	**5,630**	**18,150**	**30,660**

Source: Analysis of data from the CZM–USGS Massachusetts Shoreline Change Project.

Losses assume a constant shoreline erosion rate. Future impacts presented for three time periods identified in the table by their central year: 2030 (near-term, 2020–2039); 2050 (mid-century, 2040–2059); and 2070 (mid-late century, 2060–2079). Modeling results not available for 2090 (end of century, 2080–2099). Totals may not sum due to rounding.

No coastal erosion threats expected for inland regions (Berkshires and Hilltowns, Greater Connecticut River Valley, Central, and Eastern Inland).

Coastal erosion is often measured as the rate of change in the position or horizontal displacement of a shoreline over a specific period, measured in units of feet or meters per year. Erosion rates vary as a function of shoreline type and are influenced by episodic events. The analysis of coastal erosion rates is based on the 2021 update to the Massachusetts Shoreline Change Project data set (Bartlett et al., 2021). The data set is composed of transects at 50-meter intervals along ocean-facing sections of the Massachusetts coast. These transects are used to estimate long-term (approximately 150-year) and short-term (approximately 30-year) shoreline change rates (Bartlett et al., 2021). Transects are only shown where the average rate of erosion was greater than the standard error.

Innovative technologies and capabilities enable the use of LiDAR or UAS-SFM[1] to document shoreline change over a short period (Farris et al., 2019). In Massachusetts, LiDAR is used for the 2021 update of the Massachusetts Shoreline Change Project (Bartlett et al., 2021). These innovations enable improved capacity to predict, respond, and understand risks from coastal erosion. It is worth noting that shoreline change rates do not indicate how much erosion occurred in an individual storm event, but an average rate of erosion. The Massachusetts Shoreline Change Project provides publicly available information on coastal dynamics, including a viewer tool and guidance on interpreting data (Massachusetts Office of Coastal Zone Management, n.d.).

There are many challenges in projecting future rates of erosion during accelerated sea level rise. Such an effort must be based on local geomorphology, sedimentology, vegetation, human influences, and other factors. For example, a recent study of major geotechnical parameters and edge erosion along the Great Marsh in Massachusetts found

[1] SfM is the technique of deriving a 3D surface from multiple overlap images (Nagarajan et al., 2019).

that differences in geotechnical properties of marsh edge classes did not explain edge erosion (Houttuijn Bloemendaal et al., 2021). The study findings highlight the need for further research to understand the complex interactions and factors that determine edge erosion. Most studies use marsh edge properties as determinants of edge erosion. Projections of erosion can be used in land use and management strategies, restoration and conservation priorities, and hazard management and climate adaptation to define areas in which development should be limited; land uses, and critical facilities should be retrofit, redesigned, and relocated; or special construction measures should be used.

Long-term shoreline change rates likely underestimate the potential for shoreline change and potential retreat over a shorter period and may not adequately consider and measure rapid impacts from storm events (Oakley, 2021). Shoreline change is defined as a change greater than 0.1 feet each year: areas experiencing erosion are losing shoreline at a rate higher than 0.1 feet per year while areas that are accreting are building at a rate higher than 0.1 feet per year.

5.4.2.2.3 Severity/Intensity

Climate change impacts are both increasing the rate of erosion and expanding the areas that are experiencing erosion over time. Sea level rise can increase the gradual rates of erosion and the severity, intensity, and frequency of events that lead to episodic coastal erosion.

Ongoing erosion is characterized in the Massachusetts Coastal Erosion Viewer for all open ocean facing shorelines. As Table 5.4-1 above illustrates, the coastal storms with the most impacts (e.g., erosion and flooding) between 1978 and 2022 are the Blizzard of 1978 and Hurricane Bob in 1991. The other coastal storms in this table still had significant enough impacts to trigger federal disaster declarations but were much less severe than the storms of 1978 and 1991. As indicated above, the data available do not distinguish between coastal erosion impacts and flooding impacts.

5.4.2.2.4 Warning Time

Coastal erosion occurs not only as a result of the impacts of high-intensity single storm events but also due to gradual changes in land use, sediment supply, vegetation, shoreline composition and sediment type, and watersheds. This hazard can cause the destruction of buildings and infrastructure, affecting critical facilities and lifelines and—if precautions are not taken—posing significant risks to public health and safety. Coastal locations with bluffs, primary frontal dunes next to the shoreline, locations with narrow or eroding beaches, and buildings and roads close to the shoreline are most vulnerable.

Although coastal erosion is a long-term process, it may be more likely to occur or accelerate during high tide events. Areas experiencing coastal erosion at a constant rate over a period can identify emerging risk. Communities can incorporate coastal erosion rates from the Massachusetts Shoreline Change Project into their hazard mitigation planning. There are numerous efforts throughout the state to manage erosion risk through both nature-based approaches and grey infrastructure as well as planning for retreat. These efforts can be monitored for their effectiveness over time to inform long-term planning and hazard risk reduction. In areas where long-term erosion is anticipated to result in significant land loss and place residences and infrastructure at risk, a balance of short-term risk reduction and long-term adaptation approaches should be implemented.

Coastal erosion can also occur quickly through episodic events. Storms can cause larger amounts of erosion or concentrate erosion in a short amount of time and have the power to change the coastline through beach, dune, and bank erosion; overwash; and inlet formation. These events can result in significantly higher rates of erosion over a short period and present risks to critical assets, lifelines, and ecosystems. Episodic erosion events may have reduced warning times. The extent of erosion during an episodic event is difficult to predict, which underlines the importance of long-term planning to identify buildings and infrastructure near the shoreline that could be vulnerable to an episodic, high-consequence erosion event.

Natural recovery after episodic erosion can take months or years. If a dune or beach does not recover quickly enough via natural processes or is unable to due to armoring that has reduced the sediment supply or end effects of coastal engineering structures, coastal and upland property may be exposed to further damage in subsequent events.

5.4.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

Most local hazard mitigation plans in coastal communities reviewed are concerned with erosion and the impacts of erosion on landward structures and ecosystems. The hazards of coastal erosion and coastal flooding are often discussed in tandem. All plans that identify coastal erosion as a hazard of concern discuss the phenomenon in the context of sea level rise and coastal storms with concern for episodic events. Coastal local hazard mitigation plans also include a focus on shoreline management measures. For example, the *Point of Pines and Riverside Area Coastal Resilience Feasibility Report* (AECOM, 2021a) identified shoreline management as a top priority action for *The City of Revere, Massachusetts: Hazard Mitigation Plan—2022 Update* (AECOM, 2021b).

In addition to information from local plans, a report published by the Trustees of Reservations, a local conservation organization, contributes research and local hazard information outlining how coastal erosion is affecting Martha’s Vineyard and Nantucket (Trustees of Reservations, 2021). The report estimates that the islands have lost 3,300 acres of coastal area since recordkeeping began in 1845. It notes that land loss is an issue of heightened concern because of limited availability of land for conservation and the challenge of competing with development for limited lands. Less than 10 percent of land on Martha’s Vineyard is available for development. Similarly, 8.6 percent of land is available for development on Nantucket.

Table 5.4-3. Highlight of Local Plans and Municipal Vulnerability Preparedness (MVP) Program Planning Reports

Plan Name	Location-Specific Hazard information	Vulnerability Information	Dollar Value of Local Assets
City of Salem Hazard Mitigation: 2020 Update (draft), February 2020	• Discussed in general terms as a hazard of concern associated with sea level rise and storm surge, of concern for beaches, dunes, banks, and impact to roads. • The town has land use ordinances that regulate erosion control and land contour changes. Many of Salem's seawalls are privately owned.	• The city has indicated an interest in conducting an as-built assessment of its seawalls.	Not provided.
The City of Revere, Massachusetts: Hazard Mitigation Plan—2022 Update, December 2021	• On Broad Sound, 5 miles of the east-facing shoreline is exposed. The remaining shoreline is semi-protected by offshore structures. • Wave energy tends to focus at two locations: between Revere and Beach Streets and at Carey Circle. • Historical shoreline changes due to erosion are challenging to quantify because extensive human intervention has altered the coastline.	• The city has 15 structures (11 bulkheads/seawalls, three revetments, and one breakwater), six of which are owned by the city. Most structures were rated as C: in need of moderate to limited repair.	Not provided.
Dukes County Multi-Jurisdiction Hazard Mitigation Plan Update: 2021, May 2022	• Identifies most of the shoreline around the county as at risk for erosion. • There are areas experiencing a breach-	• The North Shore of Dukes County is also considered vulnerable because of the high density of the built environment and	Not provided.

Plan Name	Location-Specific Hazard information	Vulnerability Information	Dollar Value of Local Assets
	and-heal cycle, such as the Wasque Point and North point on Chappaquiddick. • The areas with fastest erosion are along the south shore as the longshore transport moves sediment from Aquinnah and Chilmark bluffs to Muskeget Channel. Higher erosion rates are observed at Edgartown. • Erosion rates on the south side range from a foot or so per year at the Gay Head cliffs to more than 10 feet per year at the Edgartown end. • The south side of Edgartown experiences erosion at rates of 10–12 feet per year.	aging infrastructure close to the shoreline. • Most shoreline protection was built by the U.S. Army Corps of Engineers or the Commonwealth and has not been properly maintained. The stone dike on Canapitsit Beach, Cuttyhunk, is identified as an ongoing project. • Homes built before 1978 near bluffs—15 homes in Aquinnah, 28 in Chilmark, 55 in Edgartown, 78 in Oak Bluffs, 48 in Tisbury, 16 in West Tisbury—are grandfathered under the Wetlands Protection act and are difficult to regulate.	
2021 Hazard Mitigation Plan: Plymouth, Massachusetts, 2021 *Climate Ready Healthy Plymouth* (MVP report), June 2020	• The Plymouth coastline is sandy and highly dynamic, with structures that disrupt natural accretion. Long Beach is a barrier beach subject to migration from sea level rise and coastal processes causing movement toward the mainland shoreline. Long Beach experiences deposition on the landward side.	• Manomet/Stage Point experiences the greatest erosion, with rates as high as 19 feet per year (+/- 9 feet). • The Manomet Point road bank was severely undercut during Winter Storm Riley in March 2018.	In 2016, beach nourishment in Long Beach cost about $444,000 (p. 37).

Plan Name	Location-Specific Hazard information	Vulnerability Information	Dollar Value of Local Assets
Town of Hull Hazard Mitigation Plan: 2018 Update, April 2018 *Town of Hull Community Resilience Building Workshop: Summary of Findings* (MVP report), February 2019	• Concern with seawall failure and increased rates of coastal erosion due to sea level rise.	• Concern with the South Shore area because of its dynamic environment and forces of erosion and deposition that change the beach profile.	In April 2010, 500 feet of seawall in Marshfield collapsed because erosion had undermined its foundation.

5.4.2.3 Secondary Hazards

Several hazards identified in the Risk Assessment contribute to coastal erosion. Coastal erosion impacts are closely connected with storm hazards and coastal flooding, and damage associated with these hazards often contributes to episodic erosion. Secondary hazards and effects associated with coastal erosion include:

- Landslides and associated types of ground failures.
- Increased flood risk.
- Loss of habitat for vegetation and native species, resulting in pressure on ecosystems that can result in biodiversity loss and exposure to invasive species.
- Decreases in sediment that can contribute to steepening of the nearshore profile which increases wave effects.
- Mobilization of contaminants into water sources.
- Degradation of natural protection to flooding, changing the risk profile for coastal areas and removing the buffering effects of coastal ecosystems.
- Inlet formation that can increase the waves reaching shorelines previously protected by barrier beaches. These breaches can also increase the tide range, increasing erosion of the shorelines in the estuary.

5.4.2.4 Exposure and Vulnerability

Where erosion occurs is largely tied to geomorphological and sedimentological characteristics. Shoreline development, changes to the nearshore environment, and sea level rise will likely result in increased rates of erosion. Intense storms also can cause significant erosion events over short durations, beyond historically experienced and observed ranges. Coastal erosion affects all sectors including the large number of communities and cultural, ecological, and economic resources along the coast.

The MA Climate Assessment identified coastal erosion to be a medium priority, citing its localized effects and potentially severe impacts. In parallel, the assessment estimates that losses are anticipated to be major, with impacts concentrated along Cape Cod and the Islands. Table 5.4-4 below summarizes the priority potential impacts of coastal erosion in the Commonwealth using themes identified in the 2023 State Hazard and Climate Adaptation (2023 SHMCAP) Risk Assessment, based on information from analysis and research, the MA Climate Assessment, and information related to past events in the Commonwealth.

Table 5.4-4. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Coastal Erosion

Sector	Priority Impacts and Vulnerabilities
Human	• Impacts to residences along coastal areas experiencing high erosion, with heightened risk to structures near the shoreline • Disproportionate impact on communities with reduced ability to evacuate or relocate and environmental justice communities • Impacts to areas receiving residents who relocate from at-risk coastal communities
Governance	• Reduction in state and municipal revenues (**most urgent**) • Increased cost in responding to climate migration (**most urgent**) • Increase in demand for state and municipal government services (**most urgent**) • Challenges to law enforcement and rescue personnel around episodic erosion events • Challenges in maintaining local and state beaches
Infrastructure	• Damage to rails and loss of rail/transit service (**most urgent)** • Damage to coastal buildings and ports • Damage to other transportation infrastructure including roads and bridges • Damage to critical infrastructure along the coastline • Coastal landform degradation resulting in decreased protection to coastline communities (buffers)
Natural environment	• Marine ecosystem degradation (**most urgent**) • Coastal wetland degradation (**most urgent**) • Increased pressures to coastal ecosystems from development as the area of coastline communities is reduced
Economy	• Damage to buildings including housing, government infrastructure, and businesses • Damage to tourism and recreational amenities such as beaches and facilities • Costs associated with maintaining safe public access (affected by coastal erosion)

5.4.2.4.1 Human

People living along the coastal areas of the Commonwealth, particularly along the eastern and southern shorelines that are exposed to nor'easters and hurricanes, are at risk of losing property, homes, infrastructure, utilities, and possibly neighborhoods to erosion. These risks may lead to population displacement and consequences from property damage. Erosion and associated increased flood risk may necessitate the relocation of community assets and people (people living and working near shorelines), disrupting neighborhoods and community functions.

There are several ways to define a "coastal" area in Massachusetts. For example, CZM serves [78 coastal communities](#) that fall within its defined coastal zone boundary. The MA Climate Assessment defined coastal regions to include Boston Harbor; North and South Shores; Cape, Islands, and South Coast; the population in these regions makes up nearly 43 percent (3 out of 7 million) of the Commonwealth's total population.

This analysis uses the framework defined by the National Oceanic and Atmospheric Administration's (NOAA's) Office for Coastal Management to discuss human populations located in [coastal counties](#). The framework identifies coastal counties as those "that are directly adjacent to the open ocean, major estuaries, and the Great Lakes, which due to their proximity to these waters, bear a great proportion of the full range of effects from coastal hazards and host the majority of economic production associated with coastal and ocean resources." Using NOAA's definition, eight out of the Commonwealth's 14 counties are coastal counties and 52 percent of the total population (3.6 out of 7.0 million) resides in a coastal county (Table 5.4-5 below). Following this approach, the Risk Assessment team conducted its analysis for coastal erosion at the county level.

Table 5.4-5. Population Projections for Coastal Counties in Massachusetts

County	Population 2020	Projection 2030*	Projection 2040*	Population change 2020–2040
Barnstable	213,505	199,466	176,007	-17.6%
Bristol	563,301	567,277	568,250	0.9%
Dukes	17,430	19,584	19,793	13.6%
Essex	787,038	816,022	827,531	5.1%
Nantucket	11,212	11,804	12,212	8.9%
Norfolk	703,740	765,912	797,619	13.3%
Plymouth	518,597	534,464	539,424	4.0%
Suffolk	801,162	900,586	950,251	18.6%

Source: UMass Donahue Institute (2018).

*Projections are calculated from 2010 Census data.

Coastal communities overall are exposed to direct impacts from coastal erosion through damage to community infrastructure such as roads, as well as interruption of infrastructure and utility services including water, wastewater, power, communications, and transportation. Livelihoods that depend on shoreline health and coastal environments may be disrupted and workdays can be lost, or jobs can be displaced if significant shoreline change results in the loss of land uses and small businesses. Coastal communities may also experience impacts from changes and stress on natural environments. Populations dependent on cultural, ecological, or recreational value of coastal habitats will experience disproportionate impact due to erosion.

Cultural and archaeological resources are also at risk from damage, disruption, and loss. Some archaeological sites or areas of cultural importance may be difficult to relocate or protect. Other structures may be protected, adapted, and relocated. For example, Nauset Light, located within the boundaries of the Cape Cod National Seashore, was first established in 1797 as a light tower and later built into its current structure. The Nauset Lighthouse was moved in 1996 and the keeper’s house was moved in 1998 away from the cliff to protect the structures (National Park Service, n.d.; Nauset Light Preservation Society, n.d.). Actions to protect cultural and archaeological resources will require planning, funding, and attention to preservation.

Vulnerable Populations

Coastal erosion is both a chronic and an episodic hazard. In most situations, coastal erosion is not a life-threatening hazard, but it presents a threat to human life and safety under certain conditions. During high-erosion episodes, communities near the coast can be damaged when the coastline erodes quickly and waves overtop beaches, dunes, or coastal protections, resulting in flooding and exposure to wave action. For structures located on coastal banks, a short-term erosion event can threaten the integrity of buildings and make it necessary to condemn the building and evacuate the inhabitants. During short-term erosion events, the most vulnerable populations include:

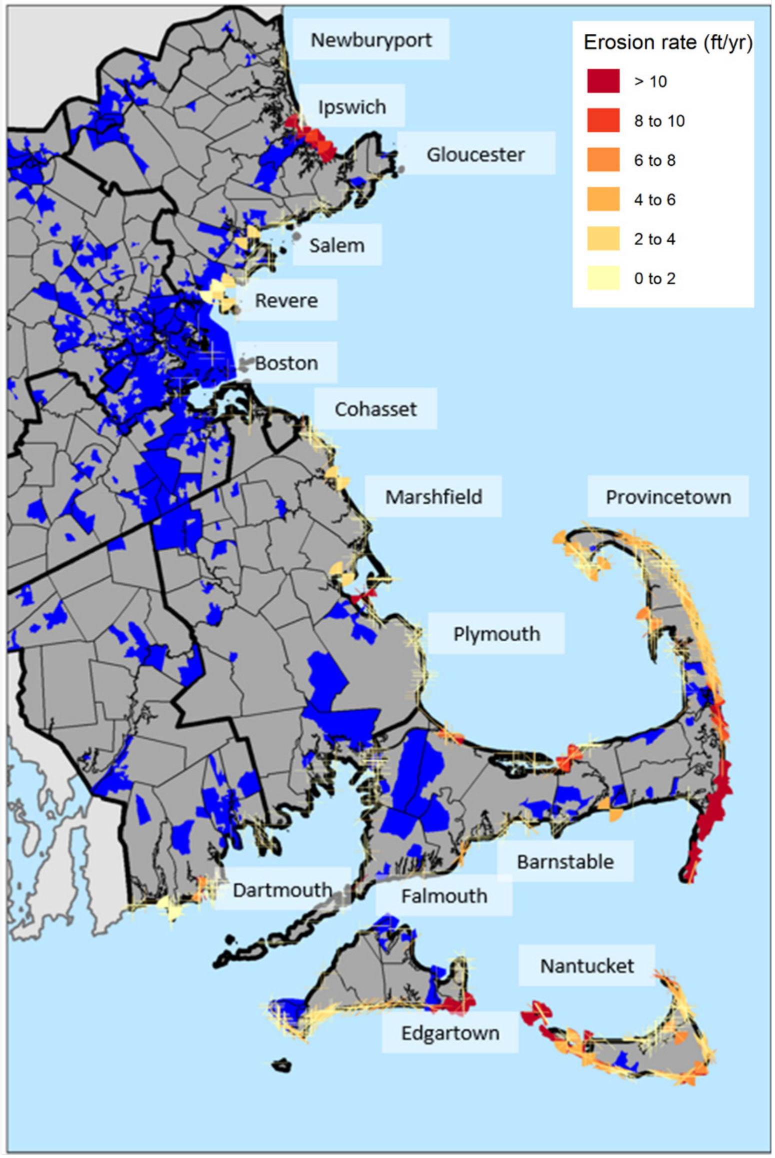
- People experiencing physical mobility challenges that make evacuation difficult—for example, people over the age of 65, young children, and people with mobility challenges.
- Households with limited transportation options or financial constraints that limit their ability to evacuate or temporarily relocate.
- Low-income, underrepresented populations and renters with limited ability to prepare for, respond to, and recover from a significant erosion event.
- Communities who depend on coastal roads—which can be damaged by coastal erosion—to access work, education, and health services.

In the medium term, shortly after an episodic erosion event, communities with limited resources and opportunities to recover may be most affected by damage caused by coastal erosion. The availability of credit, savings, access to support networks, and safety nets can influence the extent to which these costs burden populations. If an event makes evacuation or temporary housing necessary, communities with the least resources and ability to mobilize will be disproportionately affected and experience more disruption.

In the long term, coastal erosion can affect communities directly and indirectly. Relocation is one direct impact to people living close to the shoreline. There are many documented instances of households paying to relocate their homes or structures being red tagged and later removed. A “red tag” is a way of identifying buildings that experienced or are at risk of experiencing damage and may be unsafe for occupancy. Coastal erosion can lead to land loss, increasing pressure on the existing land to absorb the displaced land uses. For example, in Martha’s Vineyard and Nantucket, some residents are moving from one place on the island to another, placing pressure on existing housing and increasing housing prices, displacing low-income communities. As more areas may need to be relocated in the coming decades, there is potential for disproportionate impacts on year-long residents with limited economic resources and elderly residents with limited relocation opportunities. Relocation can also place pressure on receiving communities if they are not prepared for increases in population.

Undocumented residents and people experiencing linguistic isolation are uniquely vulnerable to short-, medium-, and long-term impacts from coastal erosion. In short-term episodic events where human safety may be at risk; these populations may not have access to the early warning and evacuation information and resources that documented residents have. After an event, the absence of social services and restrictions in accessing government support can prolong the length of disruption and increase vulnerability. Over the long run, undocumented populations may face greater challenges and heightened vulnerability if they need to relocate to find employment and affordable housing.

Overall, underrepresented populations, low-income households, people with mobility challenges, those over 65 or under five years old, single-parent households, and undocumented residents, may experience impacts disproportionately. The map in Figure 5.4-3 shows areas of Cape Cod and the Islands that are home to communities with environmental justice concerns, as well as shoreline transects experiencing high short-term erosion rates.



Blue represents Census block groups that meet at least one of the criteria used for MA Environmental Justice populations. Yellow to red shading represents rates of erosion by transect. Analysis from the CZM–USGS Massachusetts Shoreline Change Project.

Figure 5.4-3. Map of communities with environmental justice concerns and transects with high erosion rates for Cape Code Islands.

Population Projections

The populations in counties in Cape Cod and the Islands—areas experiencing the highest rates of coastal erosion—are projected to grow slowly or decrease over time. Notably, Barnstable County is expected to experience a population decline of over 17 percent between 2020 and (with projected populations) 2040. While Suffolk County experiences relatively slower rates of erosion, the area continues to be at high risk, especially because of the population density and projected growth, the built environment, and economic activity concentrated in the Boston area. Also notable is the population growth in Dukes and Nantucket, which is projected to increase by 13 percent and 9 percent in 20 years (between 2020 and 2040), respectively. Along the north shore, Essex County, which is also exposed to coastal erosion, is projected to experience a 5 percent increase in population between 2020 and 2040.

Health Impacts

An eroded coastline has less capacity to act as a buffer against the storm surge associated with hurricanes, nor’easters, or other coastal storms, as well as sea level rise. For communities living near a rising sea, this can have impacts on water systems, including septic systems and well water. Some communities may experience saltwater intrusion to freshwater systems and salt-sensitive components during storm events, especially if there is wave overtopping. Coastal erosion increases exposure to flooding events, which can spread contaminants and displace sediments. Effects on transportation infrastructure can limit people's ability to access essential services like healthcare, schools, work, and grocery stores. The dramatic changes in coastal environments during episodic events with high erosion rates could be a source of stress for populations living along coastlines and other people who value natural coastal habitats. Some areas may experience displacement where erosion results in significant land loss. This form of migration can lead to mental health challenges such as anxiety and stress. Coastal erosion can also affect habitat quality, with downstream impacts to people.

5.4.2.4.2 Governance

Coastal erosion can result in damage or loss of state and local government–owned buildings; require additional government resources; and result in vulnerabilities that result in damage, disruption, or loss of the assets and resources of coastal municipalities, utility and infrastructure agencies, natural resource managers, and coastal communities and local businesses. Impacts of coastal erosion on human, economic, environmental, utility, and infrastructure systems will increase demand for state and municipal government services and resources to conduct studies, run programs, develop policies, implement projects, partner with local jurisdictions, and engage locally. The local hazard mitigation plans analyzed by the Risk Assessment team reflect funding allocated by public entities for shoreline management to build and maintain shoreline protection measures. Private entities are also investing in shoreline protection measures. Governments can also experience changes in revenue sources when hazards result in changes to land use, the need to direct resources to reduce risks and increase resilience, or the need to fund new programs and research to better understand and provide guidance and support on an issue.

Lifelines

- **Safety and security.** When damage is caused by episodic erosion or the gradual progression of erosion, government services are needed for emergency response, recovery, repair, and restoration of critical services and lifelines.
- **Health and medical.** Damage to transportation infrastructure can limit access to health facilities. Increased flooding can spread chemical and bacterial contamination, which can put pressure on public health systems and increase the number of people

needing medical care. Coastal erosion can increase the risk of injury during storm events.

- **Energy.** Damage to structures can place pressure on the power grid. Essential energy infrastructure near coastlines could be vulnerable to coastal erosion. Service to coastal homes and businesses may be damaged, necessitating retrofits and relocations to restore and maintain service.
- **Communications.** Governments need to invest in risk monitoring and early warning systems to respond to episodic coastal erosion events that could put people, property, and safety at risk. Communications infrastructure along the shoreline could be damaged or lost during coastal erosion events and require retrofits, relocations, or reconstructions.
- **Transportation.** Transportation assets near the coast that are currently experiencing frequent damage. The most exposed assets are at-grade assets (assets crossing between roads or on the same level or elevation with the road).
- **Food, water, shelter.** Damage to critical transportation assets can interrupt supply chains and affect food availability, as well as making trips to the grocery store difficult. Disruption to power can cause food spoilage and result in lack of access to fresh, safe food. Coastal erosion presents threats to food security, water supply, and shelter where erosion events might cause damage to, disruption of, or loss of infrastructure, utilities, and housing.
- **Hazardous material.** Coastal erosion in connection with coastal flooding events could spread contaminants from septic systems, roads, and the built environment.

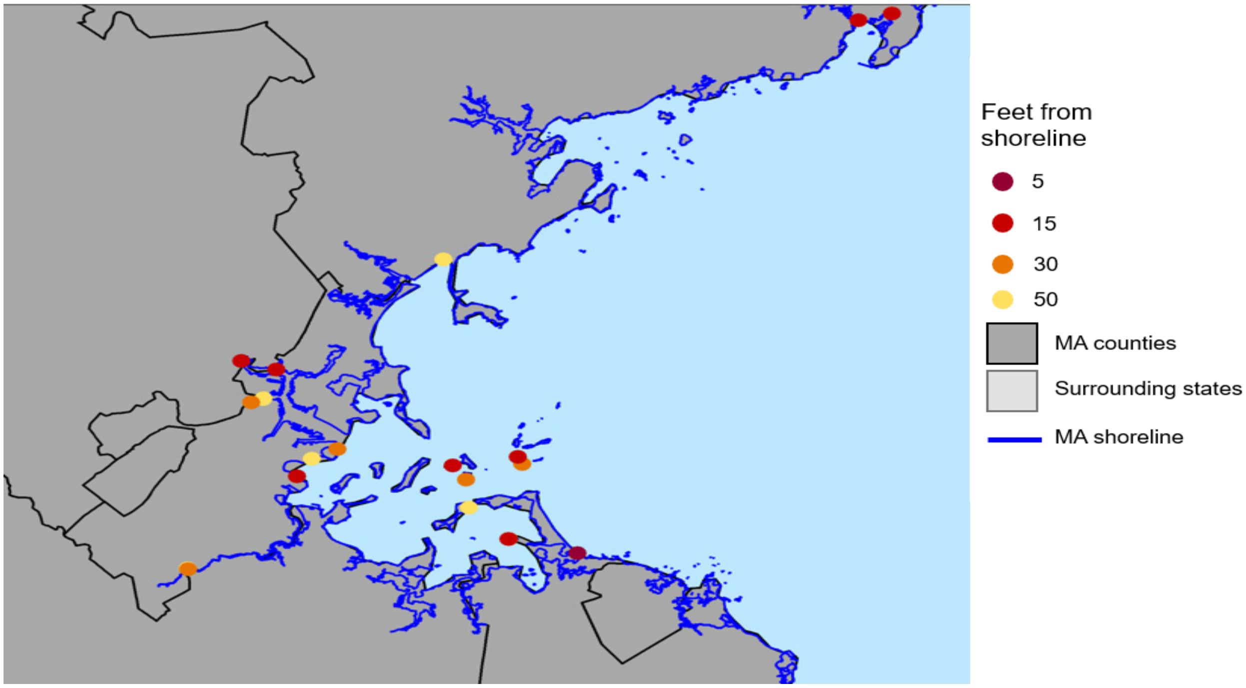
Coastal erosion is already impacting government capacity through multiple avenues. Public institutions in Massachusetts are experiencing increased demand on their time, attention, and funds to address the impacts of erosion on state, community, and private assets and natural resources. To confront this issue, coastal communities throughout the state have invested in research and studies to identify erosion hot spots and understand their risk. Federal and state agencies are also investing in developing data products and reports that enable communities to understand their exposure and develop adaptation plans. Developing data and information that can be used to support actions and implementation requires funding and attention from all levels of government.

Damage, disruption, or loss to state-owned assets—buildings, parks, trails, roadways, utilities, infrastructure, natural areas, open spaces, and others—can occur gradually or suddenly as part of a high-erosion event. Governments are facing costs to repair or relocate state-owned assets at risk from or damaged by coastal erosion.

According to a Massachusetts Division of Capital Asset Management and Maintenance (DCAMM) inventory, there are 130 state-owned assets and 32 critical facilities within 50 feet of the shoreline—a relatively small number. Suffolk County has the most state-owned assets[2] within 50 feet of the shoreline. It also contains 11 of the 32 critical facilities inSuffolk County, including a seawall, harbors and marine transportation assets, the Craigie Drawbridge, and the Charles River Dam operation station, with a replacement value of $33.01 million. Essex and Plymouth counties each have 20 assets within 50 feet. In Plymouth, seven of these assets are considered critical assets, including two seawalls, a pier wall and pier system, an electrical substation, and staff quarters. The replacement value of the staff quarters and electrical substation is approximately $650,000. In Essex County, six of the 20 facilities are considered critical: for example, the drawbridge operations, the Lynn Heritage pier, and a pumping station. Bristol has 13 state-owned assets, of which four are critical facilities (a transformer building, piers, and a boathouse dock); Barnstable has 12 state-owned assets, of which three are critical (an aquaculture laboratory, a dock steam generator, and a fish pier septic system). While most state-owned assets are in Suffolk County, many are associated with recreation: for example, pavilions and canopies (19 assets), swimming infrastructure (eight assets), picnic areas, and gazebos.

Figure 5.4-4 illustrates the state-owned assets considered to be at high risk of exposure.[3] Three of the state-owned assets in this list are considered historic, including the staff quarters on Bumpkin Island in the town of Hingham, built in 1800. Most state-owned assets near the coast are where they are because of their function—for example, recreational amenities, natural environments, or piers. Most state-owned assets identified have protective functions. For example, the DCAMM inventory identifies 18 state-owned assets within 30 feet of the shoreline, and four of these are seawalls.
Table 5.4-6 lists these 18 assets, along with their condition; note that several of the shoreline management assets are considered to be in poor condition or at risk of failure.

[2] Number of assets in the municipalities with the most state-owned assets within 50 feet of the shoreline: 39 assets in Boston, 14 in Hull, 14 in Revere, 9 in Bourne, 9 in Lawrence, 6 in Lynn, 5 in Chelsea, 4 in Salisbury.
[3]This map is based on DCAMM's database. A separate Massachusetts inventory of seawalls and other coastal structures (https://www.mass.gov/service-details/inventories-of-seawalls-and-other-coastal-structures) was not used in the Risk Assessment



Map based on DCAMM data.

Figure 5.4-4. State-owned critical facilities within 5 feet, 10 feet, and 50 feet from the shoreline.

Table 5.4-6. At-Risk State-Owned Assets Within 30 Feet of the Shoreline

County	State-Owned Assets
Norfolk	• Tileston dam house 1 (Milton)
Plymouth	• Shade shelter (Hingham), condition: good • Staff quarters (Hingham), condition: poor • Temporary pier float system (Boston), condition: fair • Seawall (Hull), condition: fair • Seawall (Hull), condition: adequate • Pier wall (Hull), condition: poor
Essex	• Pumping station (Gloucester), condition: adequate • Boat dock (Lawrence), condition: good • Drawbridge operations (Gloucester), condition: N/A
Suffolk	• Craigie Drawbridge (Boston), condition: fair • Water intake (Boston), condition: adequate • Seawall (Boston), condition: fair • Seawall (Chelsea), condition: fair • Sailing Center pier (Boston), condition: fair • Harbor Point on the Bay Pier & Plaza (Boston), condition: good
Bristol	• Boathouse dock (Fall River), condition: adequate
Middlesex	• Draw Seven pier (Somerville), condition: adequate

Table based on DCAMM data.

The data used to identify state-owned assets that could be at risk of coastal erosion included estimates of the cost of construction for some of these properties. All buildings listed in Table 5.4-7 below are currently in use for activities like social services, maritime activities, or residential services. This list does not attempt to estimate the value of all state-owned assets at risk of coastal erosion, but it provides an order of magnitude estimate with examples of some assets that are near shorelines experiencing erosion. The cost of replacing some assets could be significantly higher than the cost of construction. The number of assets that need to be rebuilt can also have significant impacts on government budgets.

Table 5.4-7. Costs of Construction for a Sample of State-Owned Assets Near the Shoreline

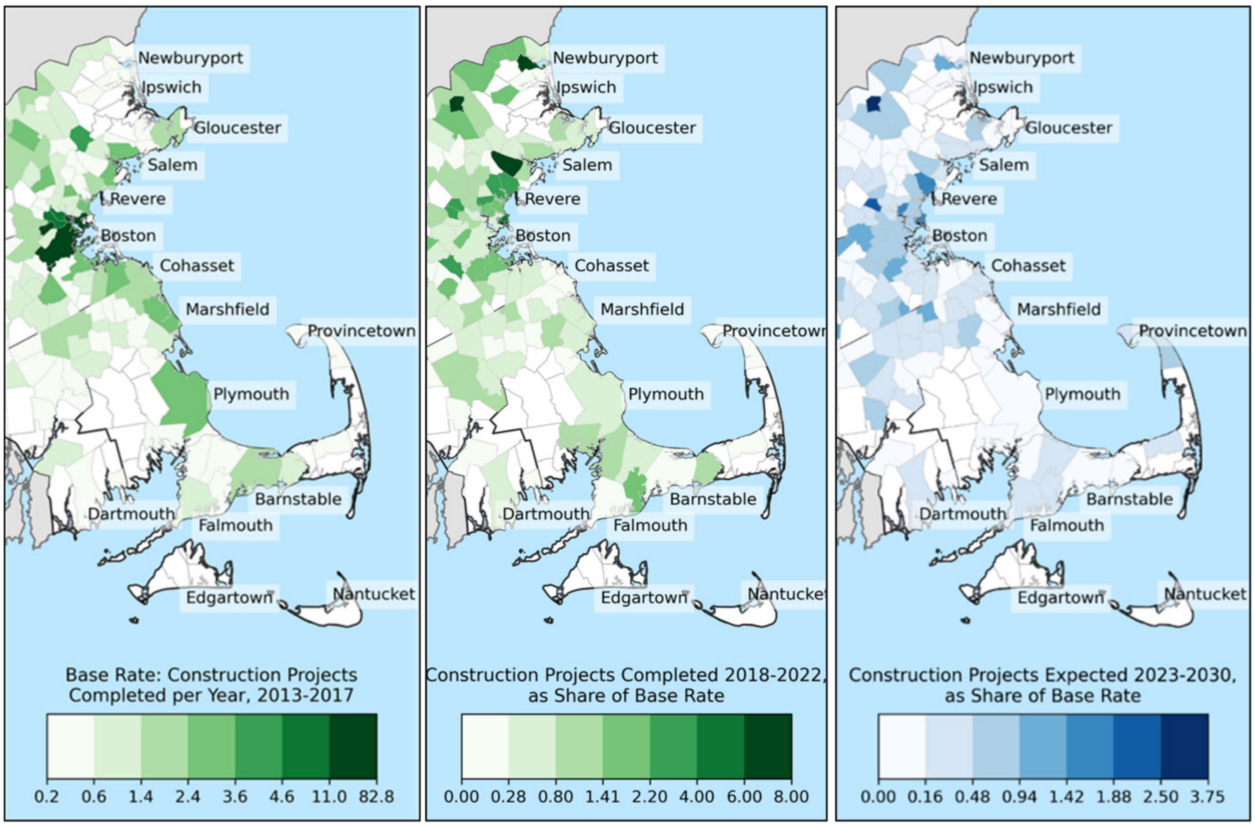
Asset	Type of Asset	Cost of Construction	Condition	Year Built	County	Town
Shade shelter	Social Services	$1,605,212	Good	1996	Plymouth	Bumpkin Island
Staff quarters	Residential	$46,542,429	Poor	1800	Plymouth	Bumpkin Island
Temporary pier float system	Maritime	$1,605,230	Fair	2001	Plymouth	N/A
Boat dock	Maritime	$1,605,210	Good	1994	Essex	Eaton Street
Harbor Point on the Bay Pier & Plaza	Maritime	$1,605,196	Good	1986	Suffolk	Harborwalk

5.4.2.4.3 Infrastructure

The most common infrastructure near the shoreline includes transportation systems, housing, businesses, recreational areas, and shoreline management structures. The impacts of coastal erosion on buildings include increased stresses on building materials. Coastal erosion can result in damage, disruption, or loss of essential infrastructure including homes, utilities, and infrastructure, particularly underground, linear infrastructure including water supply, sewers, power, roadways, rail, and trails. Investments to manage erosion and shorelines are especially exposed to damage, reduced lifespans, and often experience higher costs of repair.

Changes in Development

Changes in construction can be used to understand how risks and vulnerabilities to coastal communities and their assets and services are changing over time. Current information on the locations of new and planned construction indicates an increasing number of people and buildings near shorelines. Between 2013 and 2017, construction along the shoreline continued along the Boston Harbor and North Shore regions of the state. Planned construction, indicative of increased development, is projected throughout the coast, especially in the Boston Harbor area and in areas of Cape Cod experiencing high rates of erosion. Most municipalities within the Boston Harbor region and coastal areas along Revere are projected to have the highest number of construction projects are also identified as environmental justice communities. Refer to the Risk Assessment Introduction (Section 5.1) and Technical Methods (Appendix 5.B) for more information on the data referenced and methods used to conduct the analysis.) Figure 5.4-5 depicts a series of three maps which illustrate construction projects completed in 2013–2017, 2018–2022, and (a projection) 2023–2030. The number of construction permits in each time period identifies areas experiencing higher density of construction relative to other parts of the state. The change in density of construction suggests how the change in density in certain areas evolves.



Map created using MassBuilds data.

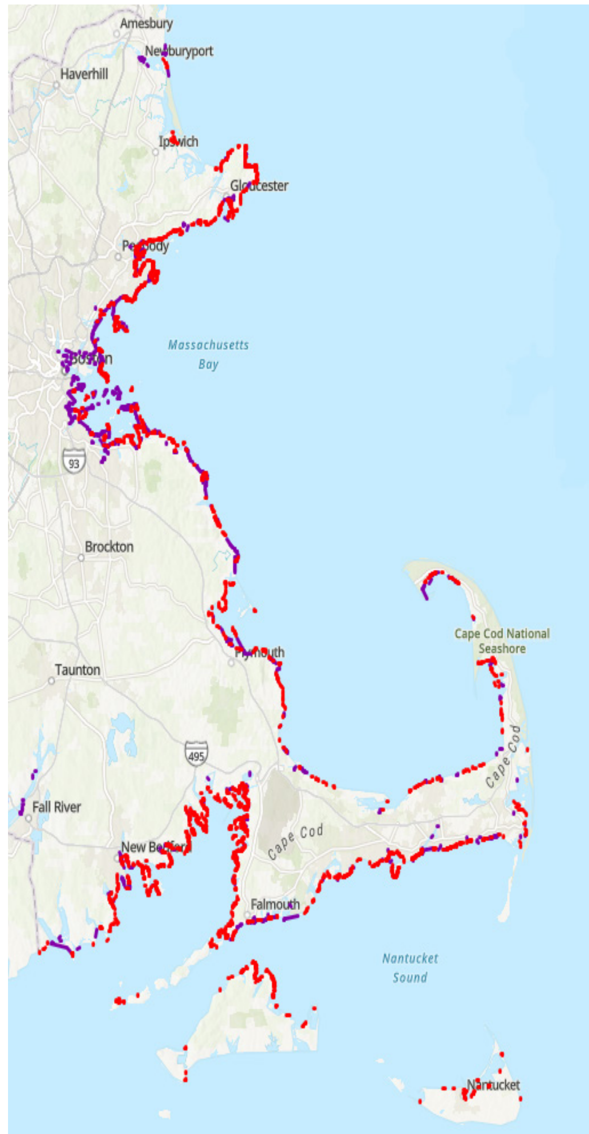
Figure 5.4-5. Changes in construction projects completed by municipality, compared to construction during the 2018 SHMCAP (2013–2017).

Shoreline Protection

The Massachusetts Coastal Erosion Commission's 2015 report estimated that 27 percent of the exposed coastal shoreline was armored by some form of shoreline management, including seawalls, revetments, armoring, and beach and dune nourishment projects (Massachusetts Coastal Erosion Commission, 2015). The study estimated that the percentages of coastline managed by engineered structures were as follows: Boston Harbor (58 percent), North Shore (46 percent), South Shore (44 percent), South Coastal (36 percent), and Cape Cod and Islands (13 percent). The estimates were developed based on a public inventory conducted in 2009, updated in 2013, and published in 2015.

In 2013, the Massachusetts Department of Conservation and Recreation began an effort to update its Coastal Infrastructure Inventory and Assessment to reflect current conditions, update costs for investments needed to maintain coastal structures, and incorporate impacts from sea level rise. The update also identified the capacity of Massachusetts coastal structures to resist major coastal storms and prevent storm damage. New data reports were released in 2014 and 2015. These reports are available in the [State Library of Massachusetts] online portal under "Massachusetts Coastal Infrastructure Inventory and Assessment Report."

Table 5.4-8 summarizes information on shoreline protection, taken from a private inventory conducted in 2013. The inventory reports are available from CZM. The estimates presented are likely an underestimate of the number of coastal management structures. For example, the *Dukes County Multi-Jurisdictional Hazard Mitigation Plan Update 2021* included actions to maintain and add structures (Martha's Vineyard Commission, 2022). This plan illustrates a theme from local hazard mitigation plans for areas experiencing erosion: the need to maintain, strengthen, or develop new structures.



Map of shoreline protection structures registered with CZM, as of January 2023.

Figure 5.4-6. Coastal areas with private (red) and public (purple) management structures.

Figure 5.4-6 illustrates areas along the shore with private and public management structures. The map illustrates data on over 1,100 miles of coastline and ocean-facing structures available through the Massachusetts Ocean Resource Information System (MORIS). The structures included in the data are bulkhead/seawalls, revetments, groins, and sandbags. Some shoreline protection structures can also be degraded by erosion. The Nantasket Beach Reservation seawall, for example, is near shoreline eroding one to two feet per year.

Table 5.4-8. Miles of Coastline Protected by Shore-Parallel Coastal Engineered Structures: Coastal Regions and State Total

Region	Shoreline Length (Miles)	Private Structure Length (Miles)	Public Structure Length (Miles)	Percent Shoreline with Structure
North Shore	160	50	24	46.3
Boston Harbor	57	12	21	57.9
South Shore	129	28	29	44.2
Cape Cod and Islands	615	66	11	12.5
South Coastal	154	49	7	36.4
Total	**1,115**	**205**	**92**	**26.6**

Source: Massachusetts Coastal Erosion Commission (2015).

Agriculture and Aquaculture

The combined impacts of land loss caused by erosion during episodic events and over time could reduce the area available for human activity, including agricultural production. As erosion reduces natural shoreline protections, inland areas are increasingly exposed to flooding, and storm events could have a greater impact on agricultural lands in coastal areas, increasing areas at risk from inundation, resulting in saltwater intrusion on soils and water sources, and directly reducing the land available for agricultural uses.

Coastal erosion also has a significant impact on aquaculture, which relies on a healthy coastal marine environment. Marine environments can be damaged by changes to the flow and composition of sediments. Aquaculture is an economically and culturally significant industry in the Commonwealth, and damage and loss to it would be a significant impact.

Energy

Energy infrastructure on the coastline could be damaged or disrupted by coastal erosion over time or during episodic events. Land loss due to coastal erosion may increase exposure of energy infrastructure—including poles, transmission lines, pipelines, and substations—to increased coastal flooding, damage to salt-sensitive components, and corrosion. These impacts may lead to the need to retrofit and possibly relocate segments of the network or specific assets.

Public Safety

Eroded coastlines have a lower capacity to buffer upland areas against storm surge associated with coastal storms (including hurricanes, nor’easters). This increases the vulnerability of populations living on the coast to flood risk, storm damage, and further exposure to erosion. Damaged roadways also limit the ability of fire, police, and emergency response to provide aid during emergencies. Damaged power and communications infrastructure would limit emergency responders' ability to communicate with one another and local jurisdictions and community responders, and power disruption may require the evacuation of people who have underlying health conditions or need medical equipment to nearby hospitals.

Public safety facilities and equipment may experience direct loss, damage, or disruption. Exposure to ocean water can increase the rate of corrosion of internal equipment. This is of particular concern for public safety facilities along the coast. Damage to water and sewer infrastructure can also increase the risk of public health impacts.

Transportation

Coastal erosion often results in damage and loss of roads, bridges, rail, and airports located near coastlines. Transit service disruptions have disproportionate implications for communities that are transit dependent. With one of the lowest rates of car ownership in the country, Massachusetts has a significant population that relies on transit, with the highest densities being in Boston. This includes communities who depend on public tensible for accessible, reliable mobility. This can be a result of challenges affording, owning, and accessing a car for individual mobility. Coastal erosion damages infrastructure elements directly when the sediment beneath the road or the bridge supports becomes unstable or disappears entirely, resulting in scour and undermining the entire structure. Continuous coastal erosion may result in repetitive damage to roads and increased costs for maintenance and repair. This damage is especially pronounced for transportation infrastructure near the coastline that provides critical lifeline routes as well as access to recreational and maritime activity. Ports and other facilities in areas of the coast experiencing erosive wave action and exposure to ocean waters can experience higher rates of degradation and maintenance costs as a result of erosive forces. Transportation assets along the coast often are the only access into or out of communities and are critically important to either relocation or retrofitting to reduce risk of erosion and flood risk. An example of a heavily used access route that regularly floods during king tides is Morrissey Boulevard in Boston.

Multiple roads and rail lines are in areas near eroding shorelines and should be considered for risk and possible retrofitting. For example, North End Boulevard, in the northern part of the state, travels directly along shoreline that is eroding more than 5 feet per year. Cranberry Highway in Cape Cod is routed within 50 feet of shoreline eroding between 2 and 8 feet per year. Beach Road in in Westport experiences overwash and and erosion during coastal storms. Additionally, many sections of the MBTA Newburyport/Rockport Line are within 50 feet of shoreline eroding up to 8 feet in certain areas. Particularly vulnerable portions include parts of the line routed through Newbury, Rowley, Ipswich, Saugus, Revere, Salem, Beverly, and Manchester. In Cape Cod, a section of the MassDOT Woods Hole Branch in the town of Bourne passes near shoreline eroding up to 2 feet per year.

Water Infrastructure

Coastal erosion damages septic systems, drinking water, and wastewater pipes. Pollution from erosion events could cause damage, disruption, or loss of infrastructure to support water-dependent and water-related uses such as maritime, fisheries, and other industries. Sea level rise will exacerbate coastal erosion, causing the intrusion of seawater into supplies of fresh water that serve both private wells and municipal water systems. As coastlines erode, septic systems and sanitary sewer systems may be damaged, resulting in the discharge of wastewater to the surrounding environment. Underground tanks containing a variety of contaminants can also be compromised. Damage to both types of structures can contaminate surface and subsurface drinking water supplies (including public and private wells), resulting in potential adverse health impacts (McKenzie et al., 2021).

5.4.2.4.4 Natural Environment

Coastal erosion is affecting coastal ecosystems, which have already experienced stressors from human activity and increasingly from climate impacts. According to the MA Climate Assessment, 66 percent of marsh areas present in the Commonwealth as of 2022 are projected to transition to different marsh-type habitats by 2070 (Commonwealth of Massachusetts, 2022). Factors that can limit or compromise a habitat’s adaptive capacity include the speed of erosion and the balance between natural rates of accretion and climate change influenced increases in erosion rates and the availability of upland that allow for upland transgression that shifts wetlands horizontally and vertically. Saltwater intrusion and inundation of aquifers, wetlands, and ecosystems can also restrict an ecosystem’s ability to adapt to new conditions. Estuaries are also at risks from changing coastlines: if the elevation and coastal conditions change, these highly productive habitats may transition to open marine environments over time, particularly without upland areas to allow for wetlands’ natural ability to adapt by shifting inland and upward.

Coastal erosion contributes to a higher rate of change over a shorter amount of time limiting the extent to which coastal ecosystems can adapt to changing conditions. The MA Climate Assessment identified coastal erosion as an urgent impact on the natural environment sector with anticipated major magnitude, potential for disproportionate exposure, and moderate adaptation gaps (Commonwealth of Massachusetts, 2022). The assessment identified the impacts of coastal erosion on water quality, land use, and habitat quality as urgent to the Commonwealth. The impacts are anticipated to be higher in areas that are not protected by natural habitats including wetlands (Commonwealth of Massachusetts, 2022). Coastal erosion can have a marked impact on coastal habitats with effects on both human and ecological systems. Natural areas along the coast threatened by high erosion rates include Plum Island State Reservation, Parker River National Wildlife

Refuge, Sandy Point State Reservation, Crane Beach on the Crane Estate, Cape Cod National Seashore, Monomoy National Wildlife Refuge, South Beach, Coskata-Coatue Wildlife Refuge, Norton Point Beach, and Long Point Wildlife Refuge.

Salt marshes have a high carbon storage capacity; impacts on their health can reduce or eliminate their carbon capture capacity (Mazzocco et al., 2022). A restored salt marsh can take as long as 100 years to obtain the carbon stock a naturally occurring salt march would have (Burden et al., 2019).

Healthy natural ecosystems have historically protected shorelines and allowed them to respond to coastal erosion. Ecosystem health can be damaged by coastal erosion when the overall rate of erosion outpaces sediment accretion, leading to coastal wetland change and degradation of marshes, beaches, and dunes (Commonwealth of Massachusetts, 2022). For example, seagrass can reduce wave-generated erosion (Boudouresque et al., 2021), but eelgrass habitats in Massachusetts are at risk of impacts from changes in temperature, salinity, and invasive species (Massachusetts Division of Marine Fisheries, n.d.). The Division of Marine Fisheries' eelgrass restoration and monitoring program monitors eelgrass and implements programs to protect this habitat.

Pressure on Habitats from Human Activity

Coastal development reduces habitat areas; exposes habitats to pollution; reduces sediment supplies; introduces edge effects that include the appearance of non-native or invasive species, light pollution, and increased disturbance; and physically alters ecosystem hydrology. In regions where coastal erosion is threatening roads, homes, and other structures, relocating structures may place pressure on local habitats through land use change (new development) or increased density, depending on where these land uses are relocated. Relocating these land uses and infrastructure could also reduce impacts to natural areas and provide them with the elevation and upland spaces necessary to support the movement of wetlands and allow for improved connections between watersheds and shorelines, increasing the availability of sediment to the shoreline. However, it is important to consider that as coastlines are changed by coastal erosion, humans and ecosystems are sharing a decreasing coastline. Habitat reduction from coastal erosion can create crowding, increased competition, and risks of predation without careful planning, siting, and design.

Unplanned or reactive approaches to coastal erosion could lead to a loss of biodiversity, natural and cultural resources, and disruption to networks and systems of habitat along the Massachusetts coast. In geographies with limited areas to expand, the pressure can lead to fragmentation and habitat reduction (Cape Cod National Seashore, National Park Service). However, there are laws and regulations to reduce these risks, including the Massachusetts Wetlands Protection Act and associated regulations, which protect the ability of dunes and wetlands to migrate naturally. Regulation could contribute to the health of the coastline. Additionally, the beaches, wetlands, and biodiversity of Massachusetts coastlines are highly valued culturally and economically, bringing economic benefits from recreation and tourism industries and defining the values of local communities.

Damage to Habitats

Coastal erosion of beaches affects important habitats for coastal breeding birds, fauna, and wildlife, with impacts on wildlife management areas and wildlife sanctuaries managed by federal, state, and local government. Coastal erosion can damage or result in loss of wetlands, salt marshes, mudflats, dunes, and natural uplands that support natural communities, native species, and rare species and provide upland transgression zones. These impacts put severe pressure on species that depend on the unique habitats along the Massachusetts coastline. Species that depend on coastal habitats and would be especially affected include terns, plovers, the salt marsh sparrow, and migratory birds. Massachusetts has over 50 percent of the U.S. population of roseate terns and 15 percent of the global population of piping plovers (MassWildlife, 2023).

5.4.2.4.5 Economy

The Massachusetts coastal region is an important driver of economic growth and concentration of economic activity. About 74 percent of the Commonwealth's population lives in coastal areas where coastal employment is estimated to generate $206 billion in annual wages (NOAA, 2023). The Massachusetts Maritime Economy Report, published by the Seaport Economic Council, estimates that maritime economic activities such as marine conservation, tourism and recreation, transportation, living resources, and offshore mineral activities generate $6.8 billion in labor income and contribute $17 billion to the economy (Borges et al., 2018). Port facilities need direct and safe access to ocean waters to make the marine economy work. For example, the Port of New Bedford brings in the highest amount of revenue in the U.S. after Alaska due to cod fishing and scallop fishing (Massachusetts Division of Marine Fisheries, n.d.; Standard-Times staff, 2021).The concentration of economic activity along the coast of Massachusetts generates a high level of exposure to potential damage from coastal erosion. Even locations that are experiencing moderate to low rates of erosion but are highly dense can experience significant loss and economic impacts.

Housing and Property Values

Coastal erosion causes disruption, damage, or destruction of community assets and services such as parks, schools, small businesses, roadways, and utilities. In areas that are at chronic and sustained risk of damage, property values and tax income could be negatively impacted. In some areas, the population during the summer can double, creating stress on limited available land. Housing and property values may be lost as coastal erosion decreases the availability of land for housing, existing housing units are lost, and repeated damage and insurance requirements make this housing less accessible or attractive to homebuyers.

Impacts to Recreational Benefits

Coastal erosion can significantly change and damage coastal areas with high ecological and recreational value, including natural reserves, beaches, and conservation areas. Beyond the value for tourism, residents also enjoy the sights and recreational opportunities available in the Commonwealth. Opportunities for recreational activities will face many changes—for example, more frequent extreme weather, such as hurricanes, could disrupt travel and damage coastal infrastructure like hotels and rental homes. Beachgoers place a lower value on trips to narrower beaches, which may result in less frequent and lower-value trips to shoreline recreation sites due to sea level rise and coastal erosion (Parsons et al., 2013). Other impacts include loss of popular trails, overviews, parks, and beaches, as well as wetlands and ecological areas; these would reduce the value to locals and tourists alike.

Impact on Tourism Industry

The tourism industry depends on the availability of attractions such as beaches, bluffs, trails, parks, shorelines, natural areas, wetlands, and other recreational areas and amenities, along with a workforce to support the tourism. Coastal erosion damages buildings and businesses that service the tourism industry, including hotels, inns, tour operators, naturalists, waitstaff, and more. Impacts of coastal erosion on housing affordability place stress on service workers. The existence of erosion can increase the potential for damage during storm events, resulting in increasing costs for repair; these costs will be onerous for the tourism industry, which is made up of seasonal, small, and local businesses.

Industries dependent on access to safe, affordable, and available recreational facilities are experiencing impacts from coastal erosion as land loss changes beach profiles and increases the cost of maintaining coastal recreational facilities. The economic and recreational value generated by ecosystems such as the Great Marsh could be affected as erosion changes shorelines over time (Wigand et al., 2017). The *Great Marsh Coastal Adaptation Plan* estimates that the tourism and commercial fishing activity that the Great Marsh enables supports 1,000 families directly (Schottland et al., 2017).

Beyond value for tourism, residents enjoy the sights and recreational opportunities available in the Commonwealth and consider its natural and recreational assets an important part of Massachusetts culture. Opportunities for recreational activities will face many changes—for example, more frequent extreme weather, such as hurricanes, could disrupt travel and damage coastal infrastructure like hotels and rental homes. Beaches experiencing historical erosion include Cape Cod National Seashore from Eastham to Provincetown, Crane Beach in Ipswich, Nantasket Beach in Hull, and Horseneck Beach in Westport. Impacts to infrastructure will reduce access and services needed to support the tourism industry, including roads, power, communication, and water. Coastal hotels and lodging, port infrastructure, and road delays could cause significant disruption at coastal destinations.

Impact on Marine Ecosystems

Changes in coastal systems from erosion will also affect nursery health for ecologically and economically important species. Significant erosional events and sediment movement across time can disrupt shellfish habitats, especially when coastal marshes face impacts from land loss, flooding, and rapid sediment changes (Wigand et al., 2017). Stress on shellfish habitats can reduce the shoreline protection ecosystem services they provide, which are cost-effective techniques to combat costal shoreline erosion in low energy environments (McClenachan et al., 2020).

Impacts from degradation of coastal environments is not limited to the shoreline and can negatively impact the marine environment more broadly. Coastal erosion interacts with stressors like loss of salt marsh habitat. Additionally, when erosion affects coastlines, the reduced ability for the coastline to provide protection from flooding in coastal areas can increase the risk that pollution will affect local hatcheries and marine ecosystems. Marine ecosystems are also negatively affected by erosion prevention measures such as the installation of shoreline management infrastructure, which can degrade marine ecosystems and damage coastal health and biodiversity.

Reduction of Protective Ecosystem Services

Coastal erosion has significant impacts on communities, increasing flood risks for communities and exposing communities, infrastructure, utilities, and community lifelines and critical assets to increased erosion and flood risk. Coastal erosion can damage wetland and salt marsh functions, such as providing habitat for native species; filtering pollutants; retaining and trapping sediment; and buffering the shoreline from flooding, pollutants, and erosions. Erosion of marsh edges and mudflats is an important source of sediment for the marsh platform, helping to build and maintain elevation. With reduced sediment, the ability of coastal resource areas such as dunes and beaches to provide storm damage prevention and flood control benefits is significantly reduced.

Chapter 5. Risk Assessment and Hazard Analysis

Coastal Flooding

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5.5 Coastal Flooding

5.5.1 Coastal Flooding Problem Statement

Massachusetts' entire coastline is at risk from coastal flooding and storm surge, including routine tidal flooding and flooding caused by storm events. With projected increases in sea level rise due to climate change of 2 feet by 2050 and 4 feet by 2070, both tidal flooding and storm-related flooding are projected to increase in duration, intensity, frequency, and areas affected by flooding. Additionally, increased frequency of extreme weather could also cause stronger, more frequent storm surges and coastal flooding. These hazards are likely to affect:

- **Geographies.** Eastern Plymouth County historically has been the most at risk from coastal flooding impacts. Suffolk County has the greatest estimated population (over 32,000) that will be exposed to projected coastal flooding, followed by Plymouth, Essex, Norfolk, and Barnstable counties. Saltmarshes in the Boston Harbor and North Shore areas are also at risk, as are coastal wetlands throughout the Commonwealth. Due to population density and vulnerability of the central artery and tunnel system—which could be damaged due to coastal flooding and storm surge—Boston faces additional risks. Cape Cod may be at increased risk due to low-lying roads and evacuation routes that could be damaged or blocked due to flooding.
- **Populations.** Populations that will be most vulnerable to coastal flooding and storm surge are those with low socioeconomic conditions; people who are young, elderly, or mobility-impaired (particularly people who need help with activities of daily living and medical care); renters; people with compromised immune systems; and people experiencing linguistic isolation. Coastal flooding can also result in public health impacts, such as increased exposure to mold or mycotoxins and associated health impacts, increases in mosquito-borne illness, increased gastrointestinal illness due to runoff, limited or interrupted access to hospital and medical providers due to flooding and road closures, danger due to downed powerlines or fast-moving debris, and the potential for contamination of well water. People in flood zones who become isolated during or after flooding due to damaged transportation infrastructure will also be at risk.
- **Jobs and the economy.** Coastal flooding and storm surge will cause damage to buildings, infrastructure, and natural and working lands, which may result in interrupted business activity and operations and impacts on tourism and the tax base. Recent estimates from a variety of scientific journals estimated the total cost of projected sea level rise by 2100 to result in billions to trillions in damage depending on mitigation and adaptation actions taken and associated level of the rise in water levels.

- **Specific sectors.** Sensitive assets such as hospitals, schools, prisons, care facilities, and underground and at-grade living quarters and sensitive components will have more significant risks and consequences from inundation. Many key sectors that will be affected by coastal flooding and storm surge. Agriculture—particularly cranberry bogs and small farms in coastal areas—is likely to be affected by saltwater intrusion into aquifers in agricultural areas. Saltwater intrusion also poses a risk to water and wastewater infrastructure and may result in the need for facility relocation. Natural resources in coastal areas, such as coastal wetlands can be impacted by increased inundation and exposure to saltwater impacting their health and ability to provide ecosystem services like flood protection. Critical facilities infrastructure, such as energy facilities, ports, natural gas terminals, chemical storage facilities, and more may suffer hampered or disabled operations. The transportation sector is also likely to experience impacts, with many bridges, culverts, roads, interchanges at risk of flooding. Neighborhoods, cultural assets, and community assets are at risk and can be more difficult to adapt.

5.5.2 Coastal Flooding Risk Assessment

5.5.2.1 General Background

5.5.2.1.1 Coastal Flooding

Due to climate change effects such as sea level rise and increased intensity of coastal storms, coastal regions of Massachusetts are at increasing risk of chronic and storm-driven coastal flooding. Coastal flooding results from a combination of factors, including waves, tides, storm surges, and gradual sea level changes. The most intense storm surges occur during hurricanes and nor’easters, when low barometric pressures (which temporarily force an increase in ocean levels) and wind-driven water combine to push coastal waters landward. All these forces behind coastal flooding exhibit natural variability, on differing time scales, but sea levels and the intensity and frequency of hurricanes are worsened by climate change—as the climate warms, sea levels rise due to the combination of thermal expansion of water volume, melting of glaciers and other ice sheets, and other factors. Climate predictions also suggest that nor’easters could become more frequent, more intense, or both because of climate change (though, overall, the scientific evidence for climate change effects on nor’easters remains uncertain). Coastal flooding is often compounded by a lack of adequate drainage systems in areas behind seawalls and revetments; if seawater overtops sand dunes, seawalls, revetments, or other protective structures and cannot drain, that flooding will likely have a greater impact on an area than if it were to quickly drain from an area.

Storm surge and coastal windstorm frequency and intensity are affected by increases in sea surface temperature, with elevated temperatures further increasing risks of damaging flood and windstorm episodes. When these hazards combine with higher sea levels, this combination can lead to more damaging storm surges and cause devastating episodic flooding. A particular concern arises during what are commonly known as “king tides” (or more formally perigean spring tides): unusually high tides that occur naturally roughly three to four times per year and will be exacerbated by sea level rise.[1]

5.5.2.1.2 Sea Level Rise

The projections of sea level rise draw from the *2022 Massachusetts Climate Change Assessment* (MA Climate Assessment). The projections used in modeling coastal flood risks are consistent with the approach used in the U.S. Global Change Research Program’s 2017 National Climate Assessment (NCA4) and the global and regional sea level rise scenarios developed for use in climate impact assessment (Payne et al., 2018, p. 8; W. Sweet et al., 2017). The U.S. Global Change Research Program used this approach to develop projections of sea level rise for each of four representative scenario groups: Intermediate, Intermediate–High, High, and Extreme. The Commonwealth has chosen the High scenario as the preferred scenario for assessment of vulnerability and flood risk, consistent with an “unlikely to exceed” (83 percent) probability for a higher greenhouse gas emission scenario when accounting for possible ice sheet instabilities. For the higher emissions alone (without consideration of ice sheet instabilities), the High scenario is consistent with an “extremely unlikely to exceed” (95 percent) probability.

The relative sea level rise that Massachusetts residents may see in the future, and that was used as input for the Massachusetts Coast Flood Risk model (MC-FRM), reflects both sea level and land level changes, as well as other regional factors. On the northern coast of Massachusetts, this scenario corresponds to about 14 inches between 2008 and 2030, 29 inches between 2008 and 2050, and 50 inches between 2008 and 2070. Corresponding estimates for the southern coast of Massachusetts are slightly higher: 14 inches by 2030, 30 inches by 2050, and 52 inches by 2070. Information in Table 5.5-1 corresponds to the NCA4 results plotted in Figure 5.5-1, with the key difference that the estimates in Figure 5.5-1 are measured from a year 2000 base, for global mean sea level rise, while the estimates in Table 5.5-1 are measured from a 2008 base, for specific Massachusetts coastal locations.

After the analysis was conducted and the MA Climate Assessment completed, the National Oceanic and Atmospheric Administration (NOAA) released an update to the sea level rise estimates used in the MC-FRM modeling in February of 2022. The new NOAA sea level rise report maintains a similar uncertainty characterization. However, the sea level rise projections are different.

Table 5.5-1 includes the same projections from NCA4 and the updated NOAA 2022 projections (W. V. Sweet et al., 2022). Comparing the “high” scenarios from both the NCA4 and NOAA2022, it appears that the NCA4 High scenario sea level result in 2030 is not projected to occur until about 2050 in the NOAA 2022 update. Similarly, the 2050 NCA4

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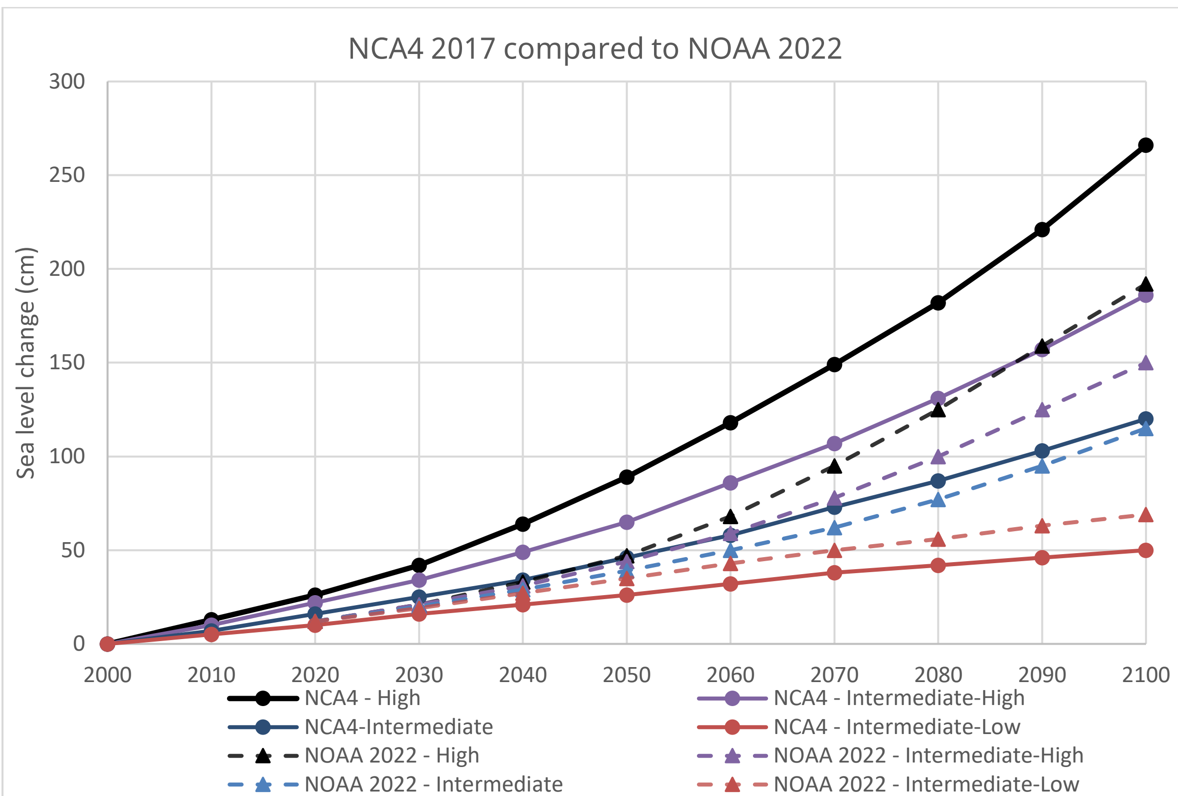
[1] The number of king tides per year is highly variable based on Earth and moon orbits. For an accessible explanation of king tides, see https://stonelivinglab.org/news-article/high-tides/.

result is not expected to occur until about 2070 in the NOAA 2022 update. However, due to uncertainty of timing and the need to consider increased-intensity storm events and hurricanes in addition to sea level rise, this difference should not affect planning for sea level rise or implementing large infrastructure projects or other similarly significant land use decisions.

Table 5.5-1. Sea Level Rise Projection Relative to the 2008 Present-Day Tidal Epoch

Sea Level Rise Projection	2030	2050	2070
North	1.2 feet (14.4 inches)	2.4 feet (28.8 in)	4.2 feet (50.4 inches)
South	1.2 feet (14.4 inches)	2.5 feet (30.0 inches)	4.3 feet (51.6 inches)

Source: Woods Hole Group (2022).



Comparison of selected global mean sea level rise projections from the NCA4 (used in the MC-FRM modeling for this section) and from a 2022 NOAA report (W. V. Sweet et al., 2022), in centimeters sea level change from the year 2000 global baseline sea level. Solid lines are for NCA4 scenarios, dashed lines for NOAA 2022 scenarios. Darker blue colors show the current area within the 100-year return period coastal floodplain; lighter blue colors show how the for the 50th percentile reported result.

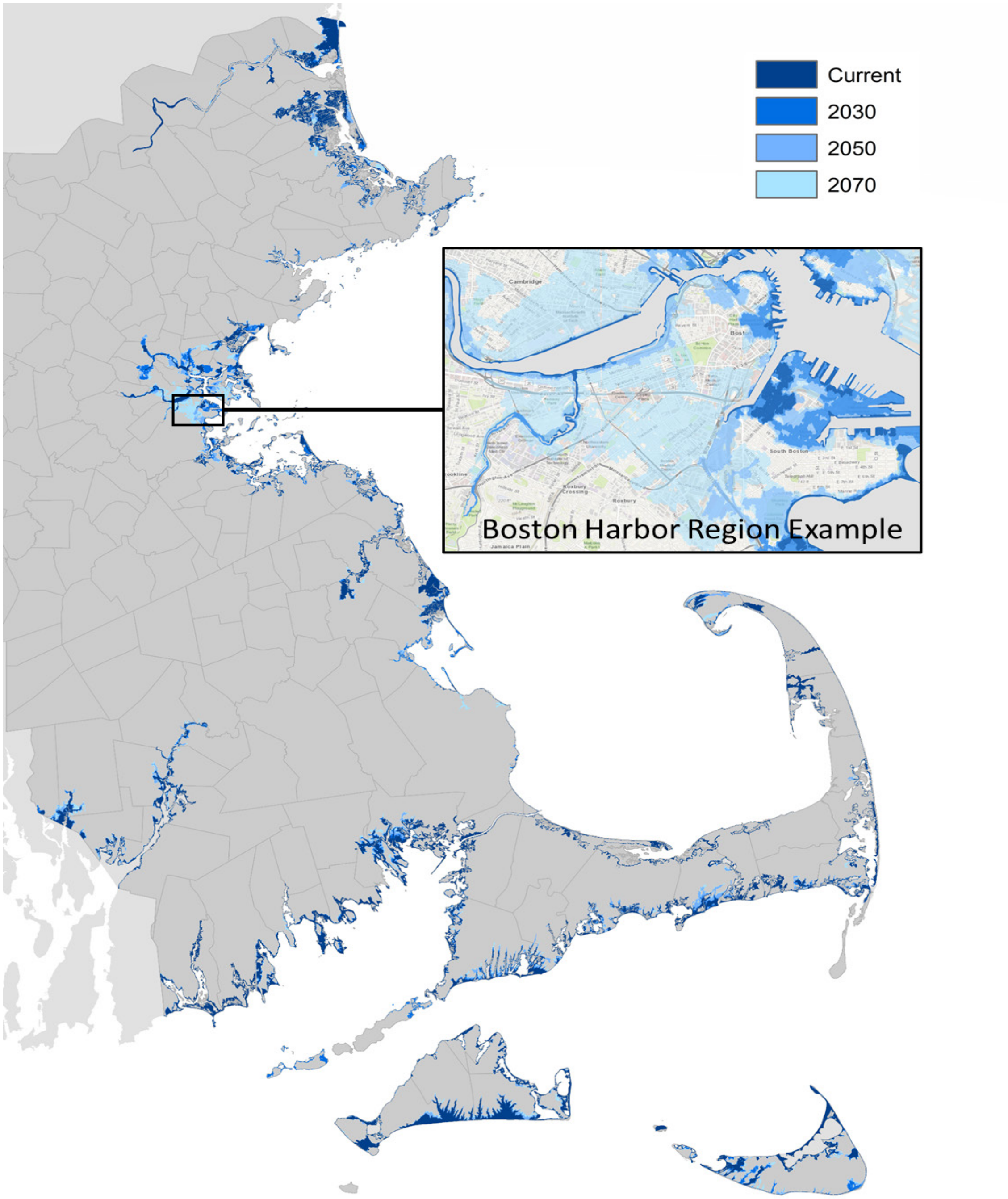
Figure 5.5-1. Sea level change projections from the NCA4 2017 and NOAA 2022 reports.

5.5.2.2 Hazard Description

Coastal flooding is the result of coastal storm events, high tide events, hurricanes, nor'easters, and extreme precipitation events that lead to combined riverine and coastal flooding. Sea level rise increases the risks associated with coastal flooding, including the extent, frequency, depth and duration, and intensity of coastal flood events.

5.5.2.2.1 Location

Based on the analysis described above, there will be increases in the frequency, extents, duration and depth, and water surface elevation of future coastal flood events.
Figure 5.5-2 below shows the projected extent of coastal flooding during a 1 percent annual chance storm today and in 2030, 2050, and 2070. The entire coast of Massachusetts is subject to flooding; however, based on the analysis and maps presented in this assessment, some areas may experience more frequent or more extensive flooding than others.



Spatial extent of the 1 percent annual chance (100-year) flood event in three future time periods: 2030, 2050, and 2070. The darkest blue shows the current area within the 100-year return period coastal floodplain, and lighter blue colors show how the area could expand through 2070. The inset provides detail for the Boston Harbor region, as an example. Map created by ERG using MC-FRM flood modeling.

Figure 5.5-2. Inundation extent of 1 percent annual chance (100-year) flood.

5.5.2.2.2 Previous Occurrences and Frequency

Most data on previous coastal flooding events are associated with specific storms and recorded in the NOAA National Climatic Data Center's Storm Event Database (NOAA, 2022). Nine such events have occurred in Massachusetts between 2006 and 2018. In 2018 there were three major storms: a bomb cyclone in January and two storms in March that caused an estimated $345,000 in damage (NOAA, 2022).

Table 5.5-2 lists the Federally Declared Disasters that have occurred in Massachusetts coastal counties since 1978. This list of disasters was cross-referenced with National Flood Insurance Program (NFIP) claims data to ensure that these events did result in coastal impacts (e.g., flooding and erosion). These federal payments include all damages that the federal government covered, and the chart shows the trend and magnitude of costs in 2023 dollars to illustrate the significant costs of the 1978 and 1991 events relative to the other events. Those costs far outweigh the cost of the more recent, albeit more frequent and less damaging events declared in the Commonwealth.

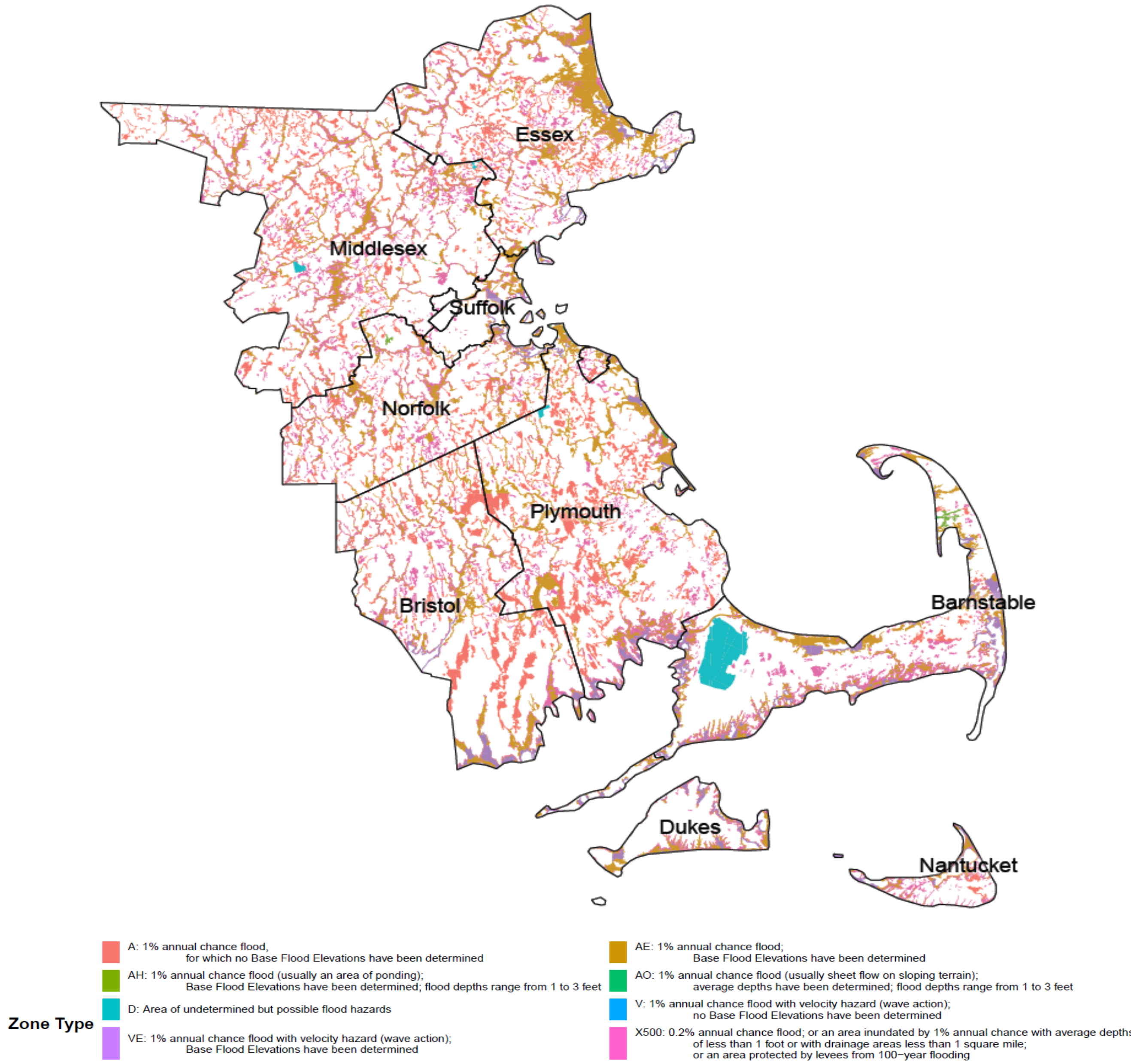
Table 5.5-2. Public Assistance Damage from Federal Disaster Declarations Affecting Coastal Counties

Storm	Public Assistance Damage in Millions (Adjusted to 2023 Dollars)[a]
February 1978	$238
August 1991	$301
October 1991	$25
December 1992	$25
March 2001	$13
April 2007	$16
October 2012	$13
February 2013	$16[b]
January 2015	$25[b]
March 2–3, 2018	$19[b]
March 13–14, 2018	$9[b]

[a] Inflation adjustments were made using the U.S. Bureau of Labor Statistics' CPI Inflation Calculator.
[b] These amounts are not final; the Federal Emergency Management Agency (FEMA) is still reviewing them.

FEMA Flood Insurance Rate Maps

FEMA provides a characterization of the current hazard (i.e., without consideration for climate change) using floodplain boundaries, as shown in Table 5.5-3. These data include the locations of the FEMA flood zones, the 100-year flood zones or 1 percent annual chance flood event areas (including both A Zones and V Zones), and the 500-year flood zones or 0.2 percent annual chance event areas.



This map shows the types of flood zones in coastal areas across Massachusetts, as designated by the Flood Insurance Rate Map (FIRM) databases.

Figure 5.5-3. FEMA coastal flood risk zones.

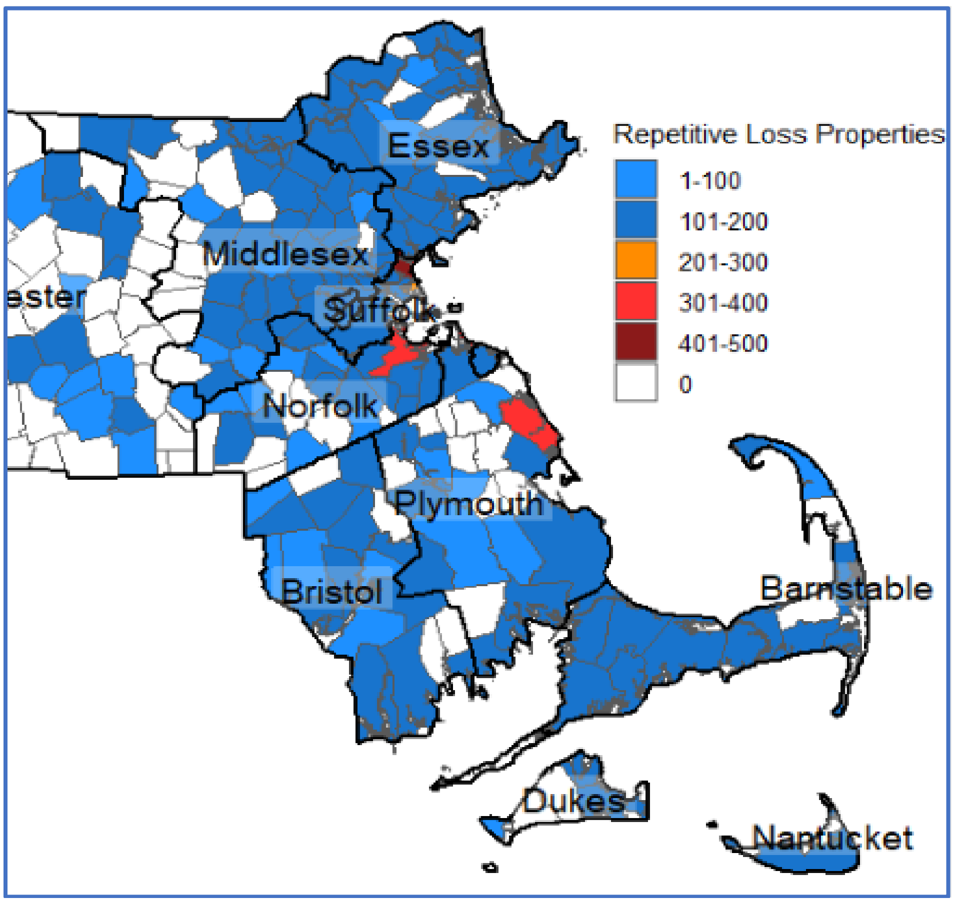
The newest FEMA FIRMs are shown above. These FIRMs are used to support floodplain regulations and mandatory purchase of flood insurance for federally backed mortgages. A useful but incomplete indicator is historical claims data—incomplete because many properties are not required to and choose not to carry flood risk insurance.[2] Communities

[2] If there is a mortgage, the bank must require flood insurance as a condition of the loan, except in the town of Chilmark. (Chilmark does not participate in NFIP, so flood insurance is not required there.)

participate in NFIP so that homeowners and businesses can purchase flood insurance for their properties.

As well as providing FIRMs, FEMA (together with the Commonwealth) identifies repetitive loss properties, shown below in Figure 5.5-4. A repetitive loss property is a property that has experienced at least two flood events that caused damage over $1,000.

Both the FEMA flood zone maps and the repetitive loss property data are used to identify properties most at risk from flooding and areas that should consider flood mitigation strategies such as building codes, floodplain management strategies, regulations, land use zoning, prioritizing hazard mitigation funding and actions, and relocation or retrofits to reduce risk.



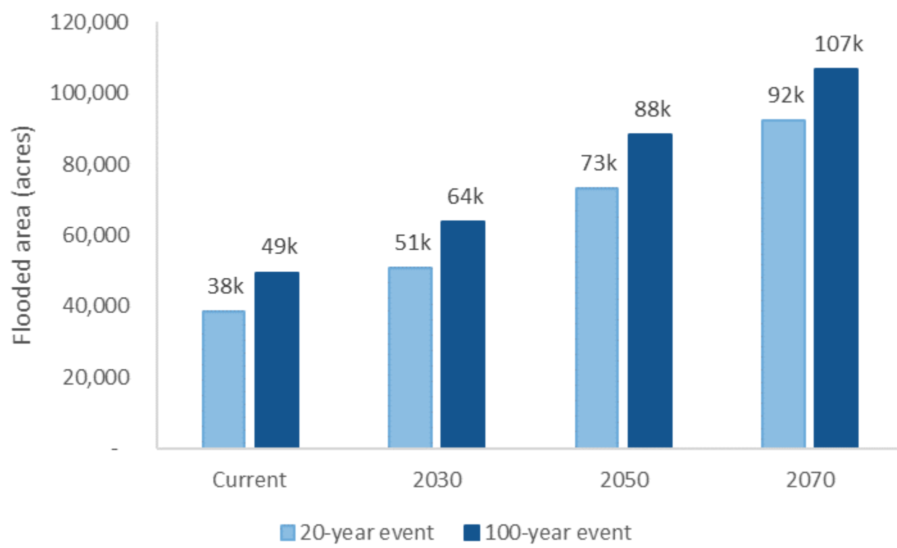
Source: ERG analysis using data from FEMA (2022).

A repetitive loss property is a property for which NFIP has paid two or more flood insurance claims of more than $1,000 within any 10-year period since 1978. This map shows the counts of these properties by town. Note that, due to FEMA restrictions on personally identifiable information, it is difficult to differentiate between coastal and inland-related flooding claims.

Figure 5.5-4. NFIP repetitive loss properties in coastal counties.

5.5.2.2.3 Severity/Intensity

The surface elevation of flood water is also an important determinant of impacts to both built infrastructure and natural areas. Figure 5.5-5 shows how the developed land area in coastal Massachusetts that could be flooded with 12 inches or more of corrosive seawater for both the 5 percent annual probability storm and the 1 percent annual probability changes over time. The area with at least 12 inches of water inundation expands substantially over time, from 38,000 acres currently (for the 1999–2017 period) to a projected 73,000 acres in 2050 and 92,000 acres in 2070 because of climate change for the 20-year event. The city of Boston's *2021 Natural Hazard Mitigation Plan Update* notes that, as Boston's coast is highly developed, coastal flooding (from storm surge or extreme high tides or a combination of both) could have significant effects on the city's population (City of Boston, 2021). For example, the plan explains that, as of 2017, a 5-foot storm surge at high tide could flood about 132 miles of roadway in Boston (City of Boston, 2021). Given Boston's role as an economic hub for the surrounding area, coastal flooding in Boston would have impacts beyond the city itself.



Source: Spatial analysis of MC-FRM results.

Current period is based on 2008 data.

Figure 5.5-5. Coastal areas flooded with 1 foot or higher water depth.

Note that these estimates reflect the impacts of stillwater flooding and coastal flood inundation but exclude the additional damage that might result from wave action. Wave action can exponentially increase damage due to increased force on structures.

Potential Effects of Climate Change on Coastal Flooding

As described in detail throughout this section, coastal flooding is already being affected by climate change in the form sea level rise, increased frequency and intensity of coastal storm events, and the likelihood that hurricane intensity will shift north due to climate change. Climate change is projected to increase the intensity, duration, frequency, and areas affected by coastal flooding by affecting the processes described above. Raising water levels will increase the frequency of what are now 1 percent chance, .05 percent chance events as well.

5.5.2.2.4 Warning Time

Although coastal flooding and inland flooding mechanisms are very different, the warning times available for coastal floods are generally similar to those for inland flood events. Most warning times for coastal flooding could be described as more than 24 hours due to awareness of incoming storms and how they correlate with the tides and whether king tides are possible. The National Weather Service NWS) issues coastal flood watch/warnings on a county scale on a continuous basis (available at the [NOAA Storm Prediction Center]). NWS briefs state and local emergency managers and notifies the public via traditional media and social networking platforms.

As noted above, mean sea level has been rising very gradually over the last century and will affect tidal levels and permanent inundation on a longer time scale. This affords communities the opportunity to plan infrastructure improvements in preparation for elevated water levels, but it also can result in unexpected flooding in new areas, as well as more frequent, deeper, or longer-lasting flooding than historical patterns would suggest due to the length of time and complexity of adapting shoreline infrastructure and communities.

NWS issues storm surge watches and warnings to highlight coastal areas with significant risk of life-threatening inundation from an ongoing or potential tropical cyclone, subtropical cyclone, or post-tropical cyclone. A storm surge watch is issued, generally within 48 hours, for the possibility of life-threatening inundation from rising water moving inland from the shoreline. The watch is issued earlier if other conditions such as wind may limit the time to take protective actions for surge, such as evacuations. A storm warning is issued, generally within 36 hours, if there is a danger of life-threatening inundation.

5.5.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

Many of the local hazard mitigation plans reviewed identify coastal flooding as a cause of significant damage in coastal towns and note that coastal regions of the Commonwealth are particularly sensitive to sea level rise, increased frequency of storms, intensity of storms, precipitation, wind speeds, and ocean warming. As sea levels rise, coastal areas will be particularly vulnerable to coastal flooding. Table 5.5-3 below provides examples of how coastal flooding was treated in three plans under review.

Table 5.5-3. Highlight of Local Hazard Mitigation Plans

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Town of Hull Hazard Mitigation Plan: 2018 Update, April 2018	Reported losses on repetitive loss properties indicate that a flood event resulting in property damage occurs on average a little more often than once a year.	Eastern coastline faces the greatest exposure to wind driven waves.	Repetitive loss properties had a total of 749 losses between 1978 and 2015, totaling $6,618,446 in damage.
Local Multi-Hazard Mitigation Plan 2017 Update, town of Swansea, August 2017	Storm surge and wave action occur along the coast. Small, localized areas to moderate area depending on the magnitude of the storm.	Typical storm surge is only a few feet, but storm surge of up to 18 feet can occur in high winds.	Not provided
2021 Hazard Mitigation Plan: Plymouth, Massachusetts, 2021	Experiences significant coastal flooding several times per year due to coastal storm surges resulting mainly from winter storms and nor'easters.	Plymouth is at high risk for future coastal flooding events.	Total cost of coastal infrastructure repairs, 2003 through 2018: $2,974,347.53.

5.5.2.3 Secondary Hazards

Coastal flooding and storm surge can have primary impacts, as described above. They can also contribute to several secondary impacts and effects, including:

- Saltwater intrusion to groundwater, freshwater systems, and salt-sensitive habitats
- Potential increase in coastal erosion
- Mobilization of contaminants, toxics, and other debris
- Combined riverine and coastal flood risk, as well as increased inland flood risk, as urban drainage systems that rely on gravity systems can no longer drain; sea level rise influences over groundwater rise pushing flood risk inland
- Potential for damage or loss of wetlands that are small or fragmented or lack upland and inland migration space, resulting in a loss of habitat, water quality benefits, and any benefits provided to reduce flood and erosion risk to shoreline assets.

5.5.2.4 Exposure and Vulnerability

According to the MA Climate Assessment, nearly 43 percent (3 million out of 7 million) of the Commonwealth's total population resides on the coast. Table 5.5-4 below provides population projections for coastal counties in Massachusetts through 2040.

Table 5.5-4. Population Projections for Coastal Counties in Massachusetts

County	Population: 2020	Projection: 2030*	Projection: 2040[a]	Population Change: 2020–2040
Barnstable	213,505	199,466	176,007	-17.6%
Bristol	563,301	567,277	568,250	0.9%
Dukes	17,430	19,584	19,793	13.6%
Essex	787,038	816,022	827,531	5.1%
Middlesex	1,605,899	1,686,641	1,736,669	8.1%
Nantucket	11,212	11,804	12,212	8.9%
Norfolk	703,740	765,912	797,619	13.3%
Plymouth	518,597	534,464	539,424	4.0%
Suffolk	801,162	900,586	950,251	18.6%

Sources: 2010 U.S. Census data and projections by UMass Donahue Institute (2018).

[a] Projections are calculated from 2010 Census data.

To consider the magnitude of exposure to coastal flooding, the Risk Assessment team sought to estimate the population living in areas exposed to a 1 percent and 0.2 percent annual probability of experiencing flood events. The team used FEMA-developed flood zone maps that identify different types of flooding risk. These maps are the basis for floodplain management regulation that affects insurance requirements on mortgages, zoning, and other aspects of the built environment. Table 5.5-5 below lists the total population, then:

- The population living in census blocks that are exposed to a 1 percent annual chance of flooding in the A Zone. The 1 percent chance "A" Zones reflect all FEMA A Zones, including those in coastal areas.
- Populations living in census blocks that are in zones designated as V Zones. The 1 percent annual chance flood with velocity hazard reflects the "V" Zone. The V Zones are the coastal areas with 1 percent or greater annual chance of flooding and an additional hazard associated with storm waves.
- Populations living in census blocks exposed to a 0.2 percent annual chance of flooding. The areas include all FEMA X Zones, including those in the coastal areas.

In the table, values in the V and X Zone columns are interpreted as additional populations and percentages to the values in the A Zone. Note that digitized FEMA flood zone maps were not available for analysis for Franklin County when this Risk Assessment was published. The table estimates the number of people in floodplain areas. The table is not based on MC-FRM.

Table 5.5-5. Estimated Population Exposed to the 1 Percent and 0.2 Percent Annual Chance Flood Events

County	Total 2020 Population	1 Percent Annual Chance Flood Event A Zone		1 Percent Annual Chance flood with Velocity Hazard, V Zone (Increment to 1 Percent Annual Chance Results)		0.2 Percent Annual Chance Flood Event (Increment to 1 Percent Annual Chance Results)	
		Exposed Population	% of Total in County or Statewide	Additional Exposed Popu-lation	% of Total in County or Statewide	Additional Exposed Popu-lation	% of Total in County or Statewide
Barnstable	213,505	25,162	11.8	7,200	3.4	13,186	6.2
Bristol	563,301	60,687	10.8	7,436	1.3	25,040	4.4
Dukes	17,430	1,828	10.5	1,038	6.0	534	3.1
Essex	787,038	86,342	11.0	8,178	1.0	28,871	3.7
Middlesex	1,605,899	124,921	7.8	—	—	54,666	3.4
Nantucket	11,212	467	4.2	145	1.3	814	7.3
Norfolk	703,740	81,836	11.6	3,893	0.6	20,668	2.9
Plymouth	518,597	79,731	15.4	8,324	1.6	13,216	2.5
Suffolk	801,162	37,930	4.7	4,764	0.6	8,037	1.0
Total	**5,221,884**	**498,904**	**9.6%**	**40,978**	**0.8%**	**165,032**	**3.2%**

Table developed using MassGIS FEMA Q3 flood zones and census block population estimates from the 2020 Census.

5.5.2.4.1 Human

Communities at risk from coastal flooding include broad segments of the general population in the highest-risk zones for coastal flooding, identified in Section 5.5.2.2.1 above (particularly in Figure 5.5-2, which identifies the estimated population at risk from flooding within FEMA flood zones). Communities throughout the Commonwealth experience flooding; therefore, the extent of areas that experience coastal flooding in Massachusetts communities is best understood as an estimate. Coastal flooding can affect communities in a variety of ways through:

- Damage to, disruption to, or loss of homes; businesses; critical assets; and lifelines such as schools, hospitals, power, and water supply
- Transportation network disruptions or loss
- Direct injury and mortality
- Exposure to contaminants
- Loss of wages due to business interruption
- Damage to cultural resources

Coastal flooding impacts on affordably priced housing can be a major contributor to the long-term economic impacts of coastal flooding and storms on a region. As described in detail below, a significant number of federally subsidized housing units are concentrated in the Boston, Chelsea, Revere, and Quincy areas, where there is also a higher concentration of Commonwealth-designated environmental justice block groups of all categories.

The MA Climate Assessment analyzed how these risks are distributed within the community, finding that slower emergency response caused by traffic delays could have a highly disproportionate effect for the following populations:

- Low-income populations are more likely to live in coastal areas with a 40 percent higher risk of high-tide flooding-related road impacts than the rest of populations living in coastal areas.
- Priority populations that live in coastal areas experience a 223 percent higher risk of high-tide flooding-related road impacts than the rest of the coastal area.
- Language-isolated populations are more likely to live in coastal areas with a 133 percent higher risk of high-tide flooding-related road impacts than the rest of the coastal area.
- Priority and low-income populations are more likely to live in coastal areas that have a 244 percent higher risk of high-tide flooding-related road impacts than the rest of the coastal area.

These results reflect the high level of traffic delays expected in the large urban areas of Suffolk and Middlesex Counties in the Boston Harbor region. Priority and language-isolated populations were also shown to be disproportionately affected by health impacts associated with extreme storms and power outages (Commonwealth of Massachusetts, 2022).

The potentially elevated risk of complications associated with chronic obstructive pulmonary disease (COPD), renal disease, respiratory conditions, and pregnancy, which have been shown to lead to health effects from a variety of flood and emergency response delays during extreme coastal flood events (such as nor'easters and hurricanes), means populations with high baseline prevalence of these conditions are particularly vulnerable. In addition, populations that rely on electricity for medical devices have a high vulnerability to power outages associated with coastal flood risk.

Flooding-Caused Traffic Delays

Over the next century, climate change is expected to increase coastal traffic delays during storm events when roads become impassable due to the combined effects of sea level rise and storm surge events. These events will affect access to transportation networks, thereby delaying access to critical emergency response services, especially hospitals, emergency medical services (EMS), law enforcement, and fire response—with adverse consequences for human health and property.

The Risk Assessment team evaluated this impact of coastal flooding quantitatively using the results of road delays associated with high-tide flooding, along with a method for estimating the human health impact of road delays on the provision of fire and emergency medical technician responses. The economic impacts of traffic delays due to flooded or damaged roadways from sea level rise and storm surge were estimated for access to three critical emergency response services: hospitals, EMS, and fire response. Additional non-quantified but important impacts affect law enforcement response time as well as the need for law enforcement traffic control during these emergencies.

Traffic delay data were used to calculate delays in emergency response time. Using the referenced FEMA methodology, emergency response delays are translated into average mortality rates per incident and multiplied by the incremental loss of life using an estimate of individual values for fatality risk reduction. The metric that results is the economic value of losses from sea level rise– and storm surge–induced traffic delays per incident, as a function of response time delays for three categories of emergency response: structure fire, EMS call for cardiac arrests, and unintentional injury. See Table 5.5-6 for details.

Table 5.5-6. Emergency Response Service Impacts from Traffic Delays Due to Sea Level Rise and Storm Surge: Annual Total Expected Impacts from Climate Change ($)

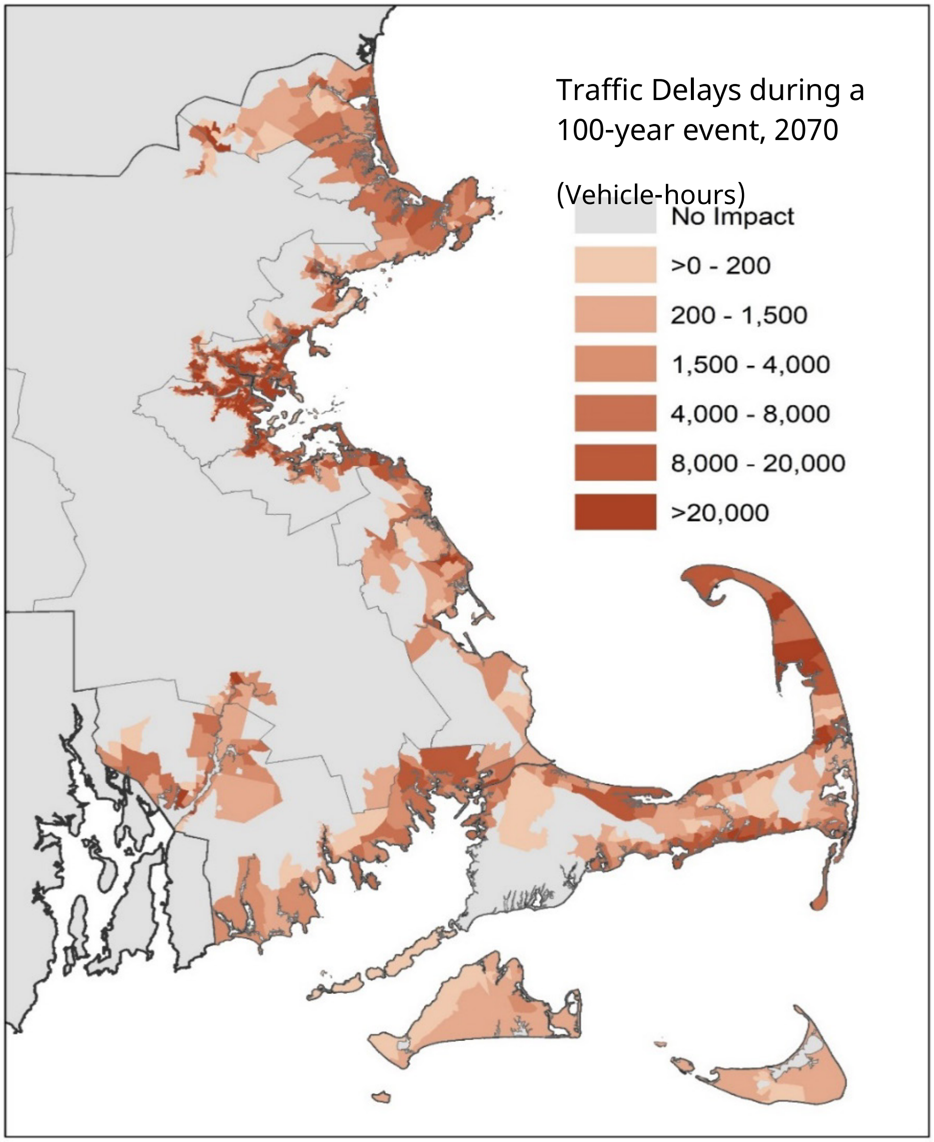
Region	Current	2030	2050	2070
Eastern Inland	$600	$200	$500	$1,000
Boston Harbor	$220,000	$110,000	$475,000	$1,300,000
North and South Shores	$14,000	$10,000	$24,000	$43,000
Cape, Islands, and South Coast	$11,000	$4,700	$16,000	$27,000
Statewide	**$250,000**	**$130,000**	**$520,000**	**$1,400,000**

Source: MA Climate Assessment analysis (Commonwealth of Massachusetts, 2022), using a FEMA-developed methodology.

The analysis estimated the economic impact of coastal flooding to human health and property losses associated with road delays for emergency service calls. The road delays are from flooding events from accelerated sea level rise and storm surge from climate change. Future impacts are presented for three periods identified in the table by their central year: 2030 (near-term, 2020–2039), 2050 (mid-century, 2040–2059), and 2070 (mid-late century, 2060–2079). Modeling results are not available for 2090 (end of century, 2080–2099). Values may not sum due to rounding. Damage includes increases in mortality associated with delayed emergency response, using the value for avoided fatal risk employed throughout the SHMCAP.

According to this methodology, there are no impacts from sea level rise– and storm surge–induced traffic delays in the Berkshire and Hilltowns, Greater Connecticut River Valley, or Central regions. However, if inland patient needed to be transported to a coastal facility, that patient’s ability to access care could be an affected.

The spatial distribution of these impacts is concentrated in the Boston Harbor region, reflecting the spatial pattern of both sea level rise and storm surge–induced traffic delays and the intensity of traffic demand in that region, particularly in Suffolk and Middlesex counties (see Figure 5.5-6, for example). Delays are likely to be less intense in other counties and regions, in part because of the availability of less vulnerable alternative routes for emergency response during flooding and extreme events.



Source: MA Climate Assessment analysis (Commonwealth of Massachusetts, 2022) using a FEMA-developed methodology.

Delays are measured in vehicle hours.

Figure 5.5-6. Traffic delays affecting emergency response by block group for a 1 percent chance annual coastal flood in the 2070s.

Flood-Related Injury and Morbidity Risk

Flood and storm events could reasonably be anticipated to increase the risk of injuries and disease both during and after the event. Injuries or acute morbidity may be associated with flooding itself, actions taken to evacuate, individual responses to the loss of shelter, and loss of utilities such as electric power. Some of these injuries or acute medical conditions may be severe enough to require emergency department visits, hospital admissions, and/or emergency responses from trained medical personnel.

Some existing literature documents adverse health outcomes and mortalities linked to medical technology failure and food spoilage linked to extreme coastal flooding. Much of this research in the U.S. examines the effects of power outages in New York City, particularly after the August 2003 nor’easter and the 2012 Hurricane Sandy blackouts. During power outage periods in New York State over the course of a decade, one study reported an increase of 3 to 39 percent for hospitalizations from COPD, an average $4,670 increase in hospital costs per case, and a 38 percent increase in comorbidities per case (Zhang et al., 2020). Increased frequency of power outages due to extreme weather threatens the reliability of oxygen-supplying devices relied on by many people suffering from COPD. COPD is currently Massachusetts’ fourth leading cause of death, claiming nearly 3,000 lives in the Commonwealth in 2017. Climate impacts on populations that rely on electricity-dependent medical equipment are an area of ongoing research, with at least one study focused on Massachusetts (Webb et al., 2021), though data limitations stemming from medical privacy have restricted the scope of such research to date.

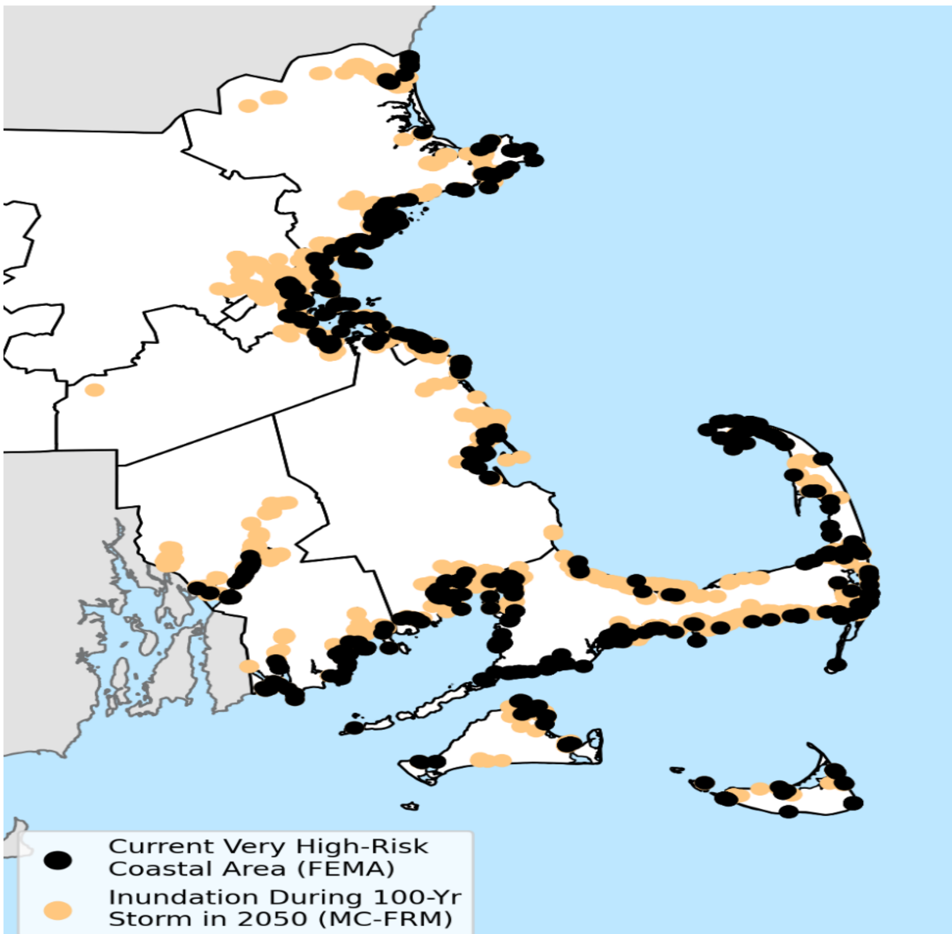
A handful of additional studies in New York report on other health effects linked to storms and power outages. A study of the effects of Hurricane Sandy relates disruptions in dialysis services before, during, and following the storm to increased New York City emergency department visits, hospitalizations, and mortalities among patients with end-stage renal disease, when compared with hurricane-unaffected renal disease populations (Kelman et al., 2015). A more general assessment of outages in New York City found similar results, reporting higher incidence of respiratory disease hospitalizations and renal disease hospitalizations, as well as mortality (Dominianni et al., 2018). A mortality-focused study reported increases in accidental (122 percent) and non-accidental (25 percent) deaths in New York City following the widespread August 2003 blackout, with elevated mortality risk persisting for most of the following month (Anderson & Bell, 2012). Another study reported a 16.6 percent increase in emergency department visits pertaining to pregnancy complications, a 26.7 percent increase in threatened and/or early delivery, and a 111.8 percent increase in gestational diabetes mellitus associated with power outages (Xiao et al., 2021).

Power outages can also indirectly affect health through food spoilage and/or refrigeration failure. One research team reported immediate, statistically significant increases in the ratio of diarrhea-associated emergency department visits compared to “other-cause” visits, sales of antidiarrheal medications, and gastrointestinal illness–associated employee absences (Marx et al., 2006).

Historically, the effect of more frequent floods on the production of mold, airborne mold spores, and mold fragments has been linked with increased risk of respiratory disease, including upper respiratory tract symptoms, wheezing, and asthma in sensitized people (Institute of Medicine, 2011). However, changes in respiratory illnesses associated with mold exposure with climate change have not been projected into the future.

Cultural Resources

Using spatial data on cultural heritage sites, historical places, and other sites with cultural importance and/or archives and inland and coastal flooding data identifies specific locations that may be at risk of flooding. The Massachusetts Historical Commission maintains the Massachusetts Cultural Resource Information System (MACRIS), an inventory of over 200,000 cultural resources and historical sites in the Commonwealth, including buildings, other structures, objects, and burial grounds. Figure 5.5-7 below shows the sites in this list that fall within FEMA's current 1 percent annual chance (100-year) coastal floodplain.[3]



Sources: MACRIS sites and FEMA floodplains from MassGIS; projected coastal flooding layer from MC-FRM.

Map shows coastal MACRIS sites within areas either currently identified by FEMA as very high-risk coastal areas or projected to be inundated by a 1 percent annual chance (100-year) storm in 2050 based on MC-FRM results.

Figure 5.5-7. MACRIS sites and resources vulnerable to coastal flooding.

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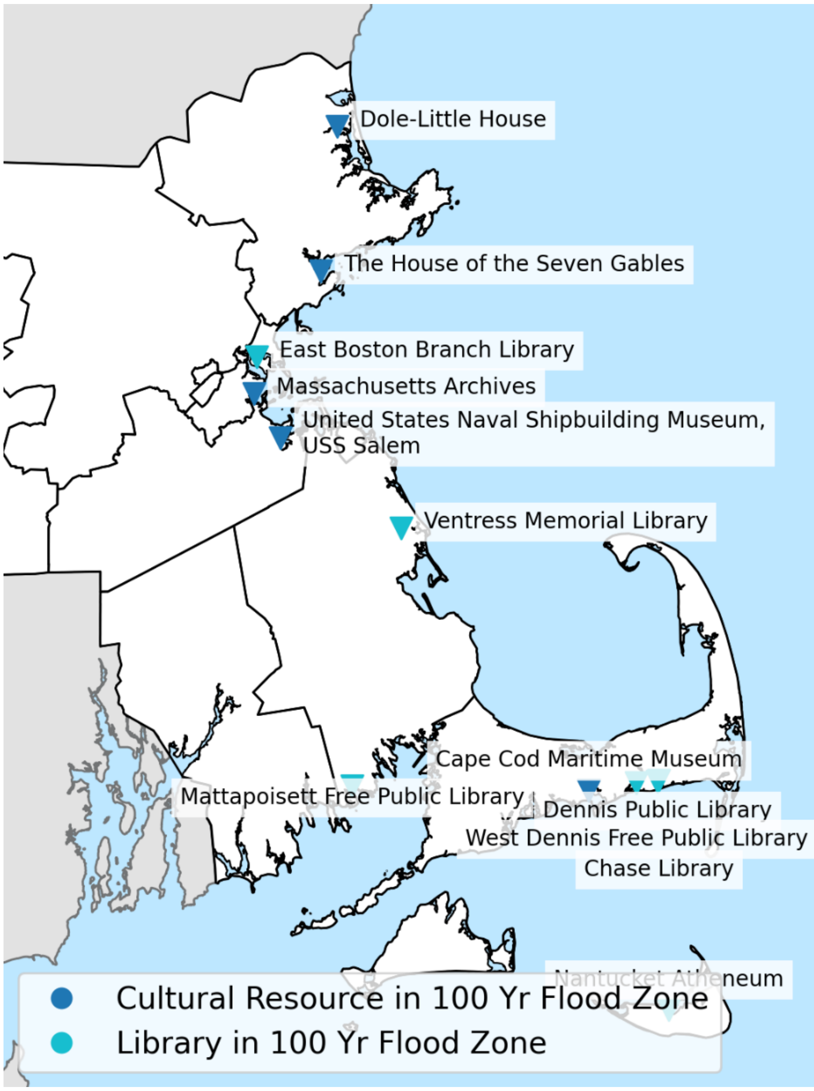
[3] Note that MACRIS includes water-based resources and sites such as footbridges and fish runs. Not all of these resources will be vulnerable to flooding.

Figure 5.5-8 below shows the cultural heritage sites and libraries with projected flooding with a 1 percent annual chance in the current period, both inland and coastal, as an example of some specific and relatively well-known sites that could be at risk of flooding.



Source: Map developed by ERG using site locations from MassGIS.

Map shows cultural heritage sites and public libraries within the current 100-year flood zone based on FEMA hazard maps. As sea levels rise and precipitation becomes more intense, more sites could become at risk.

Figure 5.5-8. Cultural heritage sites and public libraries within the current 100-year flood zone.

As part of the 2023 SHMCAP process, Massachusetts state agencies were surveyed about their primary concerns for populations served and potential disproportionate impacts from coastal flooding. Table 5.5-7 below lists the primary concerns regarding coastal flooding impacts and disproportionate impacts.

Table 5.5-7. State Agency Responses: Primary Concerns About Coastal Flooding's Impacts on Populations Served and Potential Disproportionate Impacts

Category	Primary Concerns
Populations served	• All Massachusetts residents • Shellfish dealers
Disproportionate impacts	• Impacts could be disproportionate for vulnerable populations such as elderly people and low-income households. • Those reliant on public transportation could be disproportionately affected. • Impacts would likely depend on the severity and location of the event; everyone on the Socially Vulnerable Population index is proven to be disproportionately affected by disaster, as they are typically located in less safe, less desirable areas and have a harder time bouncing back from disasters.

Source: ERG (2023).
The responses to the survey were completed by agency staff and did not go through formal review.

5.5.2.4.2 Governance

Changes in sea level and storm surge could have direct impacts on flood damage to state-owned buildings in the Massachusetts coastal zone. Additionally, state and local revenue streams could be affected as coastal property values and associated tax bases decrease. These impacts affect governance activity primarily through forced downtime (when buildings are flooded), an increased need for expenditures, or lost revenue. Demands for emergency response and recovery will strain resources of local and state governments, as well as require attention and response from others.

The MA Climate Assessment also found that exposure to coastal flood risk to state-owned buildings is likely to have limited disproportionate impact. State-owned buildings and structures in areas where priority populations live are 10 percent more likely to be damaged by coastal flooding. (This estimate was developed by estimating the number of buildings in areas designated as being home to environmental justice populations.) It is even more important to consider the impacts to people who rely on the services provided through these buildings, including people seeking income, food, or health assistance.

Government-Owned Structures

The analysis of government-owned buildings and other assets relies on an inventory of major buildings owned by the Commonwealth and maintained by the Division of Capital Asset Management and Maintenance, intersected spatially with results of MC-FRM results for coastal risks (Neumann et al., 2021). The key metric is the expected annual damage attributable to coastal flooding at state-owned buildings in the Commonwealth.

Annual expected coastal flood damage to state- and state authority–owned properties could be major due to increases in damage: $8.2 million now, $17 million in 2030, and over

$43 million by the 2070s. About two-thirds of the expected annual damage is expected at state-owned buildings, while about one-third is at state authority–owned buildings.[4] Most of the current and expected damage is expected in the Cape, Islands, and South Coast region, but damage grows faster over time in the Boston Harbor region because of the intersection of building locations and the increasing area of flood risk in that region (Table 5.5-8).

Table 5.5-8. Annual Expected Flood Damage to State-Owned Coastal Properties: Annual Total Expected Damage (Million $)

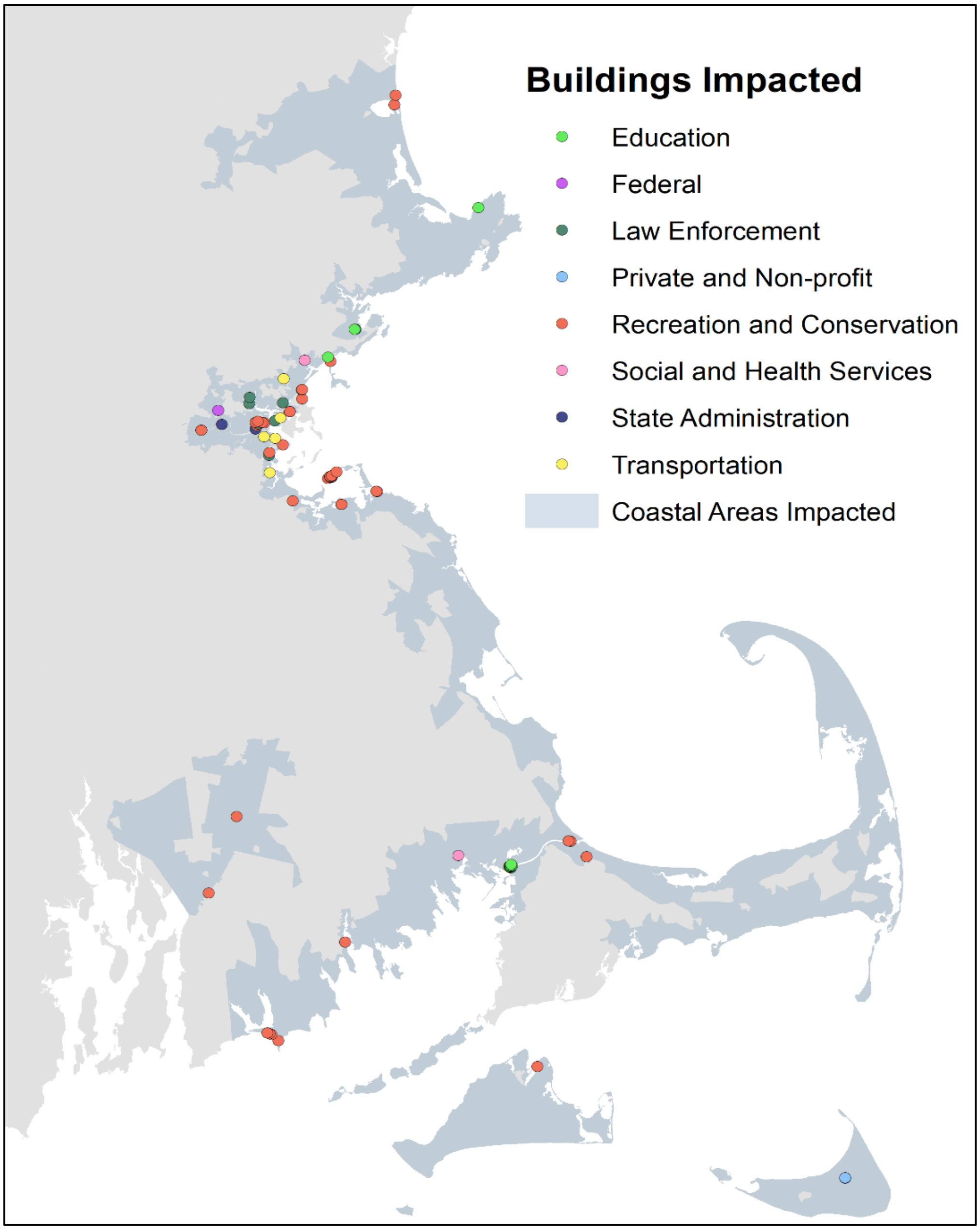
Region	Current	2030	2050	2070
Eastern Inland	$0	$0	$0	$0
Boston Harbor	$2.4	$3.2	$9.3	$21
North and South Shores	$0.3	$1.0	$7.0	$8.7
Cape, Islands, and South Coast	$5.5	$13	$20	$23
Statewide	**$8.2**	**$17.2**	**$36.3**	**$52.1**

Source: ERG analysis of DCAMM state asset database and MC-FRM results from the MA Climate Assessment (Commonwealth of Massachusetts, 2022).

This table includes flood damage from sea level rise and changes in coastal storms. Future impacts are presented for four periods identified in the table by their central year: 2030 (near-term, 2020–2039), 2050 (mid-century, 2040–2059), 2070 (mid-late century, 2060–2079), and 2090 (end of century, 2080–2099). Values may not sum due to rounding. Note that four block groups in the Eastern Inland region are considered potentially influenced by coastal floods, but no state-owned buildings are present in those block groups.

Figure 5.5-9 below shows the state ownership, in groupings by function, of buildings at risk of at least a 1% chance annual flood event (or more frequent flooding) in the 2070s, which reflects expansion of the 1% chance annual event flood zone in the current period as a result of sea level rise and storm surge attributable to climate change.

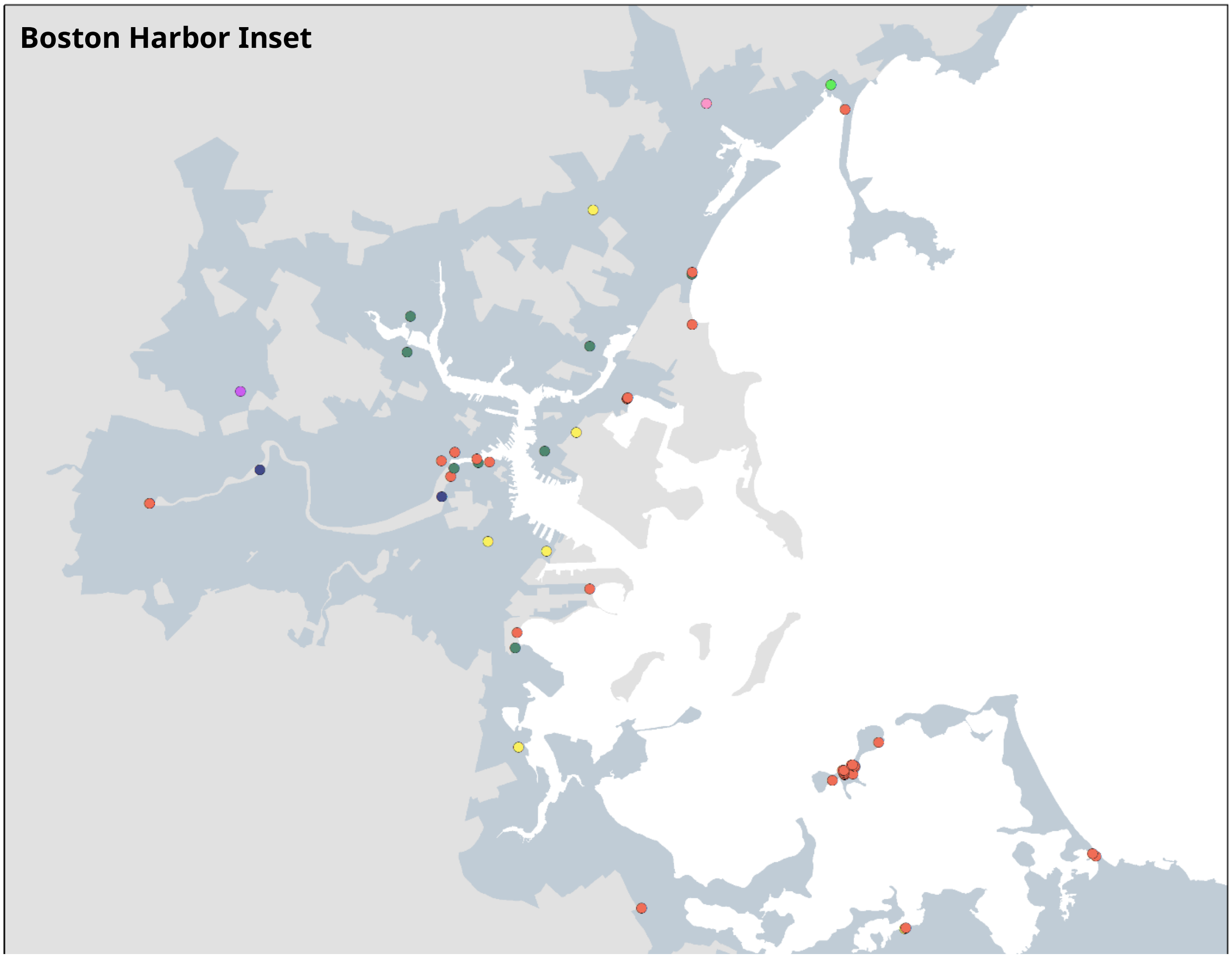
[4] Leased buildings are included in the state-owned buildings category. Authority-owned buildings are owned and managed by Commonwealth authorities, generally distinct from agencies and departments, such as the Massachusetts Port Authority and the Massachusetts Turnpike Authority.



Source: ERG analysis of DCAMM state asset database and MC-FRM results from the MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Dots show locations of buildings; colors indicate the agency or authority ownership function class.

Figure 5.5-9. State- and authority-owned buildings within the 2070 1 percent chance annual event coastal flood zone, by agency/authority function class.



Source: ERG analysis of DCAMM state asset database and MC-FRM results from the MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Dots show locations of buildings; colors indicate the agency or authority ownership function class.

Figure 5.5-10. State- and authority-owned buildings within the 2070 1 percent chance annual event coastal flood zone, by agency/authority function class.

Fiscal Impacts on Tax Revenue

Massachusetts' fiscal health depends on the tax revenues collected by the Commonwealth and other levels of government. A readily quantifiable category of the potential effect on revenues is on property taxes. Effects of climate change over time, and especially sea level rise and storm surge, can be reflected in reduced property sales prices and assessed values, and/or loss of land and structures, which reduces the property tax base. Property tax is usually the most important source of income for municipal entities.

Researchers studied the impacts of a 3-foot sea level rise on the 2015 tax base in Massachusetts, with potential impacts from inundation of land and/or structures from sea level rise (Shi & Varuzzo, 2020). The 3-foot scenario used in the paper is within the range of uncertainty for the Commonwealth's projection of the not-to-exceed estimate for sea level rise through 2050, as applied in the MA Climate Assessment. Massachusetts municipalities could experience $104 million in lost revenues by the time 3 feet of sea level rise is reached, which represents 1.4 percent of current property taxes in 89 coastal municipalities. Projected losses could increase to $946 million per year with 6 feet of sea level rise (12.5 percent of current property taxes in 99 coastal municipalities).

As part of the 2023 SHMCAP update process, Massachusetts state agencies were surveyed about their primary concerns related to coastal flooding, along with activities planned/undertaking to address it. Table 5.5-9 below outlines examples of their responses.

Table 5.5-9. State Agency Responses: Primary Concerns About Coastal Flooding's Effects on Services, with Suggested Improvements

Category	Concerns/Improvements
Services provided	• Emergency service coordination at the federal, state, and local levels • Access to water purification plant • Delays in emergency response • Damage to IT and security infrastructure and services • Damage to transportation systems
Updates, improvements, or enhancements to address concerns	• The MBTA is currently investigating the feasibility of moving a bus facility away from the coast. • Move IT infrastructure to more resilient and redundant third-party facilities and cloud solutions. • Improve/enhance communication and transportation infrastructure serving Plum Island. • Alternate locations, personnel, and equipment staged across the Commonwealth. • Conduct a study to mitigate flooding. Are any public safety answering points in a flood zone? Is there vulnerable infrastructure that serves 911 (cell towers, etc.)? • Install backup power generators to power sump pumps.

Source: ERG (2023).
The responses to the survey were completed by agency staff and did not go through formal review.

5.5.2.4.3 Infrastructure

The built environment along the coast is vulnerable to increased frequency, extent, duration, depth, and intensity of coastal flooding due to climate change effects, including sea level rise and coastal storms such as hurricanes.

Coastal Properties

Table 5.5-10 summarizes the detailed analysis of flood risks to coastal properties in Massachusetts. The "current" estimates it shows are based on 2008 sea level rise projections. The results indicate that current statewide annual average expected damage to coastal buildings is about $185 million, though some years could see more or less. Damage is projected to almost double by 2030 from changes in sea level and storm surge activity, and almost double again—to over $600 million per year—by 2050. By 2070, statewide annual average damage could be more than $1 billion per year (Lorie et al., 2020; Neumann et al., 2021). The estimates of current and projected future damage from coastal flooding largely reflect the value of vulnerable structures: for example, the total value of structures within the floodplain for the current 1 percent annual chance (100-year return period) coastal storm is just less than $55 billion, of which about $40 billion is residential, $12 billion is industrial, and $2.5 billion is commercial.[5,6]

Table 5.5-10. Annual Expected Flood Damage to Coastal Properties: Annual Total Expected Damage (Million $)

Region	Current	2030	2050	2070
Eastern Inland	$1	$2	$5	$9
Boston Harbor	$100	$210	$400	$780
North and South Shores	$25	$40	$60	$100
Cape, Islands, and South Coast	$60	$70	$140	$210
Statewide	**$185**	**$330**	**$610**	**$1,100**

Source: MA Climate Assessment analysis of MC-FRM results using methods from Neumann et al. (2021); see text for details.

Values may not sum due to rounding.

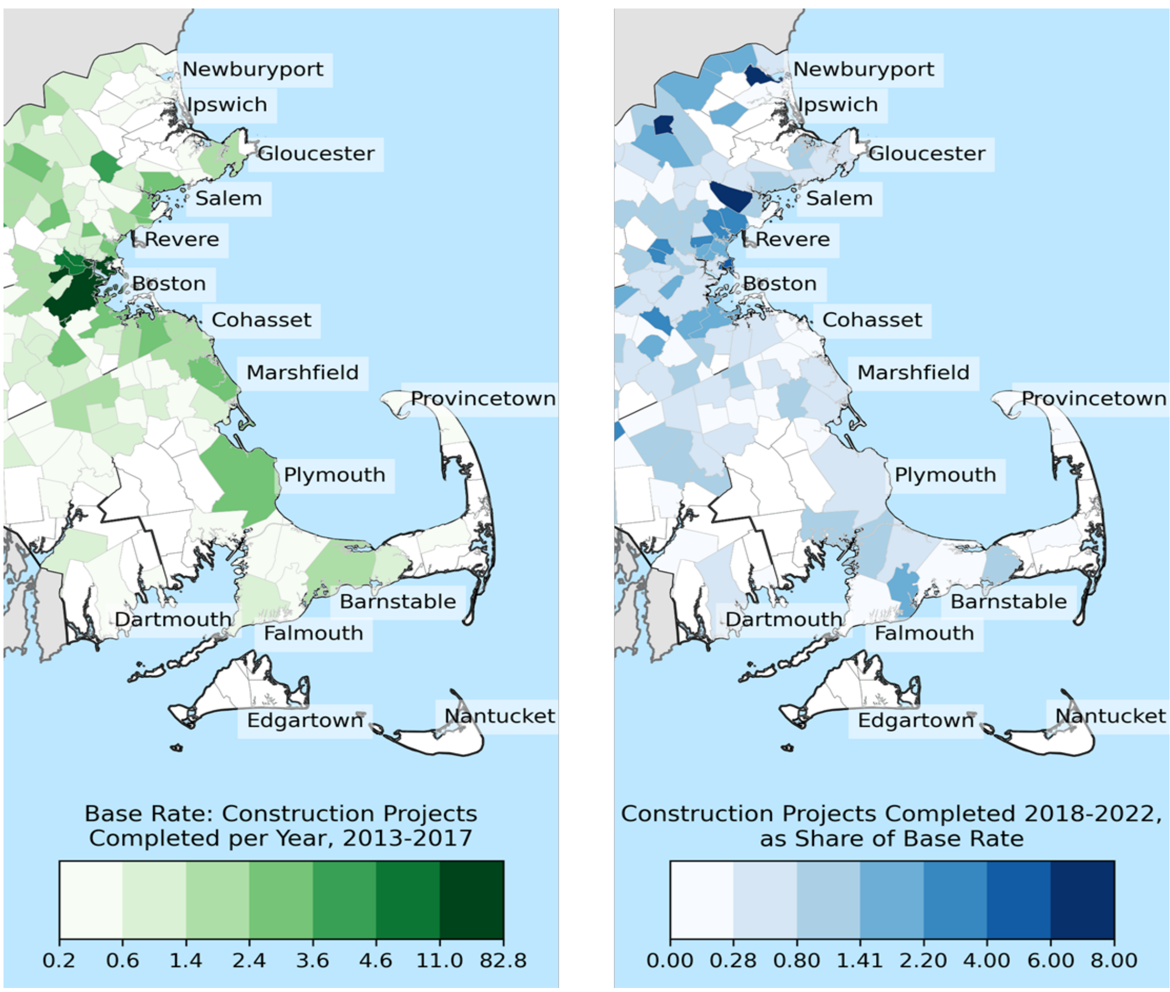
The Boston Harbor region currently experiences about 55 percent of the average annual statewide impact, but projections show damage from coastal flooding could grow faster in the Boston Harbor region than in other areas of the state due to projected local sea level rise and the existing development footprint. Note that this area continues to grow rapidly

[5] Risk mitigation infrastructure projects completed through 2017 within the Boston Harbor area, and their effectiveness in reducing coastal flood risk, were added into the MC-FRM model domain. It is anticipated that the MC-FRM may be updated on about a 10-year cycle and these anthropogenic projects would be integrated over time.

[6] The results presented here exclude the impact of coastal erosion, so they may be an underestimate. In addition, information presented in the introduction to this section suggests that the arrival times of sea levels modeled as occurring in 2030, 2050, and 2070 may be later than shown in these tables.

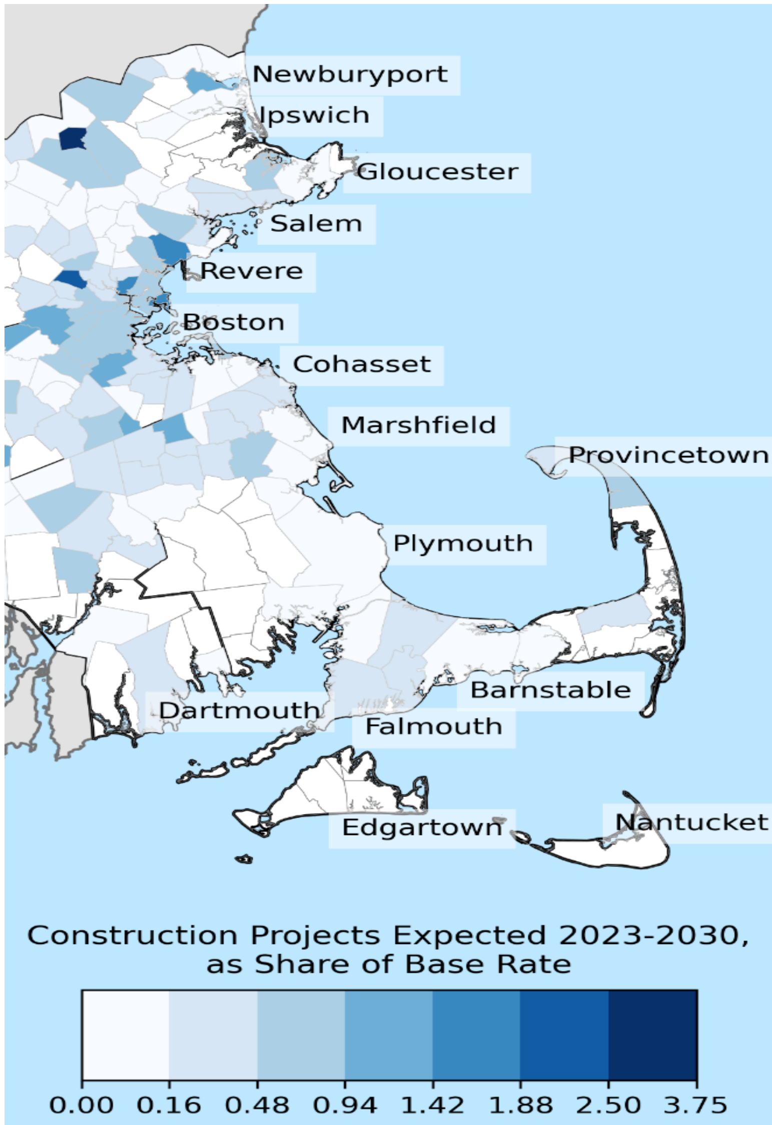
and that there are a significant number of initiatives underway to reduce coastal flood risk to shoreline assets and services. Based on current conditions, however, by 2050 structures in the Boston Harbor region would account for almost two-thirds of statewide damage.

Construction is increasing along Massachusetts' coastline, increasing the number of people and buildings at risk from coastal flooding. Accordingly, the Risk Assessment team analyzed recent development and changes in development, using a dataset of recently completed and planned construction as reported by municipal governments and information on trends in recent development. The analysis finds that construction between 2012 and 2017 concentrated in coastal Massachusetts, with an especially high number of new constructions around Boston Harbor (Metropolitan Area Planning Council, n.d.). Recent and planned construction has concentrated in the North Shore, with especially high levels of construction in areas like Revere and Newburyport. Figure 5.5-11 and Figure 5.5-12 below provide further detail on changes in development along the Massachusetts coast.



Source: MassBuilds data.

Figure 5.5-11. Base rate construction projects completed per year, 2013–2017 (left); construction projects completed 2018–2022, as share of base rate (right).

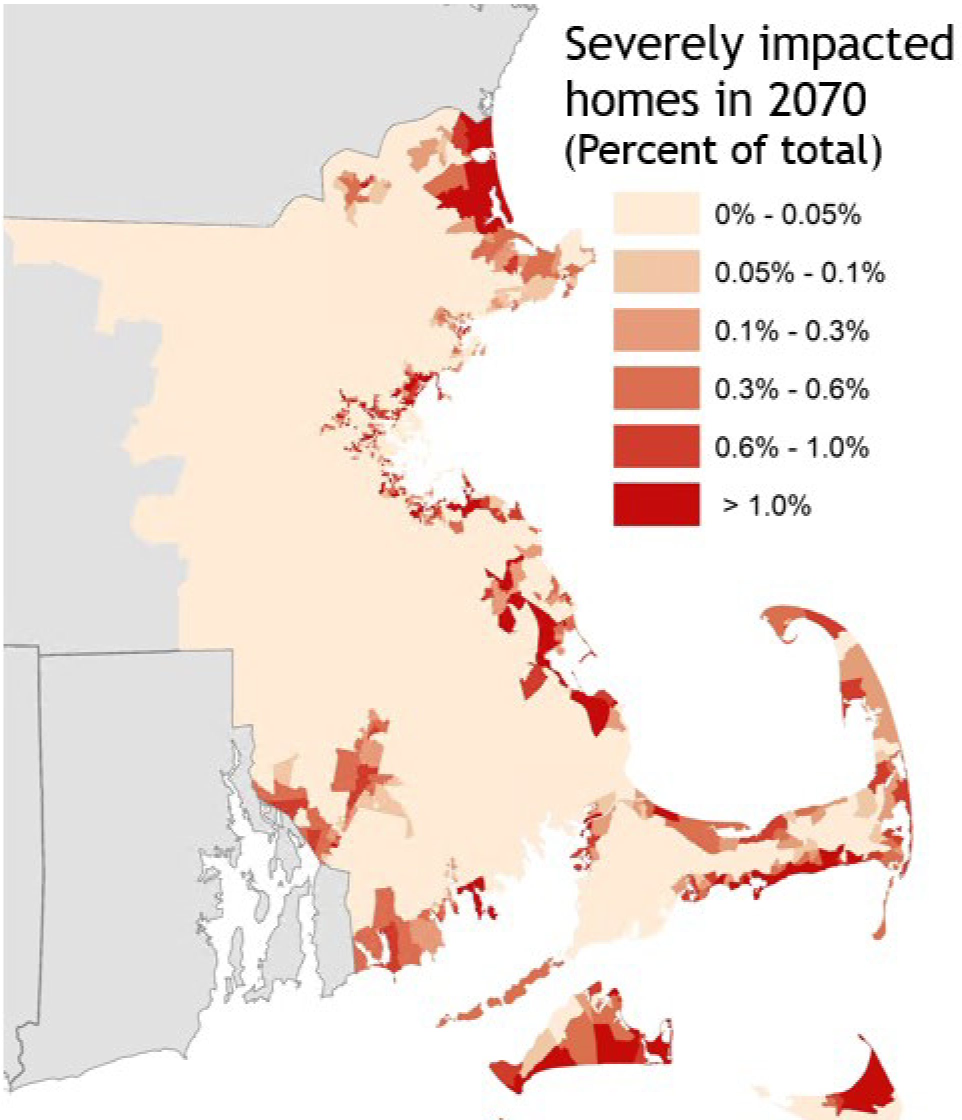


Source: MassBuilds data.

Figure 5.5-12. Construction projects expected, 2023–2030, as share of base rate.

Sea level rise and storm surge could also affect ports and marinas around the state. The direct damage to port and marina structures is mostly included in the estimates shown in Table 5.5-10, but those estimates do not include indirect damage associated with disruption of supply chains or other associated business and recreational activity; information on indirect costs is provided below in Section 5.5.2.4.5. Also not included are the costs to ports and marinas for increased maintenance, repairs, and replacements that will need to be conducted more often.

In addition to these impacts, coastal flooding poses risks to community buildings and assets, including homes and local serving businesses. Figure 5.5-13 shows severely affected areas that are at risk from current and future coastal flooding. In the deep red areas of the map, more than 1 percent of all properties in the area could experience severe annual damage if additional adaptation action is not taken.



Source: MA Climate Assessment analysis of MC-FRM results using methods from Neumann et al. (2021).

This map shows the proportion of buildings in a block group with 5 percent (of total value) or higher expected annual damage by 2070 from the combined effect of sea level rise, tides, and episodic storm surge combined. For more information on the analysis that informed the map, refer to the technical appendix.

Figure 5.5-13. Affected residential buildings by 2070.

Rail/Transit

Rail in Massachusetts consists of three main components: commuter rail, long-distance passenger and freight rail, and transit. The first and third components are concentrated in the eastern part of the state, but all regions rely on rail for movement of passengers and freight to at least some extent. Coastal flooding has been shown to affect rapid rail transit (e.g., subway and trolley systems). Martello et al. (2021) investigated measures of system resilience and found that as sea levels rise and coastal storms increase in frequency, intensity and extent, the MBTA's rail rapid transit system will experience more disruption and damage and longer recovery periods. For example, at current sea level, a 1 percent annual change coastal flood would render the Silver Line and Blue Line inoperable—an event that Massachusetts could experience today. Under a low sea level rise scenario (which could be reached by 2030), the same flood probability would *additionally* render the Cambridge–Somerville portion of the Orange Line and all transit on the Red Line south of downtown Boston inoperable. Additional effects appear later in the century (2070), with severe flood vulnerabilities for the entirety of the Red Line, all transit on the Orange Line north of Jamaica Plain, and portions of the Green Line (Martello et al., 2021).

Solar Energy Production

Some of the Commonwealth's solar energy production resources lie within the current or future FEMA 1 percent annual chance coastal floodplain. The share of solar energy production currently in this floodplain is very small, only 0.5 gigawatt hours (GWh), a fraction of the roughly 3,500 GWh of solar production throughout the state. The risk of coastal flooding of these resources, however, increases rapidly, with potentially affected solar resources rising to 11.5 GWh in 2030, 17.2 GWh in 2050, and 21.7 GWh in 2070, mostly in the North and South Shore regions. Nonetheless, even this much higher 2070 estimate of solar production at risk is about 0.6 percent of current total statewide solar production.

Lifelines

Coastal flooding affects a number of community lifelines. It affects transportation infrastructure, including mass transit and rails, which are essential for moving goods and people. This can also impede access to health and medical services. Coastal flooding can result in power outages and can interfere with energy production by interfering with solar electricity generation, as described above. Coastal flooding can also increase the risk of food spoilage.

5.5.2.4.4 Natural Environment

Coastal wetlands, including freshwater tidal wetland, salt marshes, transitional wetland, and tidal flats, provide a host of ecosystem services to coastal communities, including valuable wildlife and fisheries habitat, carbon capture and added buffering capacity from coastal storms, and preservation of open space. Species such as the saltmarsh sparrow (*Ammospiza caudacuta*), waterfowl, wading and coastal shorebirds, and juvenile marine fishes use coastal wetlands for nesting, for foraging, as nursery habitat, and during migration.

Massachusetts is home to about 50,000 acres of salt marsh (Woods Hole Group, 2016). Salt marshes can adapt to sea level rise by building elevation (capturing sediment and/or incorporating organic material from plant roots to build up the marsh plain) faster than the rate of rising sea level or by migrating inland to where conditions are suitable, including into other wetland types such as transitional brackish and freshwater marshes. In some cases, salt marshes cannot build elevation fast enough to keep up with accelerating sea level rise rates, resulting in a level of flooding that marsh plants cannot survive and leading to dieback (Ganju et al., 2020). Additionally, the process of inland migration can be limited or slowed by adjacent development (roads, tidal restrictions such as small culverts, homes, lawns, landscaping, seawalls, tide gates, tidal pumping stations, and parking lots), steep topography, and existing habitat such as forests and the invasive reed *Phragmites australis*. Historical salt marsh ditching and berm creation from agriculture and mosquito control, in addition to more current mosquito control practices, resulted in thousands of tidal ditches that may impede salt marsh platform accretion and accelerate the rate of degradation due to altered hydrology, oxygenation of the peat platform, and ditch edge effects. If salt marshes cannot keep up with sea level rise or migrate landward or into other wetlands, existing salt marsh habitat may eventually transition to mudflat habitat.

Sea level rise coupled with coastal development (leading to coastal squeeze of salt marsh habitat), reduced sediment supplies, physical alteration of salt marsh hydrology (mosquito ditching, historical agricultural practices, roads and other infrastructure), and nonpoint-source pollution has contributed to the degradation of salt marsh habitat in Massachusetts. It is important to understand the current distribution of salt marsh habitat, including salt marsh ecology, processes (including habitat transition), and functions now and into the future, in addition to designing and implementing evidence-based salt marsh restoration and adaptation techniques where appropriate to restore, maintain, and ensure resilience of this important habitat.

Conversion of salt marsh to other habitat types, including tidal flats, may result in a loss or change of critical ecosystem services such as carbon sequestration, fish and wildlife habitats, recreation, cultural value, and storm protection. Conversion is also accelerated by altered hydrology due to mosquito ditches and restrictions to tidal flow, such as those caused by agricultural embankments and road crossings. This poses a particular concern for the saltmarsh sparrow, a species of special concern pursuant to the Massachusetts Endangered Species Act. Saltmarsh sparrows nest in irregularly flooded salt marsh habitat and are the focus of federal and state conservation efforts.

The Sea Level Affecting Marshes Model (SLAMM) models potential changes in wetland habitat type for multiple sea level scenarios and time steps. These data were used to evaluate projected future coastal wetland habitat conditions of the entire Commonwealth of Massachusetts. SLAMM is an open-source numerical model that was developed specifically to evaluate potential transition of coastal wetlands with sea level rise; its parameters include elevation, wetland type, sea level rise, tide ranges, accretion, and erosion rates for various habitat types. The Risk Assessment's analysis pulls from a 2016 application of SLAMM, run to model predicted areal extent and distribution of coastal wetlands in Massachusetts as they respond to sea level rise under the Intergovernmental Panel on Climate Change (IPCC) A1B High Scenario (Woods Hole Group, 2016). Assumptions involved in the Massachusetts SLAMM modeling effort are described in the appended MA Climate Assessment, as well as the SLAMM documentation (Massachusetts Office of Coastal Zone Management, n.d.; Woods Hole Group, 2016).

Additionally, the estimated gains and losses presented Table 5.5-1 provide a first order assessment based on modeled possibilities of changes in the salt marsh wetland types. For example, predicted near- to mid-term gains in salt marsh habitat could result from displacement of freshwater wetlands and other upland wetland types, but these numbers are over-represented as they also model migration into lands that are currently developed. A key assumption in the 2016 SLAMM study was that it modeled salt marshes migrating into developed areas—necessary as a way to identify locations where salt marsh may attempt to migrate under these changing climate conditions. This assumption likely led to an overestimate of potential gains in wetland areas and an underestimate of likely overall losses, since in reality the salt marsh will be unable to migrate into developed upland areas. Scientific understanding of the process of marsh migration is still evolving, and there is much uncertainty in whether areas identified in the model that might support marsh migration in the future accurately represent where salt marshes could gain in area. More details on the changes in the various wetland types, beyond the low and high salt marsh habitat areas presented in this section, can be found in the 2016 SLAMM study and the SLAMM viewer.

Impacts to salt marshes include net changes in salt marsh habitat and transition between types of salt marsh, namely irregularly flooded high marsh and regularly flooded low marsh. Table 5.5-11 presents the SLAMM results for total salt marsh habitat changes over the century, subject to the condition noted above—that salt marsh will be allowed to migrate into developed areas. Statewide, the largest amount of net salt marsh loss occurs over the Cape, Islands, and South Coast region by 2070, with the largest amount of net salt marsh loss occurring in the North and South Shore region by 2100. There is a projected net salt marsh gain in 2050, likely due to the submergence of transitional marsh habitat that becomes irregularly inundated high marsh habitat and migration into freshwater areas and upland regions including developed areas. These gains are focused in the Eastern Inland and North and South Shore regions and are only possible if the salt marsh can migrate to new areas, which may not be the case without action. Model results indicate that areas that could gain salt marsh are concentrated in the Eastern Inland region. This is due to a combination of reasons such as displaced freshwater wetlands, transition of upland transitional marsh to high marsh habitat, and migration into undeveloped and developed areas. By the end of the century, SLAMM projects a loss of nearly half of all current salt marsh acres. For more information about this analysis, refer to the MA Climate Assessment (Commonwealth of Massachusetts, 2022, p. 98).

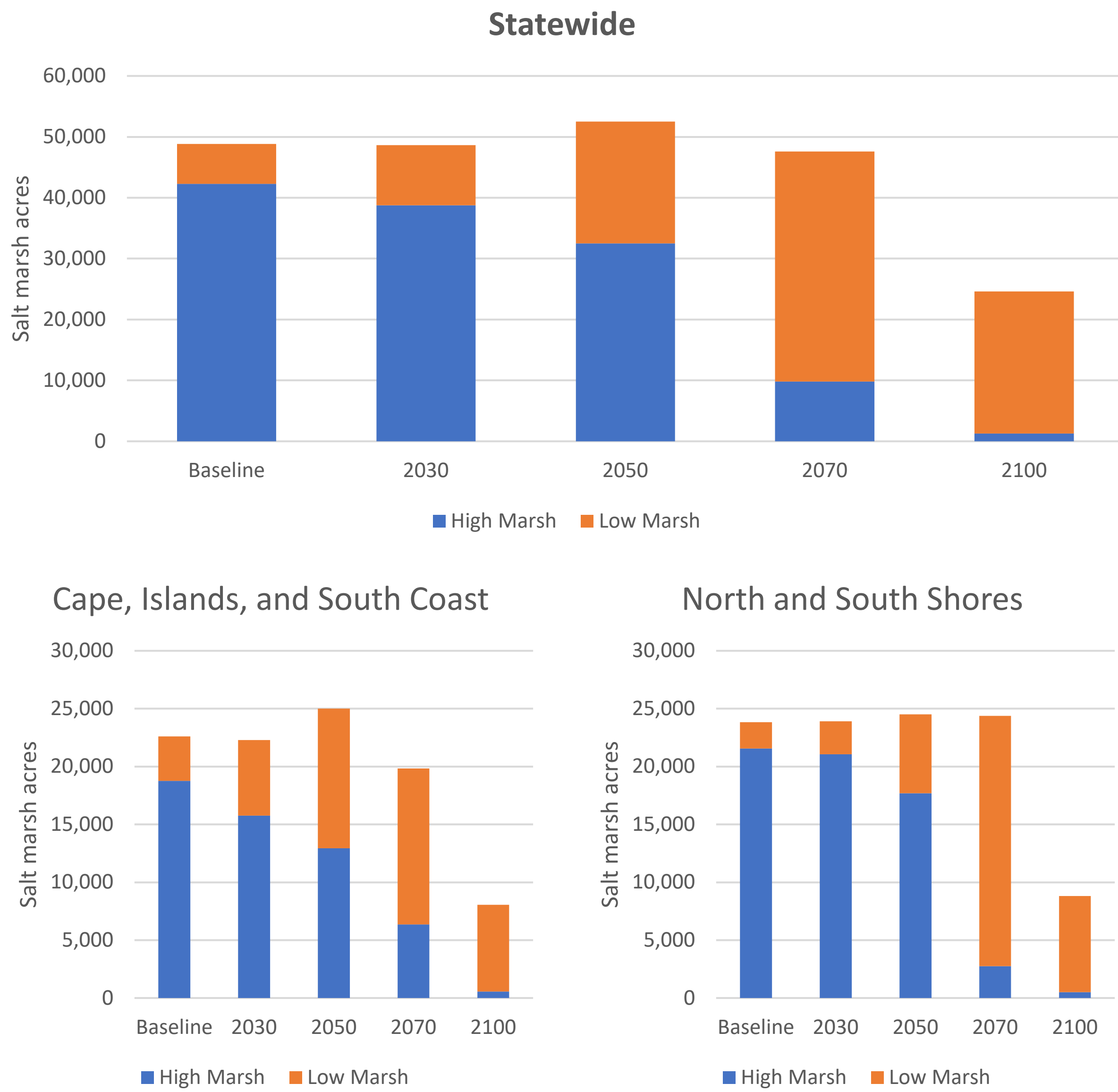
Table 5.5-11. Coastal Salt Marsh Habitat Changes by Region: Total Salt Marsh Habitat Loss/Gain (Acres)

Region	Current (2011)	2030	2050	2070	2100
Eastern Inland	10	+5	+450	+250	+50
Boston Harbor	2,400	-5	+100	+700	+5,250
North and South Shores	23,800	+50	+700	+550	-15,000
Cape, Islands, and South Coast	22,600	-300	+2,400	-2,700	-14,500
Statewide	**48,810**	**-250**	**+3,650**	**-1,200**	**-24,200**

Sources: Woods Hole Group (2016); MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Table lists acres of net salt marsh loss with percentage of today's total habitat, by region and statewide, based on the 2016 Massachusetts coastwide application of SLAMM. Positive values represent growth in net wetland area, while negative values represent losses in net wetland area. Future impacts are presented for four periods identified in the table by their central year: 2030 (near-term, 2020–2039), 2050 (mid-century, 2040–2059); 2070 (mid-late century, 2060–2079), and 2100 (late century). (The late century time period presented in this analysis differs from that presented in other analyses in this report—i.e., 2100 rather than a 20-year time period centered on 2090—due to availability of modeling results.) The sea level rise scenario used for the 2016 SLAMM study is the IPCC A1B High Scenario.

Changes to individual types of salt marsh (i.e., high marsh and low marsh) show more dramatic results. Figure 5.5-14 shows the change in salt marsh habitat by marsh type. Based on the results of applying SLAMM for Massachusetts in 2016 with the IPCC A1B High Scenario, it is estimated that 8 percent, 23 percent, 77 percent, and 97 percent of the existing statewide coastal high marsh habitat is modeled to transition to low marsh/tidal flat by 2030, 2050, 2070, and 2100, respectively. Low marsh area generally increases through 2070, primarily due to transition from high marsh. Statewide, the greatest loss of high and low marsh habitat is predicted to occur between 2070 and 2100. Proactive planning, conservation, and restoration of existing salt marsh, and preservation of and connection to land adjacent to salt marshes, including areas of potential migration, is critical to reduce the consequence of loss.



Sources: Woods Hole Group (2016); MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Acres of habitat change for high marsh and low marsh based on the 2016 Massachusetts coastwide application of SLAMM, statewide and for the two regions with the most salt marsh habitat. Coastal habitat transition from irregularly flooded marsh (high marsh) to regularly flooded marsh (low marsh) marks a transition of habitat. Future impacts are presented for four periods identified by their central year: 2030 (near-term), 2050 (mid-century), 2070 (mid-late century), and 2100 (late century).[7] The sea level rise scenario used for the 2016 SLAMM study is the IPCC A1B High Scenario, which was scaled using SLAMM to represent a relative sea level increase for each out-year.

Figure 5.5-14. Coastal salt marsh habitat transition.

[7] The late century time period presented in this analysis differs from that presented in other analyses in this report (i.e., 2100 rather than a 20-year time period centered on 2090) due to availability of modeling results.

High rates of salt marsh loss will have many follow-on impacts: for example, increased flood risk to areas inland of those marshes, the loss of essential nursery and breeding habitat for birds and commercially important fish species, and loss of carbon storage within marsh soils.

5.5.2.4.5 Economy

Coastal flooding can interrupt business and jobs in a number of sectors of the economy, including maritime industry; small coastal businesses; water-dependent or -related industries including fisheries, transportation, and shipping-dependent industries; and tourism. It can also reduce the availability of affordable housing—economically important because having accessible, affordably priced housing for the workforce is a critical factor for a state or regional economy.

Coastal flooding impacts on commercial and industrial buildings (which represent locations where Commonwealth economic activity is focused, as described in detail below) could be large, particularly when both the direct impacts of floods on the need for repair and the indirect impacts of business interruptions are taken into account. According to the MA Climate Assessment's comparison of risk of direct structural damage to nearby commercial and industrial buildings for people living in environmental justice block groups:

- The commercial and industrial buildings near where priority populations live have a 57 percent higher risk of damage than those in the rest of the Commonwealth.
- The commercial and industrial buildings near where priority and low-income populations live have a 148 percent higher risk of damage than those in the rest of the Commonwealth.

In addition, as described below, the Boston Harbor region accounts for over 90 percent of the total damage for both direct and indirect impacts. Small businesses in the Boston area will face greater affordability challenges for structure repair and to weather business interruptions. Among priority groups, small business ownership has been linked to poor access to capital (Toussaint-Comeau & Williams, 2020).

The disproportionate impacts to priority populations and environmental justice communities from coastal flooding–induced transportation delays and closures have been documented in academic literature. During disruptions, some workers may be able to avoid delays by working from home but not all workers have that option available. People working in service, medical, transportation, construction, agriculture, and other in-person jobs are affected when transportation interruptions challenge their ability to get to work.

In May 2020, following the initial COVID-19 breakout, nearly 40 percent of White workers telecommuted from home, compared to 25 percent of Black workers and 23 percent of Hispanic workers. While 46 percent of workers from high-income households (annual income greater than $100,000) worked from home, only 31 percent of middle-income earners (annual income between $50,000 and $100,000) and 18 percent of low-income earners (annual income below $50,000) did the same (Bick et al., 2020).

Impacts to the coastal-focused tourism industry also have environmental justice implications for workers in this industry. Hispanic or Latino workers make up a disproportionate share of the labor force in leisure and hospitality and therefore would be disproportionally affected by declines in the industry. In Massachusetts, Hispanic or Latino workers account for 14 percent of workers in the leisure, hospitality, and tourism industry while they make up only 8 percent of the total employed workforce. Income in this industry also tends to be lower than in other industries: 11 percent of workers in this industry live in poverty (based on federal poverty guidelines) compared to 4 percent in other industries (Melnik et al., 2018).

Availability of Housing That Is Affordably Priced

Climate change could affect the availability of affordably priced housing in multiple ways, including through coastal flood risks that can directly or indirectly affect both publicly owned housing and the market for affordable housing. An increase in demand for high-quality housing and a decrease in supply worsens the scarcity of affordably priced housing. Increasing demand for affordably priced housing can result if people are forced to relocate due to either direct damage to existing housing or climate-related economic pressures ("climate gentrification"). The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs (for all housing) to improve resiliency to threats from climate. Both demand and supply effects raise rental and ownership prices, which can effectively limit options for affordably priced housing.

Coastal flooding has been identified as a major risk factor for the availability of subsidized and income-restricted affordable housing at the national level, and a recent study has ranked Massachusetts second in the nation in the percentage of federally subsidized affordable housing units vulnerable to future coastal flood risk. By 2050, the number of units exposed per year will be 3,189 in Boston, 668 in Quincy, 510 in Cambridge, and 266 in Revere. These four cities are ranked in the top 20 cities nationally for this metric—Boston is third in the nation in expected number of exposed subsidized affordable housing units, trailing only New York (4,774 units) and Atlantic City (3,167 units) (Buchanan et al., 2020).

There are also dimensions of indirect risk concern that amplify the findings from these other, more direct damage implications of flood risks to affordably priced housing. Some analysts argue that efforts to insure properties against coastal hazards, and that aim to keep NFIP solvent by moving away from subsidized premiums, could harm low- and middle-income populations through premium rate increases. The complexities of balancing amenity and risk in the coastal zone have motivated an emerging literature on climate gentrification, a process that leads to displacement of low-income populations as wealthier residents seek higher ground and safety from coastal hazards (Anguelovski et al., 2019); new conceptual models of housing location decisions suggest low-income and priority populations will be pushed into higher-hazard areas of the coastal zone (Bakkensen & Ma, 2020)

Impacts on Businesses

Direct flood damage to commercial and industrial structures in the Commonwealth's coastal areas is projected to more than double by 2030, and the incremental cost could reach as high as $270 million annually by 2090, more than 10 times higher than current levels. These direct impacts of flooding are largest and grow most rapidly in the Boston Harbor region, where a large portion of the Commonwealth's commercial economic base is located.

Table 5.5-12. Annual Expected Flood Damage to Commercial and Industrial Sector Coastal Properties: Annual Total Expected Damage (Million $)

Region	Current (2008)	Damage Incremental to 2008		
		2030	2050	2070
Eastern Inland	$0.1	$0.1	$0.3	$0.6
Boston Harbor	$15	$30	$89	$240
North and South Shores	$2	$2	$4	$7
Cape, Islands, and South Coast	$6	$2	$9	$15
Statewide	**$22**	**$34**	**$100**	**$270**

Source: MA Climate Assessment analysis of MC-FRM flood risk and damage estimation methods from Neumann et al. (2021).

Table lists damage from sea level rise and changes in coastal storms. Values may not sum due to rounding. For more information on the analysis that informed this table, refer to the technical appendix. (Appendix 5.B)

Indirect impacts of coastal flood events could be even more consequential in economic terms. Table 5.5-13 shows estimates from recent analysis by the First Street Foundation and Arup to quantify the statewide and metro Boston area direct and indirect structural and indirect business interruption damage associated with all types of flooding—including coastal flooding, riverine flooding, and "flash flooding" associated with high rainfall events. The indirect losses from business downtimes are estimated to be six to seven times larger than the direct structure damage and could increase by over $800 million above the current baseline by 2050. The analysis also estimates that the largest losses can be expected in the Boston metropolitan area; this reflects the overall concentration of business activity in that region but also the potentially high vulnerability of that business base to coastal and other types of flooding.

Table 5.5-13. Annual Expected Direct and Indirect Flood Damage to Commercial Properties, Current and in 2050: Annual Total Damage (Million $)

Region	Current: Structure Damage	Current: Downtime Losses	Additional by 2050: Structure Damage	Additional by 2050: Downtime Losses
Boston metropolitan area	$331	$2,471	$86	$782
All other parts of Massachusetts	$113	$163	$29	$50
Statewide	**$444**	**$2,634**	**$115**	**$832**

Source: Adapted from First Street Foundation & Arup (2021).

“All other regions” is estimated by subtracting Boston metropolitan area damage from statewide damage. Values may not sum due to rounding.

Climate change could also affect supply chains and the Massachusetts businesses that rely most on them, particularly agriculture, seafood, and other perishable goods. Disruptions to supply chains for energy, raw materials, and intermediate goods essential to manufacturing can affect Massachusetts businesses’ ability to meet customer orders and keep their workforce fully engaged. Climate disruptions can also affect the transportation links in supply chains, for example when a hurricane damages a port facility. The food supply chain in and out of the Chelsea-Everett area is a critical supply chain. If flooding disrupts it, all those who rely on it will be affected, as will low-income workers who are adversely affected by loss of wages if these processes shut down. The U.S. Fourth National Climate Assessment identified the link between climate change and supply chain reliability in 2018, highlighting it as a key message in the “Climate Effects on U.S. International Interests” chapter (Smith et al., 2018). This chapter also noted that there is a lack of research on this topic; however, recent supply chain disruptions have made supply chain risk assessments (which can include climate disruption as a factor) a priority for businesses that depend critically on reliable and timely supply chain delivery for their operations.

Commuting Delays and Lost Productivity

Transportation delays (rail and road) discussed in previous sections can result in negative economic outcomes by affecting commutes and leading to lost productivity. Reduced work hours affect individuals’ earned income as well as overall economic production (e.g., GDP output) in the Commonwealth. Road delays due to high tide flooding could result in over 4 million vehicle hours of delay by 2030 and 40 million vehicle hours of delay by 2050 [see discussion in Section 5.5.2.4.1 (Human)]. While not all vehicle trips are work commutes, this could still represent a significant increase in commuting times, either resulting in lost wages and productivity, or loss of leisure time. Rail delays, both rapid transit and commuter rail, could significantly hamper people’s ability to get to work in a timely fashion. Infrastructure damage and closures could cause more long-term employment issues, particularly for people with limited alternative transportation options. A 2018 study of MBTA passengers found that about 70 percent of rapid transit and bus trips and 90 percent of commuter rail and ferry trips were commutes between home and work. 30 percent of rapid transit users and 5 percent of commuter rail and ferry users did not have a useable household vehicle, leaving limited alternatives during shutdowns (Central Transportation Planning Staff, 2018).

Impacts to Tourism

The tourism industry is a key contributor to the Commonwealth's economy. According to the 2019 Massachusetts Office of Travel and Tourism (MOTT) annual report, 2018 visitor expenditures supported over 125,000 jobs, generated $1.3 billion in state and local tax revenue, and contributed $25 billion in direct economic impact and $13.6 million in indirect impact (Massachusetts Office of Travel and Tourism, 2020).[8] At least 10 percent of domestic visitors participate in each of the following climate-vulnerable activities during trips to Massachusetts: beaches, rural sightseeing, urban sightseeing, historic places/churches, museums, and state/national parks (Massachusetts Office of Travel and Tourism, 2020). While Boston is a major tourist destination and receives the highest expenditures, tourists visit all regions of the Commonwealth (see Table 5.5-14). The Cape, Islands, and South Coast region generates the highest local taxes per capita from tourism and the Berkshires and Hilltowns region has the highest tourism-related employment per capita.

Table 5.5-14. Annual Economic Contributions of Tourism, 2018

Region	Expenditures (Million $)	Employment (Thousand People)	State Tax Receipts (Million $)	Local Tax Receipts (Million $)
Berkshires and Hilltowns	$495	4.2	$26	$15
Greater Connecticut River Valley	$902	5.6	$51	$21
Central	$1,243	8.4	$69	$30
Eastern Inland	$3,276	25.2	$184	$92
Boston Harbor	$11,201	61.3	$349	$225
North and South Shores	$917	6.4	$50	$29
Cape, Islands, and South Coast	$1,829	14.3	$82	$94
Statewide	**$19,863**	**125.4**	**$811**	**$506**

Source: Massachusetts Office of Travel and Tourism (2020).

Data available from MOTT at county level and recalculated for the MA Climate Assessment for each region based on population. Data are from 2018, the most recent year for which available data do not include the significant impacts of COVID-19 on tourism.

[8] The 2020 annual report is also available, but the more recent figures from 2019 reflect the disruptions to the tourism industry from the COVID-19 pandemic. In 2019, visitor expenditures supported over 100,000 jobs and generated $879.9 million in state and local tax revenue. Figures are provided by county and converted to MA Climate Assessment regions by population.

Impacts to infrastructure may indirectly damage the tourism industry. Coastal hotels and lodgings, port infrastructure, and road delays could cause significant disruption at coastal destinations. In general, extreme weather can deter visits. Sea level rise may also affect coastal natural resources that draw tourists, such as beaches; this may result in decreased visitation. Section 5.4 (Coastal Erosion) includes a discussion of how beach widths, and therefore beach visitation, may change due to sea level rise and erosion.

Chapter 5. Risk Assessment and Hazard Analysis

Drought

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5.6 Drought

5.6.1 Drought Problem Statement

Drought has the potential to impact all of Massachusetts, and each drought event may impact some regions of the Commonwealth at different levels of intensity and at different times. Because climate change will result in higher temperatures and changes in precipitation patterns, the risk of drought is expected to increase, with annual drought risk at its highest during the summer and fall. Drought conditions can disrupt and damage critical infrastructure, such as reservoirs, water intakes, and groundwater supplies.

Droughts can increase stress on natural ecological areas and habitats, like forests and wetlands, resulting in damage, disruption, and, in extreme cases, loss of species and habitats. A lack of water in streams can create stagnation and cause water to pool, leading to increased instances of harmful algal blooms (HABs) in aquatic habitats. Harmful algal blooms can impact access to recreational waters; damage maritime infrastructure, boats, intakes, and pumps; and result in aquatic habitat degradation for native species. Drought frequency also correlates with increases in fire risk. Drought conditions such as limited rainfall reduce soil moisture, groundwater, surface waters, and therefore irrigation water supplies, which harms agricultural production. In addition to reducing water supply, droughts also increase the cost of irrigation because crops that are mainly rainfed may need additional water. Stress to crops from reduced water and increased heat results in lower yields, alters the timing of harvests, and leads to potential crop loss (particularly for farms that rely on natural rainfall). Additionally, increased water costs affect businesses and residents with limited resources and reduced ability to absorb the impact of higher prices. People who depend on wells and aquifers will also be at a unique risk unless they can identify an alternative water supply. Drought impacts are more pronounced on individual or municipal systems that rely on smaller surface water systems. Because Massachusetts only grows a small portion of the food consumed in the Commonwealth, the risk of food shortage is not acute for droughts in the Commonwealth.

5.6.2 Drought Risk Assessment

5.6.2.1 General Background

Droughts can vary widely in duration, severity, and geographic scale. They can have broad social, economic, and ecological effects that require response from water suppliers, residents, industries, firefighters, farmers, state and regional agencies, elected officials, and nongovernmental organizations. The National Oceanic and Atmospheric Administration (NOAA) defines droughts as periods with a lack of precipitation and increased heat and evapotranspiration (NOAA NCEI, n.d.; NOAA NIDIS, n.d.-a). There are five types of droughts: meteorological drought, hydrological drought, agricultural drought, socioeconomic drought, and ecological drought (see Section 5.6.2.2 for more details).

The effects of droughts can depend on factors such as land use, which affects the land's ability to slow and store water; the baseline volume of water supplies relative to demand; and the co-occurrence of heat waves. For example, impervious surfaces associated with development can exacerbate the effects of droughts due to decreased groundwater recharge. Increased impervious cover prevents rainwater from contacting the soil, reducing the soil's ability to slow and store water to reduce the risk of hydrological, agricultural, and ecological droughts.

5.6.2.2 Hazard Description

Drought is a natural phenomenon that serves a purpose in ecological processes. However, when drought limits the capacity of natural and human systems to sustain themselves, particularly in heavily urbanized or otherwise altered lands, drought can result in hazardous impacts and negative economic outcomes when drought limits the capacity of systems to sustain themselves, particularly in heavily urbanized or otherwise altered lands. The National Drought Mitigation Center (n.d.-b) references five common, conceptual definitions of drought as categorized in the seminal work of Wilhite and Glantz (1985):

- **Meteorological drought** is when the amount and duration of rainfall in a region is less than normal. It is defined solely by the degree of dryness. Due to climatic differences, what might be considered a drought in one part of the country may not be a drought in another location.
- **Hydrological drought** results when the lack of precipitation affects streamflow, surface water bodies and groundwater such that they are below normal levels. The frequency and severity of hydrological drought is often defined on a watershed or river basin scale.
- **Agricultural drought** occurs when there is not enough water available for a particular crop to grow at a particular time. Agricultural drought is defined in terms of soil moisture deficiencies relative to the water demands of plant life, primarily crops. This type of drought can occur when there are precipitation shortages, soil water deficits, and reduced ground water reservoir levels.
- **Socioeconomic drought** occurs when the demand for an economic good such as water exceeds the supply because of precipitation-related shortfall. This differs from the other types of droughts because its occurrence depends on the processes of supply and demand.
- **Ecological drought** is a deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedback in natural and/or human systems (Crausbay et al., 2017).

There are also multiple operational definitions of drought. An operational definition attempts to quantitatively characterize a drought's onset, end, and severity level. Climate change is impacting the severity, intensity, and frequency of drought because the climate change impacts on temperature, snowfall, and rainfall can increase the intensity and frequency of drought events in the United States. The Massachusetts Drought Management Plan (DMP) defines a drought as "an abnormally dry (moisture-deficient) condition that is a shift away from average conditions for some prolonged period of time" (Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency, 2019).

Groundwater Recharge and Infiltration

Groundwater in Massachusetts has natural, seasonal fluctuations, with recharge in the late fall and early spring and depletion (in some areas) in the summer and fall. Drought conditions lead to a reduction in recharge. Although the effects of climate change on groundwater are complex, research findings show that the projected annual average groundwater recharge rates will decline as temperature increases. Climate change projections suggest that in the second half of the 21st century temperatures will continue to increase (Douglas & Kirshen, 2022). Drought impacts are exacerbated by the volume and rate of water withdrawn from natural systems over time, the reduction in infiltration into groundwater from reduced precipitation, and reduced recharge due to land use changes and soil health.

Groundwater withdrawals reduce groundwater levels, which impact water supplies and baseflow (i.e., flow of groundwater) to streams. Most communities that do not receive their water supply from the Massachusetts Water Resources Authority rely on aquifers as their primary source of drinking water (S. E. Bower & Massachusetts Rivers Alliance, personal communication, January 10, 2023). Additionally, groundwater is an important balancing parameter in the hydrological cycle and a major source of water for the environment. A reduction in baseflow can have a significant effect on aquatic life when there is no precipitation, as this is often the only source of water to streams. In extreme situations, low groundwater can become disconnected from the stream, resulting in a dry channel.

Impervious surfaces, such as pavement, roadways, parking lots, channelization of rivers and streams, seawalls, and buildings quickly remove water from the land and do not allow water to infiltrate. Development and drainage infrastructure can also interrupt natural small-scale drainage patterns and reduce natural infiltration. Poor soil management can impair water's ability to infiltrate surface soils, leading to increased water runoff (as opposed to being stored in soils and groundwater). In highly urbanized areas with abundant impervious surfaces, water is less able to enter the groundwater system and soils. These conditions remove water from surfaces and reduce the ability for water to infiltrate. This results in a rapid decline of groundwater levels during periods of low precipitation. Thus, both floods and droughts can be exacerbated by the significant alteration of natural processes (ERG & Horsley Witten Group, 2017) (see Section 5.8, Flooding from Precipitation, for more information).

Groundwater can also infiltrate into sewer collection systems, reducing groundwater. Drains connected to the sanitary systems transport groundwater and precipitation to wastewater treatment plants, where effluent is typically discharged to surface water bodies and therefore lost as a source of groundwater. However, some of this loss may be offset by leaks from drinking water supply infrastructure.

5.6.2.2.1 Location

Regions of Massachusetts can experience significantly different weather patterns due to topography; distance from the coast; and a combination of regional, national, and global weather patterns. As a result, the DMP (2019) organized Massachusetts into seven drought regions—Western, Connecticut River Valley, Central, Northeast, Southeast, Cape Cod, and Islands (see Figure 5.6-1). A regional approach allows customization of drought actions and conservation measures to address the drought conditions specific to each region. Dependent on the drought conditions, the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) may adjust the geographic scale of analysis to county or watershed scale to facilitate location-specific response actions and communications.

5.6.2.2.2 Previous Occurrences and Frequency

The Commonwealth of Massachusetts has never received a Presidential Disaster Declaration for a drought-related disaster; however, the Commonwealth has experienced several substantial droughts over the past 100 years and has recorded events dating back to 1879 (see Table 5.6-1 below).

Table 5.6-1. Droughts in Massachusetts Based on Instrumental Records

Date	Area Affected	Recurrence Interval (Years)	Remarks	Reference
1879–83	—	—		Kinnison (1931) as cited in USGS (1989)
1908–12	—	—		Kinnison (1931) as cited in USGS (1989)
1929–32	Statewide	10 to >50	Water supply sources altered in 13 communities; multistate	USGS (1989)
1939–44	Statewide	15 to >50	More severe in eastern Massachusetts and extreme in western Massachusetts; multistate	USGS (1989)
1957–59	Statewide	5 to 25	Record low water levels in observation wells in northeastern Massachusetts	USGS (1989)
1961–69	Statewide	35 to >50	Water supply shortages common; record drought; multistate	USGS (1989)
1980–83	Statewide	10 to 30	Multistate; most severe in Ipswich and Taunton River basins; minimal effect in Nashua River basin	USGS (1989)
1985–88	Housatonic River basin	25	Duration and severity are unknown; streamflow showed mixed trends elsewhere in MA	USGS (1989)
1995	—	—	Based on statewide average precipitation	EEA and the Massachusetts Emergency Management Agency (MEMA) (2013)
1998–1999	—	—	Based on statewide average precipitation	EEA and MEMA (2013)

Date	Area Affected	Recurrence Interval (Years)	Remarks	Reference
Dec 2001–Jan 2003	Statewide	—	Reached drought level 2 (out of 4 levels) statewide for several months	EEA and MEMA (2013)
Oct 2007–Mar 2008	Statewide except Western, Cape Cod, and Islands regions	—	Level 1 drought (out of 4 levels)	EEA and MEMA (2013)
Aug 2010–Nov 2010	Connecticut River Valley, Central, and Northeast regions	—	Level 1 drought (out of 4 levels)	EEA and MEMA (2013)
Oct 2014–Nov 2014	Southeast, Cape Cod, and Islands regions	—	Level 1 drought (out of 4 levels)	EEA and MEMA (2013)
Jul 2016–Apr 2017	Statewide	—	Level 3 drought (out of 4 levels)	EEA and MEMA (2013)
May 2020–Oct 2020	Statewide	—	Level 2 drought (out of 4 levels)	EEA and MEMA (2023)
Sept 2020	Central (Millers Basin), Northeast (Charles Basin), and Southeast regions	—	Level 3 drought (out of 4 levels)	EEA and MEMA (2023)
Mar 2021	Southeast	—	Level 2 drought (out of 4 levels)	EEA and MEMA (2023)
May 2022–Nov 2022	Statewide	—	Level 2 drought (out of 4 levels)	EEA and MEMA (2023)
July 2022–Dec 2022	Connecticut River Valley, Central, Northeast, Southeast, and Cape Cod regions	—	Level 3 drought (out of 4 levels)	EEA and MEMA (2023)

Notes and sources used to develop table:

(1) "—" denotes data not available.

(2) The U.S. Geological Survey (USGS) (1989) determined dry periods from streamflow and precipitation records. Dry periods that exceeded a recurrence interval of 10 years were deemed droughts.

(3) EEA and the Massachusetts Emergency Management Agency (MEMA) (2013) analyzed precipitation data only. Information presented represents a statewide average of all monitoring stations.

(4) EEA and MEMA (2023) compiled data based on historical drought declarations by the Commonwealth under the protocol in its 2019 Drought Management Plan.

Massachusetts experienced the most significant drought on record from 1960 to 1969 in western Massachusetts and from 1962 to 1969 in eastern Massachusetts (Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency, 2023). The severity and duration of the drought caused significant impacts on both water supplies and agriculture. The driest year since record-keeping began in 1895 occurred when the average precipitation statewide was 29 inches in 1965, compared to the average annual precipitation in present conditions of 48 inches. Due to the longevity of this drought, the Commonwealth instituted water use restrictions, and numerous communities began utilizing emergency water supplies. Several communities' water supplies reached a critical threshold with less than 90 days of surface water supply available. One response to reduced water supply is to decrease groundwater pumping. The last and only emergency-level (Level 4) drought was during this period.

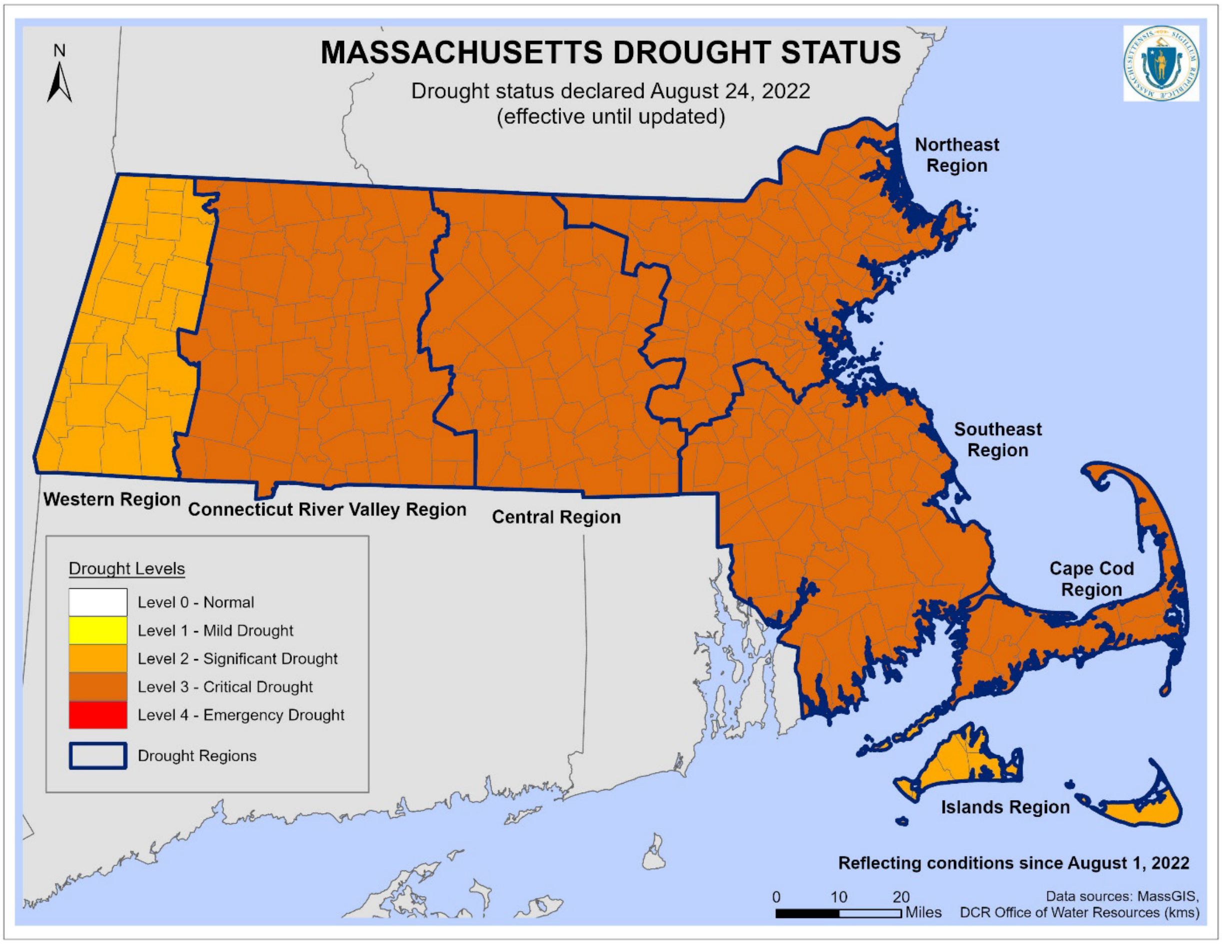
Recent Droughts

2016–2017 drought. In March 2015, Massachusetts began experiencing widespread abnormally dry conditions that turned into a long-term drought. In July 2016, based on a recommendation from the Drought Management Task Force (DMTF), the Secretary of EEA declared a Drought Watch (Level 2 of 4) for the Central and Northeast regions and a Drought Advisory (Level 1 of 4) for the Southeast and Connecticut River Valley drought regions. At the height of the drought, Drought Warnings (Level 3 of 4 levels) were issued in five out of six drought regions in November and December of 2016 (Massachusetts Executive Office of Energy and Environmental Affairs, 2019). (Prior to the 2019 DMP, there were only six drought regions.) Many experts stated that this drought was the worst in more than 50 years and the most impactful since the drought of record in the 1960s. During the drought, the Ashland, Burlington, Foxborough, Ipswich, and Plymouth public water systems requested an emergency declaration (Massachusetts Executive Office of Energy and Environmental Affairs, 2019). The Cherry Valley Water District (Leicester) and Natick also declared water supply emergencies in 2016 (Massachusetts Executive Office of Energy and Environmental Affairs, 2019). The Massachusetts Executive Office of Energy and Environmental Affairs (2019) cited that while the causes for the water supply emergencies ranged from mechanical or operational difficulties to regulatory drivers, the drought certainly contributed to difficulties in meeting demands for water in the region. The Massachusetts Department of Conservation and Recreation (DCR)'s private well survey showed that 52 percent of the 87 municipalities responding were aware of drought-related impacts to private wells, with at least 220 reported impacts during the period of analysis (Massachusetts Executive Office of Energy and Environmental Affairs, 2019). Four additional municipalities reported private dry wells to MEMA (Massachusetts Executive Office of Energy and Environmental Affairs, 2019). The drought had major impacts on the Commonwealth's agricultural producers in 2016, though the impacts were felt throughout the winter of 2016–2017. The estimated economic impact of the 2016–2017 drought is over $18 million (Massachusetts Executive Office of Energy and Environmental Affairs, 2019). The DMTF declared an end to the drought at the end of April 2017, since the entire Commonwealth had returned to "normal" conditions by the spring of 2017.

May 2020–August 2021. Heading into April 2020, the streamflow, groundwater, and soil moisture levels in Massachusetts were in the “normal” range (Horwood, 2021). However, with the combination of above-normal temperatures and below-normal rainfall over five months (i.e., May through October 2020), the Commonwealth experienced a fast-onset drought, taking numerous months to recover. In May 2020, the state was at the maximum extent of the drought with 96 percent of the state in some level of drought (Horwood, 2021). This drought event affected all New England, with many rivers and streams experiencing significant, un-navigable low flows—and in some cases, no flow. The southeastern part of the Commonwealth experienced a fast-onset drought by the beginning of August 2020 (USGS, 2020). The highest-level droughts were in September 2020 with the Millers Basin, Charles Basin, and the Southeast region at Level 3 (i.e., Critical Drought) status. As of May 2020, the Massachusetts Department of Environmental Protection (MassDEP) tracked 42 public water suppliers (PWSs) that implemented water restrictions (Massachusetts Executive Office of Energy and Environmental Affairs, 2023). By September 2020, at least 150 PWSs had restrictions in place (Massachusetts Executive Office of Energy and Environmental Affairs, 2023). Four municipalities, including Ashland, Burlington, Foxborough, and Lynnfield, had emergency declarations (Massachusetts Executive Office of Energy and Environmental Affairs, 2023). Watering restrictions and emergency declarations may be instituted due to regulatory requirements, water quality, construction, or other extenuating circumstances in addition to drought. DCR’s private well survey showed that 33 percent of the 67 municipalities received reports of drought impacts to private wells, with at least 134 incidents reported (Massachusetts Executive Office of Energy and Environmental Affairs, 2023). However, there were limited short-term agricultural impacts, potentially due to July 2021 being the wettest July on record in the Commonwealth (Massachusetts Executive Office of Energy and Environmental Affairs, 2023).

April 2022–December 2022. In April 2022, the EEA declared the Northeast and Southeast regions in a Significant Drought (Level 2). Drought conditions developed into Critical Drought (Level 3) in July 2022 for the Central and Northeast regions, while 90 percent of the state experienced some level of drought (excluding the Cape Cod region where impacts occurred later). Elevated temperatures and low precipitation exacerbated drought conditions (Town of Newbury, 2022). The EEA reported that eastern Massachusetts experienced less than 50 percent of normal precipitation, specifically for Cape Cod and Martha’s Vineyard (Massachusetts Executive Office of Energy and Environmental Affairs, 2022a). By August 2022, the entire Commonwealth was experiencing at least a Level 2 drought. During this same time period, there were more than 840 wildfires that affected over 1,400 acres of land (Massachusetts Executive Office of Energy and Environmental Affairs, 2022b). The worst month of the drought was August 2022 (see Figure 5.6-1) when all but three counties experienced Level 3 drought. Precipitation in September, October, and November contributed to some recovery for groundwater and streamflow, which brought the drought conditions back to normal for the Western, Central, and Southeast regions. In November 2022, the Northeast and Cape Cod regions were at a Level 2

(Significant Drought) status and the Connecticut River Valley region was at Level 1 (Mild Drought) status (Massachusetts Executive Office of Energy and Environmental Affairs, 2022c). The Cape Cod and Islands regions were the last to recover, with the drought ending at the end of December 2022.



Source: Massachusetts Executive Office of Energy and Environmental Affairs (2022c).

Figure 5.6-1. Massachusetts drought status reflecting conditions since November 1, 2022.

5.6.2.2.3 Severity/Intensity

In Massachusetts, drought is defined by a combination of several indices, as detailed in the Massachusetts DMP (Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency, 2019). The indices are:

1. **Precipitation.** The Standardized Precipitation Index is based on monthly precipitation totals compiled from DCR's Precipitation Program and the National Weather Service network. The Standardized Precipitation Index is widely used and can be calculated for a range of lookback periods.

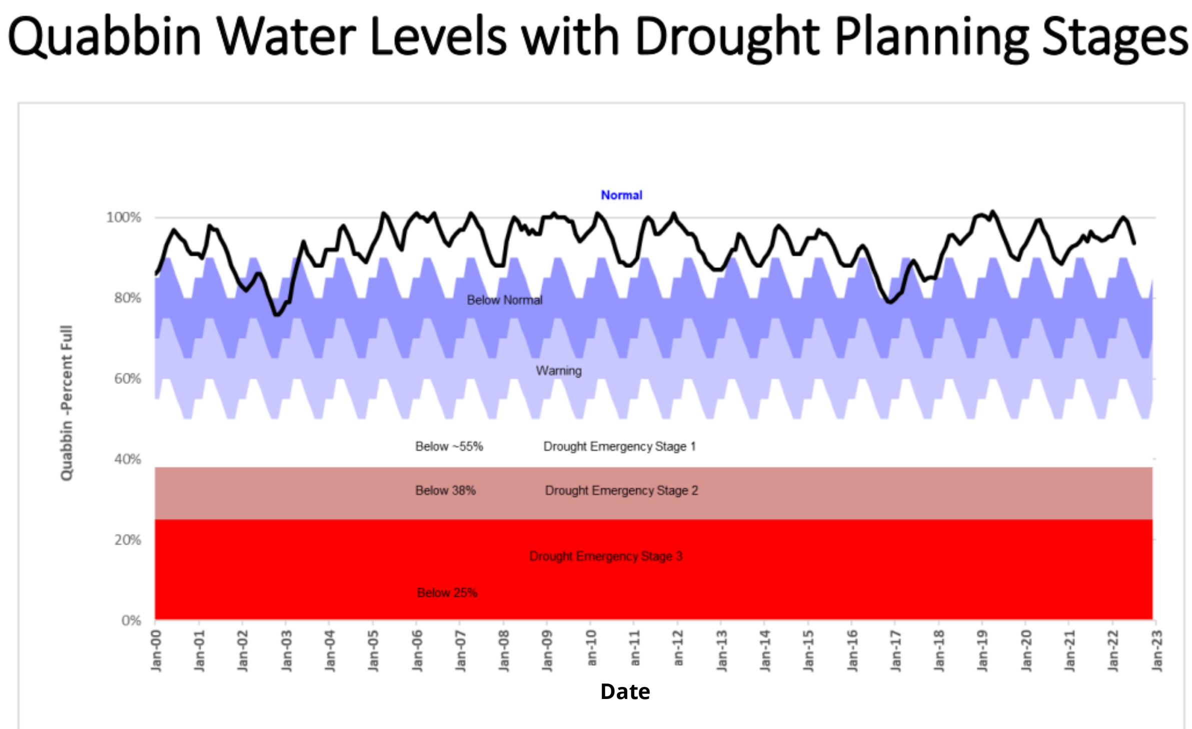
2. **Streamflow.** This index provides an early indication of impacts to rivers, streams, wetlands, and other riparian habitats due to precipitation deficits.
3. **Groundwater.** Due to the length of time required for groundwater recharge, this index provides information on drought impacts over a longer period.
4. **Lakes and impoundments.** This index captures the effect of droughts on surface-water storage, including lakes, ponds, and water supply and flood control reservoirs.
5. **Fire danger.** The Keetch-Byram Drought Index indicates the fire potential and flammability of organic material in the ground by assessing the amount of precipitation required for the top eight inches of soil to be saturated.
6. **Evapotranspiration.** This index is based on the Crop Moisture Index, which assesses the short-term or current conditions of dryness or wetness relative to the water needs of specific crops and can be used to understand potential impacts to agricultural crops.

These indices are monitored on a weekly basis and used to generate a monthly hydrological conditions report. multiple state and federal agencies monitor these indices, including DAR, DCR, NWS, and USGS. However, the DCR Office of Water Resources is responsible for delivering monthly reports on the six drought indices for MA (Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency, 2019) . The state uses the indices described above to determine the onset, end, and severity of droughts. Refer to Section 3.4.1 of the DMP for more details on the methodology and use of the indices. The DMP defines five levels of increasing drought severity:

- Normal, Level 0
- Mild Drought (formerly Advisory), Level 1
- Significant Drought (formerly Watch), Level 2
- Critical Drought (formerly Warning), Level 3
- Emergency Drought (formerly Emergency), Level 4

The drought levels are associated with state actions outlined in the DMP. In Massachusetts, the DMTF recommends drought levels for each region to the Secretary of EEA, who declares the drought level for each region of the state. Refer to Table 3 of the Drought Management Plan for a comparison of these indices.

Other entities may measure drought conditions by these or other criteria more relevant to their operations. For example, the Massachusetts Water Resource Authority (MWRA) tracks the capacity levels of its water supply sources on a daily and monthly basis and compares them with its own drought level thresholds. The MWRA and DCR monitor the reservoir levels at Quabbin (412-billion-gallon capacity) and Wachusett (65-billion-gallon capacity) Reservoirs, which supply water to 2.5 million residents and 5,500 industrial users (Massachusetts Water Resources Authority, n.d., 2022). Figure 5.6-2 shows the water capacity status at the Quabbin Reservoir, along with the thresholds used to assign drought conditions.



Source: Massachusetts Water Resources Authority (2022).

Figure 5.6-2. Water capacity status at the Quabbin Reservoir (December 1, 2022).

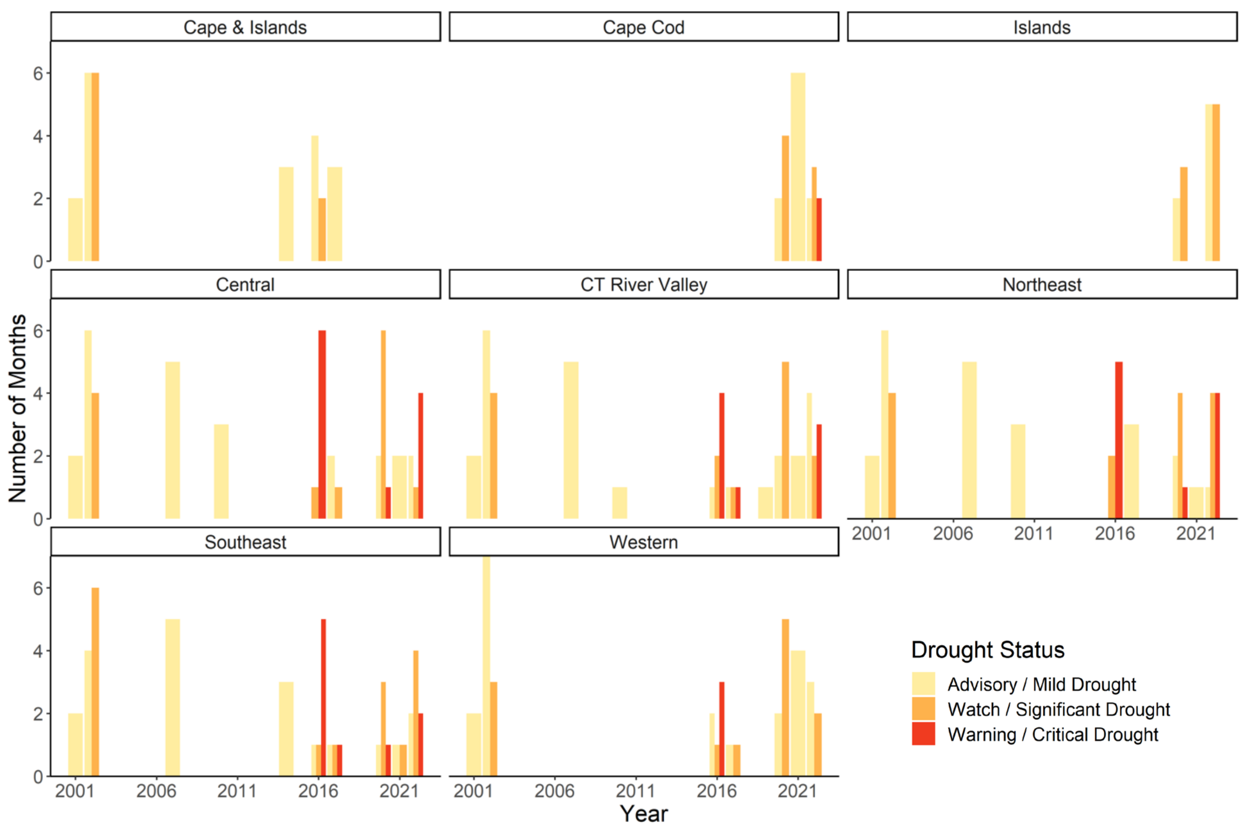
In the agriculture sector, farmers may assess soil moisture (University of Massachusetts Amherst, 2011) and calculate the water deficit for specific plants to determine irrigation needs. They may also decide to change their crop based on water deficits or harvest early for non-irrigated crops (Cornell University, 2022).

Massachusetts has recorded many periods of drought. The instances of drought below provide scale for the severity and intensity of the hazard. The following droughts are particularly relevant due to historic significance or recent occurrence:

- **1961–1969.** The drought of the 1960s is the drought of record because of its historic levels for moisture deficiency, duration, spatial extent, and impact.
- **2016–2017.** The 2016–2017 drought was severe due to its swift onset and its impacts on natural resources (including record low streamflow and groundwater levels), water supplies, farms, and agriculture.
- **2020–2021.** This drought was characterized as an extreme hydrological drought event for the whole Commonwealth. This drought spanned across New England and the event lasted several months, from May 2020 through August 2021. The southeastern

parts of the Commonwealth experienced a flash drought during which temperatures were more than 4° F above average in July 2020, total precipitation deficits were 7.3 to 8.7 inches below average across five months. An evaluation of streamflow at 76 streamgages used to calculate daily streamflow percentiles showed that mean monthly streamflows were lowest in June, August, and September of 2020. By June only 5 of 15 streamflows in southern Massachusetts were below the 25th percentile (USGS, 2020).

Figure 5.6-3 below shows the spatiotemporal severity of drought conditions in Massachusetts regions. The figure draws from EEA's determination of drought status, starting in 2001 when the Massachusetts DMP was first developed. Notably, the DMP update of 2019 revised the categories for drought severity and split Cape Cod and Islands into two separate regions. During the 2016–2017 drought, all regions except the Cape Cod and Islands regions were in "Warning" or "Critical" drought (i.e., Level 3) for at least three months.



Source: Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency (2023).

Figure 5.6-3. Number of months in drought conditions by region (based on available data).

The five drought levels in the 2019 DMP provide a basic framework for taking actions to assess, communicate, and respond to drought conditions. Under the "Normal" (Level 0) condition, data are routinely collected, assessed, and distributed. When DMTF identifies drought conditions and makes a formal recommendation to the EEA Secretary, the EEA Secretary may declare drought levels by region and call for heightened actions for each drought level, which may include increased data collection and assessment, interagency communication, public education and messaging, recommendations for water conservation measures, and a state of emergency issued by the governor (Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency, 2019). At the "Emergency Drought" level (Level 4), mandatory water conservation measures may be enacted. These regionally declared drought levels and associated state actions are intended to help the public and other affected parties respond early and effectively to reduce impacts. State agency actions are categorized seven broad categories: (1) data gathering, analysis, and reporting; (2) coordination with state and local agencies and nongovernmental organizations; (3) communication and public outreach; (4) water conservation; (5) technical assistance; (6) financial assistance; and (7) policy and regulatory actions (Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency, 2019). Massachusetts requires municipalities to implement non-essential outdoor water use restrictions through their Water Management Act permits, which specify actions during a drought based on the Commonwealth's drought declarations (Massachusetts Department of Environmental Protection, 2018). Based on the status of local water supplies, the public water supplier responsible for serving the community may coordinate with local municipalities to request mandatory or voluntary water use reduction (Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency, 2019). As required by MassDEP, water suppliers will follow the steps outlined in their Emergency Response and Contingency Plans in the event of water supply loss (Massachusetts Executive Office of Energy and Environmental Affairs & Massachusetts Emergency Management Agency, 2019).

Potential Effects of Climate Change on Drought

The likely range of consecutive dry days per year is projected to increase by up to 33 days per year in 2090, compared to the annual, statewide-average baseline of 31 days from 1986 to 2005. Table 5.6-2 indicates the projected number of consecutive dry days based on the Stochastic Weather Generator data developed for the 2022 Massachusetts Climate Change Assessment (MA Climate Assessment). The table uses regions developed for the MA Climate Assessments, which are different from the drought regions referenced in this section. Figure 5.6-4 shows how projected consecutive dry days are expected to vary across the Commonwealth. Projections from the MA Climate Assessment suggest that the average days of zero precipitation per year is likely to increase across most of the Commonwealth. In particular, the North and South Shores and Cape, Islands, and South Coast regions are expected to experience 195 and 194 days without rain in a year by 2090, compared with the current baseline of 184 and 186 days, respectively (Commonwealth of

Massachusetts, 2022). In addition, individual drought events are likely to increase in frequency and severity. As shown in Figure 5.6-4, Nantucket County experiences longer dry periods than the rest of the Commonwealth, and this trend is likely to continue in the future. These regional variations in precipitation patterns provide an additional reminder that statewide average values for continuous dry days may not accurately characterize conditions in any given situation. In addition, drought may persist with extremely low precipitation days; therefore, consecutive dry days and average dry days per year likely underestimate the potential increase in dry or drought conditions.

Table 5.6-2. Indicators of Drought—Consecutive Dry Day Events and Total Annual Days Without Rain in Massachusetts

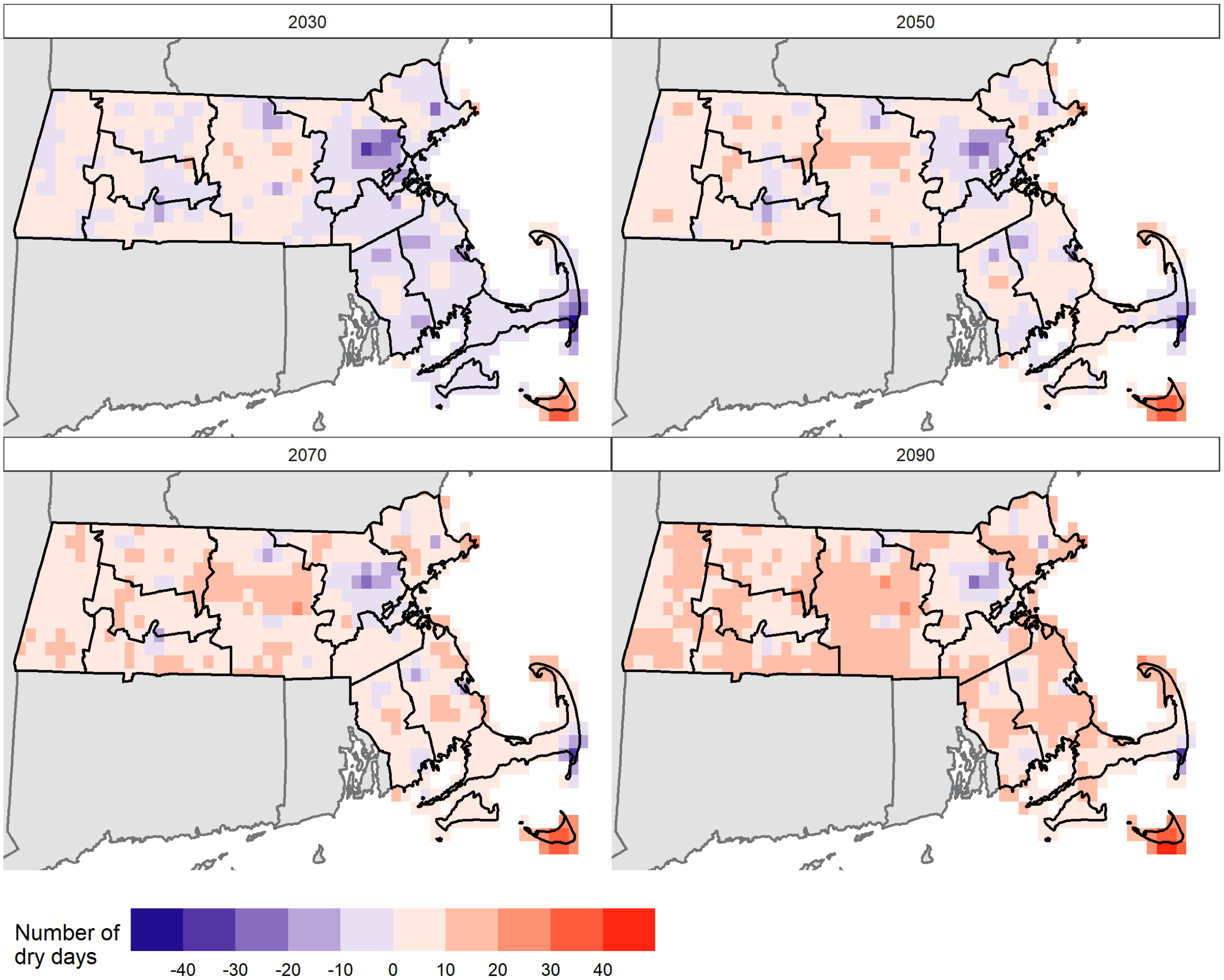
Panel A: Number of Consecutive Dry Day Events per Year					
Region	**Baseline**	**2030**	**2050**	**2070**	**2090**
Berkshires and Hilltowns	29	29	30	30	31
Greater Connecticut River Valley	31	31	32	32	33
Central	32	32	32	33	33
Eastern Inland	32	32	32	33	33
Boston Harbor	31	31	32	32	33
North and South Shores	31	31	32	32	33
Cape, Islands, and South Coast	31	31	32	32	33
Statewide	**31**	**31**	**31**	**32**	**33**
Statewide percent change	**0%**	**1%**	**2%**	**4%**	**6%**

Source: Steinschneider & Najibi (2022).

Panel B: Number of Days without Rain per Year[a]					
Region	**Baseline**	**2030**	**2050**	**2070**	**2090**
Berkshires and Hilltowns	159	161	165	167	170
Greater Connecticut River Valley	171	172	175	178	181
Central	180	182	185	188	192
Eastern Inland	186	181	185	188	193
Boston Harbor	192	185	192	194	198
North and South Shores	184	182	187	190	195
Cape, Islands, and South Coast	186	182	187	191	194
Statewide	**176**	**175**	**179**	**182**	**187**
Statewide percent change	**0%**	**-1%**	**2%**	**3%**	**6%**

Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022).

[a] Future projections presented for four time periods are identified in the table by their central year: 2030 (near-term, 2020–2039); 2050 (mid-century, 2040–2059); 2070 (mid-late century, 2060–2079); and 2090 (end of century, 2080–2099). Values may not sum due to rounding.



Source: Steinschneider & Najibi (2022).

Figure 5.6-4. Projected annual consecutive dry days for 2030, 2050, 2070, and 2090.

5.6.2.2.4 Warning Time

Drought development depends on several factors which occur at various time scales. The factors that impact drought include the circulation of the atmosphere and oceans, soil moisture, streamflow, and snowpack and melting cycles. They also are impacted by processes between the air, land, and ocean (American Geosciences Institute, n.d.; Huang et al., 2014). Modern drought warning systems utilize a range of environmental information sources to model and forecast droughts, including "weather station observations, satellite imagery, land surface and crop model simulations, and weather and climate model forecasts" (Funk & Shukla, 2020).

The National Weather Service's Climate Prediction Center releases projections for drought conditions monthly for all 50 states and Puerto Rico. The monthly forecast is based on the Climate Prediction Center's short- and medium-term temperature and precipitation forecasts, monthly dynamic models, soil moisture, and other seasonal and temporal climate factors (NWS Climate Prediction Center, 2022).

The U.S. Drought Monitor, a government-university collaboration hosted by the National Drought Mitigation Center at the University of Nebraska-Lincoln, provides weekly updates on the drought conditions across the country—the data and maps are not forecasts but weekly assessments. The U.S. Drought Monitor consists of more than 425 observers nationwide, including Commonwealth staff. These observers include climatologists, meteorologists, hydrologists, remote sensing specialists, agriculture scientists, biologists, natural resource scientists, and social scientists from agencies like NOAA, the U.S. Department of Agriculture (USDA), state governments, universities, and other agencies. These entities provide input on local conditions and impacts to the authors of the U.S. Drought Monitor map and narrative each week (U.S. Drought Monitor, n.d.-a). The USDA uses the U.S. Drought Monitor's data and maps to determine disaster declarations and low-interest loan eligibility (U.S. Drought Monitor, n.d.-b). The U.S. Drought Monitor uses five classifications for drought: D0 (Abnormally Dry), D1 (Moderate Drought), D2 (Severe Drought), D3 (Extreme Drought), and D4 (Exceptional Drought) (see U.S. Drought Monitor for more information).

The USDA Farm Service Agency (FSA) has the authority to designate counties as disaster areas according to 7 CFR Parts 759 and 762. Designated counties are eligible for disaster assistance, such as disaster payment programs and emergency loans made by the Secretary of Agriculture. Disaster designations are categorized into four types: (1) USDA Secretarial disaster designations; (2) Presidentially Declared Major Disasters and Presidentially Declared Disasters; (3) FSA Administrator's Physical Loss Notifications; and (4) quarantine designations under the Plant Protection Act and the Food, Agriculture, Conservation and Trade Act of 1990. FSA utilizes the U.S. Drought Monitor to inform declarations of severe drought events. A county is automatically declared as a disaster area if it receives a drought intensity value of at least D2 (Severe Drought) for eight consecutive weeks in any parts of the county. If any parts of a county receive a drought intensity value of D3 (Extreme Drought) or higher during the growing season of an affected crop, the county is considered a disaster area.

The Massachusetts Water Resources Commission publishes the hydrologic conditions report monthly, which includes the six drought indices and the National Climate Prediction Center's U.S. Monthly and Seasonal Drought Outlooks. Conditions are also monitored by the Commission on a weekly basis using the Massachusetts Drought Dashboard (https://www.mass.gov/info-details/drought-status). Based on the results of this monitoring, EEA may convene the DMTF as needed. The DMTF usually meets monthly during droughts, however, recent experiences with fast-onset droughts have necessitated bimonthly meetings to stay updated with on-the-ground conditions.

NOAA and other government agencies, as well as academic institutions, are advancing the science of early warnings for droughts (like the early warnings for floods and earthquakes) to better project droughts, especially fast-onset droughts. Based on the projected effects of climate change, the distributions of precipitation events will continue to become more extreme, with periods of minimal rain alternating with extreme rain events. Therefore, developing ways to project fast-onset droughts and respond to extreme and sudden conditions may be critical for sectors such as agriculture and water supply.

Climate change increases the risk of drought in the following ways:

- **Increased evapotranspiration.** Rising temperatures enhance evapotranspiration, which reduces surface water and soil moisture. The two factors (surface water and soil moisture) interact in a positive feedback loop. When evapotranspiration increases, temperatures also increase, which intensifies existing drought conditions. For more information on evapotranspiration and groundwater, please refer to the Hazard Section 5.3 (Changes in Groundwater).
- **Shifts in water availability.** Due to warming temperatures caused by climate change, the proportion of precipitation falling as snow and the extent of time it remains as snow are both expected to decline (Center for Climate and Energy Solutions, 2022). While historically the environment is accustomed to excess moisture in the spring, early and/or rapid snowmelt will result in more water in the winter and less in the spring (USGS, n.d.). Since the ground may be frozen during winter snowmelt events, the period during which snowmelt can recharge groundwater supplies is reduced. Reduced recharge can affect baseflow in streams that sustain ecosystems during dry periods and groundwater-based water supply systems. Reservoir-based water supply systems will need to regularly assess if they can meet projected demand by adjusting their operating rules to accommodate climate change-related changes in precipitation patterns and hydrology.
- **Increased rainfall and shifts in extratropical cyclones.** Projections of future changes in seasonal and annual precipitation show that Massachusetts may experience more “intense and frequent downpours” in the spring and winter months (MA Climate Assessment). In addition, climate science models have shown that extratropical storms will likely shift poleward as the global temperature increases (Tamarin & Kaspi, 2017). Although total annual precipitation has increased in Massachusetts except in the Cape Cod region, seasonal precipitation is projected to include more severe and unpredictable dry spells. More rain falling over shorter time periods will reduce groundwater recharge, even in undeveloped areas, as the ground becomes saturated and rain runs off to streams rather than recharging the groundwater. Increased rainfall will also overwhelm water storage infrastructure with flooding, which is a secondary hazard and does not contribute to future water supply.

5.6.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

Many of the local hazard mitigation plans (LHMPs) reviewed identified drought as a significant potential hazard. Many identified potential sources of groundwater to provide resilience for municipal water supply in the event of drought, including through the MRWA (the Quabbin and Wachusetts Reservoirs) (City of Boston, 2021; City of Somerville, 2022; Metropolitan Area Planning Council, 2020). Table 5.6-3 below provides examples of how drought was treated in 3 LHMPs under review.

Table 5.6-3. Highlight of Local Plans and Municipal Vulnerability Preparedness Program Planning Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Town of Carlisle Hazard Mitigation Plan 2021 Update, November 2021	Because Carlisle has significant forest cover and limited water for firefighting, the entire town is vulnerable to drought.	A lowered water table can impact those who rely on private wells.	A severe long-term drought could lead to several million dollars of potential damages, and tens of millions of dollars if drought leads to severe and widespread wildfire.
Town of West Stockbridge Hazard Mitigation Plan, 2021	The Berkshire region has not suffered a severe, emergency-level drought since the 1960s. It is unclear how well the water system could serve the demands of its customers during a severe drought emergency.	The region's farming community is vulnerable to agricultural damages from drought.	Not provided
Town of Shutesbury Hazard Mitigation Plan, January 2022	During a drought, public water supplies may not be able to maintain adequate pressure for firefighting and other municipal needs. Residential homes that rely on wells may need to drill new wells in a prolonged drought.	People with preexisting health conditions may be most at risk from decreased well water quality, including increased concentration of heavy metals.	Not provided

5.6.2.3 Secondary Hazards

Droughts can contribute to several secondary hazards, including the following:

- Impacts to the growing season due to reduced quantity of streamflow, groundwater, and surface water.
- Impairment to wetlands bordering rivers and streams due to reduced water availability.
- Reduction of aquatic organisms due to depleted oxygen levels and warmer river/stream temperatures.
- Increased susceptibility of urban trees and natural forests to wildfire and invasive pests.
- Increased erosion, reduced bank stability, and destabilized ground due to dry soil and/or vegetation dying out.
- Increased contamination concentration (such as HABs) in freshwater ecosystems during drought conditions due to less water for dilution.
- Changes in the salinity of freshwater ecosystems due to saltwater intrusion.
- Significant stress on ecosystems and native species throughout the Commonwealth, with an increased risk of invasive species and/or extirpation of native species.
- Increased fire risk and fire activity due to dried out ground fuels and dry soil.

5.6.2.4 Exposure and Vulnerability

The likelihood of drought in Massachusetts is **extremely likely or certain.** This likelihood is based on historical occurrence; current trends; and projections for near-, mid-, and long-range risks for drought. Since 2000, there has been a drought event every two to three years [see Section 5.6.2.2.2 (Previous Occurrences and Frequency)]. The effects of a drought cascade across the watershed and associated natural and socioeconomic assets and services at different timeframes and scales. For example, a precipitation deficiency may result in a rapid depletion of soil moisture, creating significant and rapid effects on agricultural assets and services. This same water shortage's impacts on reservoir levels may not affect hydroelectric power production, drinking water supply availability, or recreational uses until weeks or months later. Table 5.6-4 summarizes the potential impacts of drought events as identified in the MA Climate Assessment, information related to past events in the Commonwealth, and research evaluated to develop this report. Notably, forest health degradation and freshwater ecosystem degradation are identified as urgent impacts from drought.

Table 5.6-4. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Drought

Sector	Priority Impacts and High-Consequence Vulnerabilities
Human	• Emergency service response delays and evacuation disruptions **(most urgent)** • Increase in Mental Health Stressors • Reduction in Food Safety and Security
Infrastructure	• Loss of urban tree cover • Reduction in clean water supply • Damage to electric transmission and utility distribution infrastructure **(most urgent)**
Natural Environment	• Forest health degradation **(most urgent)** • Freshwater ecosystem degradation **(most urgent)** • Soil erosion • Shifting distribution of native and invasive species
Governance	• Increase in demand for state and municipal government services **(most urgent)** • Increase in need for state and municipal policy review and adaptation coordination
Economy	• Reduced ability to work **(most urgent)** • Decrease in Agricultural Productivity • Damage to tourist attractions and recreation amenities

Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022)

5.6.2.4.1 Human

More than 6 million Massachusetts residents receive their water supply from public water suppliers, and over 500,000 residents rely on their own groundwater wells for their water supply (Massachusetts Department of Environmental Protection, n.d.). By 2040, the population of Massachusetts is projected to reach 7.4 million (UMass Donahue Institute, 2018); Middlesex and Suffolk Counties are projected to experience the greatest population growth. Droughts can be widespread, severe and/or long-term events without discrete boundaries. Impacts of food security can extend beyond political boundaries (town, state, country borders) due to travel, migration, and movement, therefore, the entire population of Massachusetts can experience drought events. Identifying water reuse opportunities; water efficiency programs and infrastructure; changes to land use and land surface conditions; and conservation, restoration, and management strategies can reduce the intensity of drought impacts. The population's exposure to drought can vary significantly based on water supply sources and municipal water use policies, and vulnerability can vary due to the characteristics of the people and the assets exposed and the intensity and duration of that exposure.

As part of the 2023 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP) process, Massachusetts state agencies identified their primary concerns for populations served and potential disproportionate impacts from drought. Table 5.6-5 lists examples of primary concerns. The responses to the survey were completed by agency staff.

Table 5.6-5. State Agency Responses: Primary Concerns About Drought Impacts on Population Served and Potential Disproportionate Impacts

Category	Examples of Primary Concerns
Populations served	• People with disabilities • People aged 60 and above • Infants and children • All municipal, campus, hospital, and environmental police and deputy sheriffs • Injured workers • Farmers
Disproportionate impacts	• Loss of in-person services, such as in-home support and meal delivery for at-risk elderly people • Extended response times • Lowered product safety and accessibility • Headwater streams and areas with shallow aquifers [can impact habitats and people who depend on streamflow and aquifers] • Increase in HABs • Increased risk for mosquito-borne diseases when streamflow is reduced, leading to stagnant water where mosquitos breed • Food insecurity due to crop damage

Vulnerable and Priority Populations

Drought conditions can cause a shortage of water for human consumption; increase the costs of water supply services; result in a loss of urban trees and vegetation; degrade parks and recreation areas; reduce local firefighting capabilities; and affect farms and other businesses that rely on rainfall, streamflow, or small, shallow ponds. Communities particularly vulnerable to drought include the following:

- **Priority communities that will be unable to adapt to water supply shortages:** People in poverty, housing cost-burdened people, members of low-income households, members of single parent households, unhoused people, underserved/under-resourced communities, and institutionalized populations.
- **Priority population groups that are sensitive to any changes to critical lifelines:** People over age 65, people under age five, people with underlying health conditions, and people with disabilities.
- **Communities that are unable to access information to warning systems and emergency protocols:** People with low English proficiency, linguistically isolated people, underrepresented racial or ethnic communities, and isolated

communities/people with limited access to information, evacuation, and resources to adapt.

- **Workers for industries that rely on water will be severely impacted by water shortages:** Outdoor and agricultural workers, employees of fisheries, water agency workers, and emergency responders.

Drought impacts the entire Commonwealth, whether residents receive water from public water supplies or private wells. PWSs provide potable drinking water to many residential, commercial, industrial, and critical services in Massachusetts. PWSs may struggle to meet system demands while maintaining adequate pressure for fire suppression and meeting water quality standards. Therefore, robust emergency response plans are essential for ensuring the resilience of public water supplies. MassDEP requires all PWSs to maintain an emergency preparedness plan.

Residential well owners are also exposed to drought conditions when their wells no longer provide adequate water quantity or quality. People who rely on well water may not be able to find or afford alternative sources of supply for the duration of a drought.

Health Impacts

Drought has implications for public health in both the short and long term. The key impacts of droughts on public health are as follows:

- **Compromised water quality and quantity,** particularly shortages of safe drinking water (NOAA NIDIS, n.d.-c). The reduction of streamflow can increase pollutant concentrations in the water, which can affect public health via recreational swimming and fishing. With declining groundwater levels, residential well owners may experience dry wells or sediment in their water due to the more intense pumping required to pull water from a formation and raise water from a deeper depth. Wells may also develop a concentration of pollutants, including nitrates and heavy metals (e.g., arsenic, uranium) depending on local geology.
- **Diminished air quality in urban areas** due to loss of trees and vegetation, increased potential of wildfire events, and airborne toxins from cyanobacterial blooms in freshwater bodies (CDC, 2020; NOAA NIDIS, n.d.-c). Urban areas typically have higher air pollution levels compared to more rural areas. During a drought, dry soil, pollen, and smoke from wildfires can add to the airborne particulate load. Reduced air quality can have widespread, harmful health impacts, particularly for individuals with pre-existing respiratory health conditions like asthma (CDC, 2020).
- **Increased risk of illness and disease** from compromised sanitation, hygiene, food, and nutrition. Cyanobacteria normally occurs in stagnant surface water bodies, in freshwater systems such as ponds or lakes, and occasionally in marine water. Drought conditions, combined with warming temperatures and reduced waterflow, can promote HABs (California State Water Resources Control Board, 2022). HABs can negatively impact people with underlying health conditions, particularly those with

chronic respiratory conditions (CDC, 2020). Stagnant water bodies may also increase the prevalence of mosquito breeding, thus increasing the risk for vector-borne illnesses such as West Nile virus. Drought conditions can also lead to an increase in infectious diseases (e.g., *E. coli*, *Salmonella*) and pathogens (e.g., *Naegleria fowleri*) (CDC, 2020). A lack of clean water for consumption and sanitation can have significant impacts depending on the affected community's ability to acquire alternate water supplies.

- **Mental health impacts** from economic consequences and impacts to people's physical health. For example, droughts can threaten the loss of livelihood (particularly for those in the agriculture industry) and food security (due to limited growing seasons and potential malnourishment of livestock) (NOAA NIDIS, n.d.-c; Vins et al., 2015).
- **Food scarcity** during drought may impact food programs by raising food prices or generating scarcity of basic food products (Warrick, 2019). This could impact programs such as Massachusetts Department of Public Health's Women, Infants, and Children program.

5.6.2.4.2 Governance

Drought events can cause stress on services provided by Massachusetts state agencies. State agencies manage parks and facilities that depend on water availability for ecosystem health, water supplies, recreation, and natural functions. Critical facilities and lifelines such as hospitals and fire stations are most vulnerable to drought events. Health care facilities are one of the largest categories of users of MWRA services (Massachusetts Water Resources Authority, 2020). Droughts also contribute to conditions conducive to wildfires. All critical facilities in and adjacent to the wildland-urban interface are considered vulnerable to wildfire, particularly during drought events. For more information, see Section 5.16 regarding wildfires in the Commonwealth. With limited water resources due to drought conditions, it can be challenging to suppress fires, leading to extended fire incidents (Massachusetts Executive Office of Energy and Environmental Affairs, 2022b). Water restrictions during times of drought may require minor modifications to the operation of Commonwealth facilities, such as modified landscaping practices. Governmental facilities that perform "non-essential" services and rely on water to perform their core function, such as public swimming pools or grass-covered athletic fields, may face additional challenges during emergency mandatory restrictions by the governor.

All 15 local hazard mitigation plans reviewed for the 2023 MA SHMCAP update consider their municipality to be exposed to droughts to some extent. For instance, the town of West Stockbridge determined that its entire population is exposed and vulnerable to drought events and is uncertain whether its water systems could sustain demands during a severe drought emergency (Foresight Land Services, 2021). To incentivize water conservation activities, the town of West Stockbridge partners with MassDEP and other water conservation programs that encourage residents to install water-saving technologies (Foresight Land Services, 2021). The city of Attleboro's Water Department has adopted and is implementing an emergency response plan and a drought plan. the city is also evaluating options for improving its reservoir capacity and backup supply for drinking water (City of Attleboro, 2021).

As for state-level actions, Table 5.6-6 outlines examples of state agency responses to the 2023 MA SHMCAP survey related to their primary concerns regarding drought and activities they have undertaken/planned to address droughts. The responses to the survey were completed by agency staff. For additional information on state agency vulnerabilities, see DCR's 2018 Vulnerability Assessment Survey conducted as part of the 2018 MA SHMCAP.

Table 5.6-6. State Agency Responses: Primary Concerns About Drought's Effects on Services, with Suggested Improvements

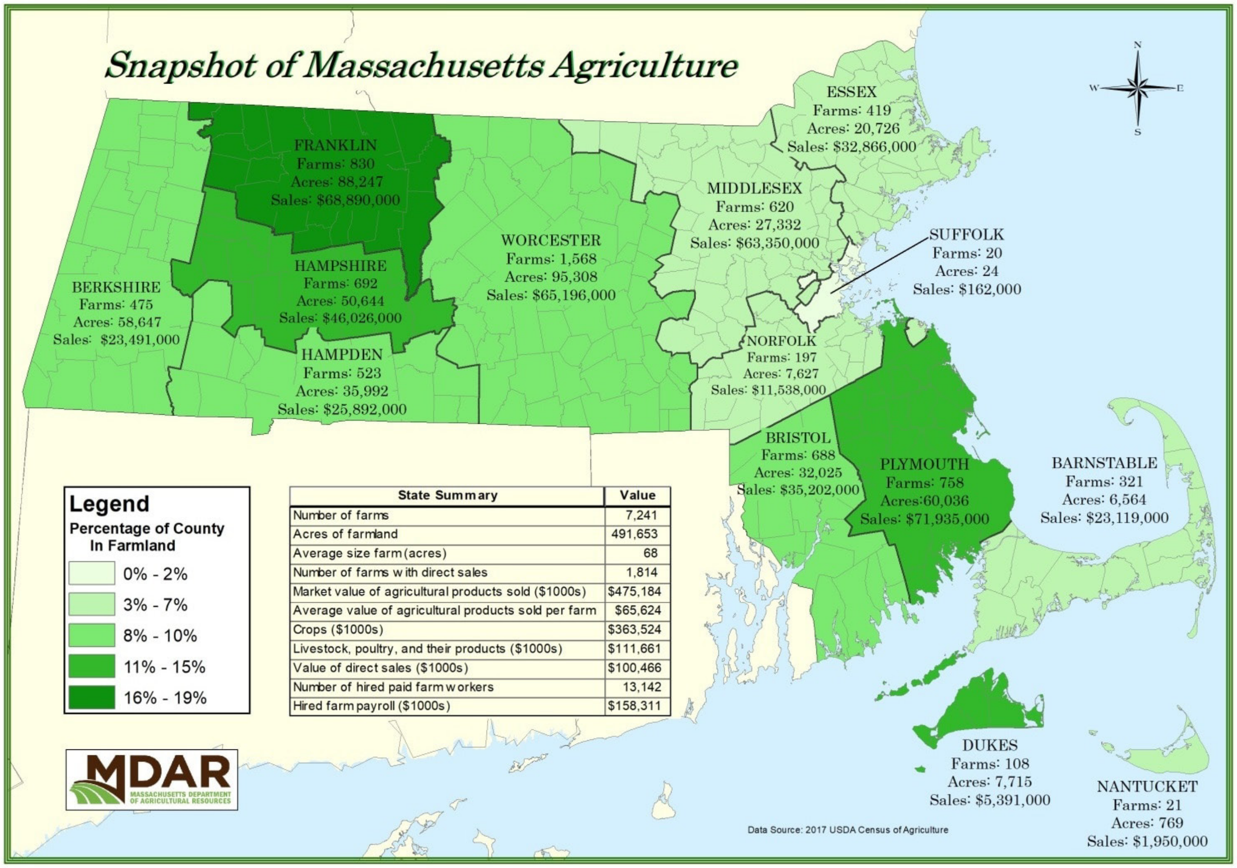
Category	Examples of Primary Concerns
Services provided	• Emergency service coordination at the federal, state, and local levels • Food programs such as the Massachusetts Department of Public Health's Women, Infants, and Children program • Provisions of parks and trees to absorb and retain stormwater • Recreational boating and fishing access • Drinking water supply
Updates, improvements, or enhancements to address concerns	• Increase funding for emergency services to allow for greater response to multiple areas • Increase capital funding to the Climate Smart Agriculture Program to help farmers build climate resilience • Reduce adjacent vegetation and remove trash/debris near fire-prone areas • Clean wells periodically to reduce mineral deposits • Implement instream flow protection, water level protection, riparian forest management, invasive species management, and floodplain connections • Review financial institution preparedness plans for continuity, disaster recovery, etc. • Support enhanced local water quality sampling • Provide technical support for local health departments • Conduct community outreach campaigns during hot and dry conditions • Implement bans on non-essential watering during drought periods to protect health and safety • Improve rainwater infiltration to recharge groundwater

5.6.2.4.4 Infrastructure

The impacts of drought on sectors of the built environment are described below. As previously described, droughts also contribute to conditions conducive to wildfires. All elements in and adjacent to the wildland-urban interface are considered vulnerable to wildfire. For more information, see Section 5-16 discussing risk from wildfires in the Commonwealth.

Agriculture

The agricultural sector experiences the most direct impact during drought events. Drier summers and intermittent droughts may strain irrigation water supplies, stress crops, and delay or move up harvests (National Drought Mitigation Center, n.d.-a). Impacts range from immediate crop failure to long-term disruption to crop planting (Engstrom et al., 2020). Farmers with livestock and poultry are also vulnerable to droughts because livestock and poultry require water throughout their life cycles and may be exposed to drought-enhanced diseases (e.g., anthrax, cyanobacteria) and extreme heat (Engstrom et al., 2020; Gessner, 2021). There is farmland throughout the Commonwealth, with approximately 10 percent (500,000 of 4.9 million acres) of Massachusetts being agricultural land. The counties with the most agricultural land are Worcester County (95,308 acres), Franklin County (88,247 acres), and Plymouth County (60,036 acres) (Massachusetts Department of Agricultural Resources, 2017). See Figure 5.6-5 for more details on the statistics of agriculture in the Commonwealth.



Source: Massachusetts Department of Agricultural Resources (2017).

Figure 5.6-5. Statistics of agriculture in Massachusetts.

Energy

Droughts can impact the reliability of electricity production plants that use water for cooling. Although hydropower only contributed approximately 5.7 percent of the Commonwealth's electricity generation in 2021 (1.1 of 19 million Megawatt-hour) (U.S. EIA, 2022), the loss of hydropower could impact the Commonwealth's goals to curb fossil fuel impacts unless generation from other renewable and alternative fuels (e.g., solar, wind) could cover the decline. There are 31 hydroelectric power plants and two pumped storage hydropower facilities in the Commonwealth (U.S. EIA, 2022). Three of these sites can produce enough electricity to sustain their operations with minimal need for additional energy from the grid (Commonwealth of Massachusetts, 2009). Additional electric generation sites can provide redundancy to the grid; however, a reliable source of water supply is essential to maintaining electricity generation.

Water Infrastructure

Drought affects both groundwater sources and smaller surface water supplies. Water supplies for drinking, agriculture, and water-dependent industries may be depleted by smaller winter snowpacks and drier summers (U.S. EPA and City of Chicago, n.d.). Reduced precipitation during a drought means that water supplies are not replenished at a normal rate. This can lead to a reduction in groundwater levels and problems such as reduced yields or wells going dry. Suppliers may struggle to meet system demands while maintaining adequate water pressure for fire suppression requirements. Private well supplies may dry up and need to either be deepened or supplemented with water from outside sources. In extreme cases, potable water could be supplied by other suppliers through emergency intermunicipal connections (interconnections) or by bulk-trucked water suppliers via distribution centers for residents. The Commonwealth has water use restrictions and PWSs that may experience drought hazards have their own emergency response plans. The MWRA has a DMP that sets mandatory water use reduction rates for three drought emergency stages. Water use reductions are triggered based on the seasonal levels of the Quabbin Reservoir. Many municipalities are also increasing water rates to reduce water use due to strained water supplies and the costs of improving water infrastructure. For example, starting in 2022, the town of Ipswich increased their water base rate from $11.25 per 100 cubic feet to $20.43 per 100 cubic feet for the summer months (May 1–September 30) and to $7.19 per 100 cubic feet for winter months (October 1–April 30) for residents, which is approximately an 81.6 percent increase of base rates for the summer months (Muldoon, 2021; Town of Ipswich Utilities Department, 2022).

Populations that use private water supplies are likely more vulnerable to droughts than those who use a public supply because private owners are less likely to measure their water levels than public sources. During a drought, water sources such as small reservoirs that are replenished by surface flows and wells that draw from aquifers that can be slow to recharge can cause water levels to become quite low. Individuals and farmers with private supplies who use such sources are particularly vulnerable to the drought hazard. DCR surveyed municipal boards of health to assess how private wells and their groundwater levels fared during the 2016–2017 and 2020–2021 drought events (V. Zoltay & Massachusetts Department of Conservation and Recreation, personal communication, January 4, 2023). Both surveys show some level of impact, especially from the more severe drought of 2016–2017.

EEA’s drought website provides resources for residents whose wells have gone dry, including the suggestion to hook up to a water connection at a local fire department or school or to purchase water (Massachusetts Executive Office of Energy and Environmental Affairs, n.d.). These are costly solutions that take time to implement and may not be financially feasible for everyone. Moreover, these situations would likely most heavily impact people with limited resources (e.g., rural, low-income, and linguistically isolated communities; elderly and disabled individuals) who cannot afford the cost of drilling a new or deeper well to reach remaining water supplies when their shallower wells have failed.

5.6.2.4.5 Natural Environment

Drought has a direct impact on natural resources, including their intrinsic value and the services they provide. Wildlife, plants, and ecological processes all depend on water. Some of those impacts can include the following (S. E. Bower & Massachusetts Rivers Alliance, personal communication, January 10, 2023; National Drought Mitigation Center, n.d.-a; NOAA NIDIS, n.d.-b; Vose et al., n.d.):

- Loss of plant, fish, and wildlife habitats due to reduced streamflow to downstream rivers, estuarine habitats, reservoirs, lakes, and ponds
- Decreased fish and wildlife health and productivity, particularly for stream fishes, due to increased temperatures and reduced streamflow
- Animal mortality due to lack of food and water
- Increased invasive plant, bacteria, and algae growth and productivity
- Increased wildfires
- Pest or insect outbreaks
- Increased local species extinction
- Changes in the timing, magnitude, and strength of mixing (i.e., stratification) in coastal waters
- Increased potential for hypoxia (low oxygen) events in water bodies
- Direct and indirect effects on goods and services provided by habitats (e.g., timber, carbon sequestration, recreation, water quality)
- Limited plant, fish, and wildlife dispersal and migration
- Increased erosion of soils amplified by wind and water

In addition to these direct natural resource impacts, a wildfire exacerbated by drought conditions could cause significant damage to the Commonwealth's environment, as well as economic damage related to the loss of valuable natural resources. Wildfire damage to the forests and lands around the Quabbin, Wachusett, and Ware Reservoirs may lead to lower water quality in those reservoirs, which are critical water supplies during times of drought for both "regular" and drought-impacted customers who use this water source on an emergency basis. See Section 5.2 (Average/Extreme Temperature) and Section 5.16 (Wildfires) for discussions of secondary hazards related to droughts.

Climate change is also likely to shift the timing and duration of seasons (Massachusetts Wildlife Climate Action Tool, n.d.). This change will likely have repercussions on the life cycles of both flora and fauna in the Commonwealth. While there are economic benefits from a lengthened growing season, a longer season also carries a range of risks. The probability of frost damage will increase, and the earlier arrival of warm temperatures may cause many trees and flowers to blossom prematurely only to experience a subsequent frost. Additionally, pests and diseases may also have a greater impact in a drier climate, as they will begin feeding and breeding earlier in the year (Land Trust Alliance, 2022). Shifting seasons can also result in a mismatch between host plant or prey availability and the life stages of animals that depend on them, resulting in less resilient ecosystems and loss of ecosystem services (Thackeray et al., 2010).

5.6.2.4.6 Economy

The economic impacts of drought can be substantial, and would primarily affect the agriculture, recreation and tourism, forestry, and energy sectors. Droughts affect the ability of farmers to provide fresh produce to neighboring communities. Insufficient water supply for irrigation will impact the availability of produce, which may result in higher demand than supply. This can drive up the price of food, leading to economic stress on a broader portion of the economy. Food banks may also experience shortages in produce and diminished capacity to provide food to pantries and other charities.

Agriculture contributes $492 million annually to the Commonwealth's economy (USDA FSA, n.d.). The top five agricultural commodities in the Commonwealth are miscellaneous crops ($284.6 million), cranberries ($70.5 million), all other animals and products ($39.3 million), dairy products (milk) ($35.8 million), and turkeys ($13.3 million) (University of Arkansas Division of Agriculture, n.d.). The Commonwealth's agricultural sector was particularly affected by the 2016–2017 drought. The Massachusetts Department of Agricultural Resources received $500,000 in capital funding and provided reimbursement funding through the newly launched Agricultural Climate Resiliency & Efficiencies program, which supported agricultural businesses that improved their climate and economic resilience and advanced the goals of the Massachusetts Local Action Food Plan (Massachusetts Executive Office of Energy and Environmental Affairs, 2019). The estimated economic impact of the 2016–2017 drought to the agricultural sector was over $18 million, and Worcester County had the highest economic loss ($7 million) (Massachusetts Executive Office of Energy and Environmental Affairs, 2019). Drought can result in farmers not being able to plant crops or in the failure of planted crops, which affects the livelihood of those working as farm workers and in food processing jobs. Crop failure also results in increased produce prices and risks to food security. Increasing globalization of the food system can reduce the impact of isolated drought events on food prices, but the financial impact on local farmers will continue to be a challenge.

Drought can also impact other industries, such as recreation and horticulture. Recreational companies that rely on water and snow, such as ski areas, swimming pools, water parks, and river rafting companies, may have a shorter season for business when precipitation is low. Landscape and nursery businesses may face decreases in sales and stress in keeping their plant inventory healthy. Social and environmental impacts are also significant, but data on the extent of damages is more challenging to collect. Although the impacts can be numerous and significant, dollar damage estimates are not tracked or available.

Chapter 5. Risk Assessment and Hazard Analysis

Earthquakes

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5.7 Earthquakes

5.7.1 Earthquakes Problem Statement

Earthquake frequency and magnitude are likely to be most significant in the northeastern part of the Massachusetts as suggested by U.S. Geological Survey (USGS) data analyzed in the Risk Assessment. A network of ancient faults runs through the Commonwealth, but the location of the faults do not provide information about where earthquakes may be centered. Most earthquakes in the region are of small magnitudes; higher-magnitude earthquakes are rare and therefore damage to infrastructure or buildings within Massachusetts is also rare. Newly available soils data enables for a finer-grain analysis of any local risks that may affect Massachusetts more broadly or may focus impacts on a smaller area of the Commonwealth.

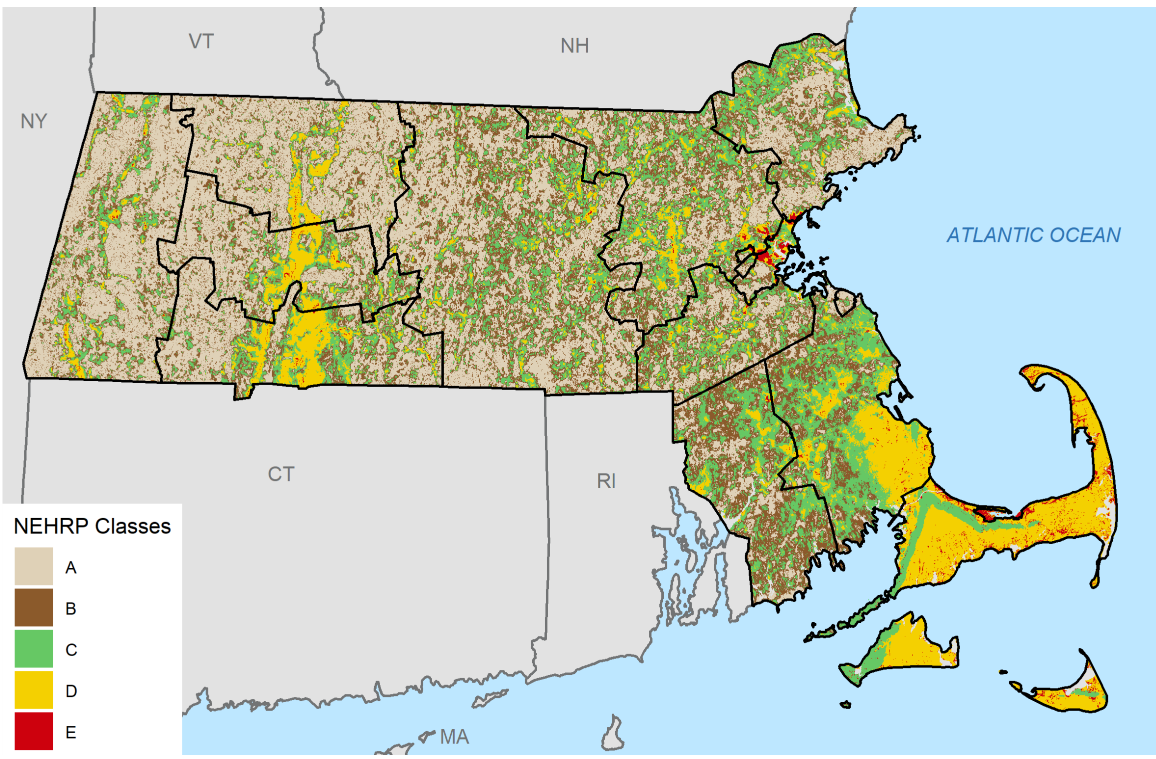
State building code requirements in place since the 1970s have provisions for earthquake-resistant design, although there are many older buildings that predate these codes and are therefore more susceptible to earthquake damage. Certain types of assets—such as bridges, tunnels, unreinforced masonry buildings, and structures in liquefaction zones—are the most vulnerable to earthquake shaking. Bridges affected by a large earthquake would need significant time and funding to replace, putting communities that depend on them at greater risk. Damage to homes and critical assets (e.g., schools, hospitals), infrastructure (e.g., rail, runways, ports) and utilities (e.g., pipelines, transmission lines), especially those in liquefaction zones, is also a significant risk. Age, maintenance, and conditions of structures can also contribute to or mitigate risks from ground shaking and liquefaction.

5.7.2 Earthquakes Risk Assessment

5.7.2.1 General Background

An earthquake is experienced as the vibration of the Earth's surface that follows the release of seismic energy in the Earth's crust. Seismic energy is released when cracks in the crust (called faults) suddenly slip. Earthquakes happen at the edges of the world's tectonic plates, which rub against each other as they move across the surface of the Earth. The stresses of tectonic plate motions also build up within the interiors of the tectonic plates, causing some faults to slip there and cause intraplate earthquakes—though these are much rarer than the plate boundary earthquakes that are common in places such as California (Richardson, n.d.). Scientists are still exploring the cause of intraplate earthquakes; many believe they occur along geologic features that were created millions of years ago and are now weaker than the surrounding areas (Kafka, 2020). New England experiences intraplate earthquakes when stress is released within the interior of the North American plate.

Ground shaking and the liquefaction resulting from it are the primary causes of earthquake damage. This damage can vary locally due to soil types that can amplify shaking or are susceptible to liquefaction. A contributor to this amplification is the velocity at which rock or soil transmits shear waves (S waves). Accordingly, the National Earthquake Hazards Reduction Program classifies soil according to S-wave velocity in the top 30 meters (100 feet) below the Earth's surface. The soil classification system ranges from A to E, where A represents hard rock that reduces ground motions from an earthquake and E represents soft soils that amplify and magnify ground shaking and increase building, infrastructure, and utility damage and losses. A seismic site classification map for Massachusetts using these soil types is shown Figure 5.7-1. Areas along the shoreline that have previously been filled are particularly at risk from liquefaction and increased damage from earthquakes.



Source: Pontrelli et al. (2023).

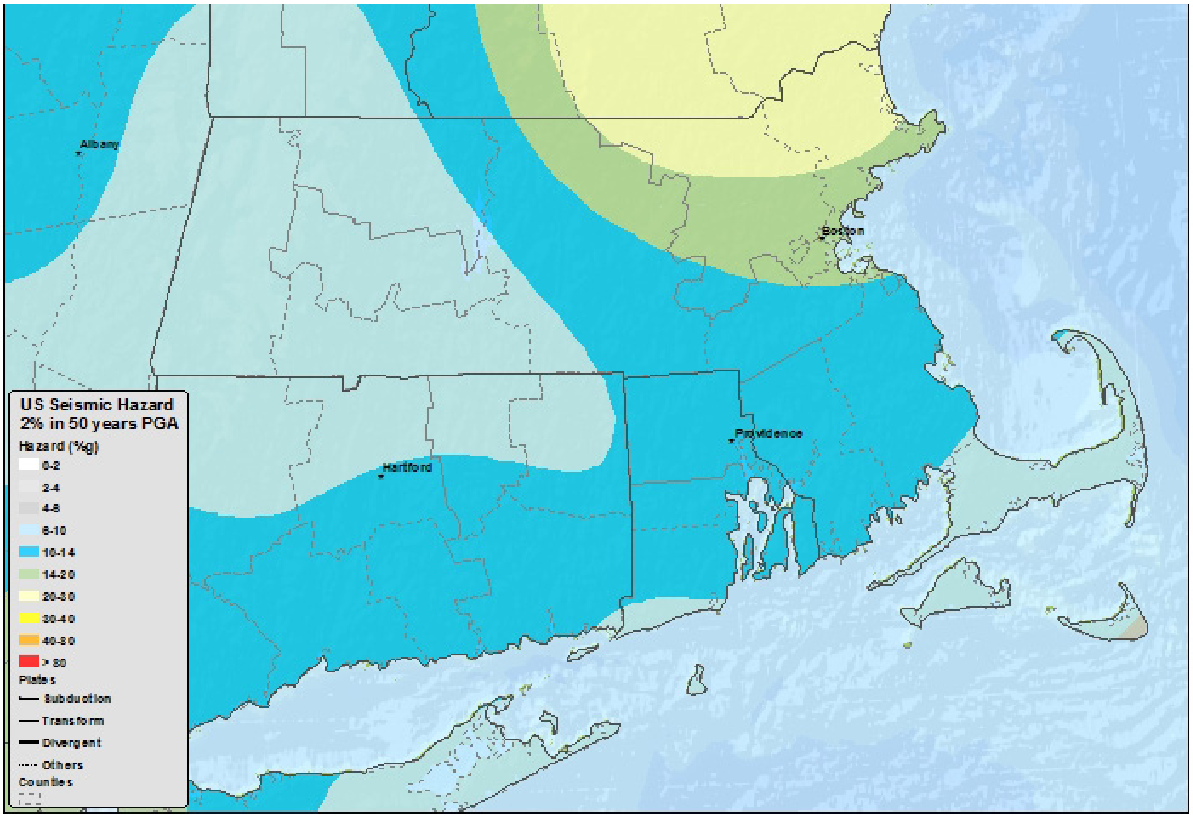
Figure 5.7-1. Massachusetts seismic site classification map.

5.7.2.2 Hazard Description

Earthquakes are experienced as a hazard in Massachusetts through ground shaking and liquefaction and can result in tsunamis and landslides depending on the magnitude and epicenter of the event. Ground shaking can be experienced broadly across the Commonwealth, while liquefaction affects areas with unconsolidated soils or on fill.

5.7.2.2.1 Location

New England is in the middle of the North American Plate. On its western edge, along the West Coast, this plate pushes against the Pacific Plate. The eastern edge of the North American Plate is at the middle of the Atlantic Ocean, where the plate is spreading away from the Eurasian and African Plates. New England’s earthquakes appear to be the result of the cracking of crustal rocks due to compression, as global plate movements very slowly squeeze the North American Plate. It has also been hypothesized that New England's earthquakes could be caused by "isostatic" rebound—the slow rebound of the crust following the retreat of the Laurentide ice sheet during the Wisconsin glaciation, which relieved stresses on the crust—although most modern earthquake data do not support this hypothesis. New England earthquake epicenters may not follow the major mapped geologic faults of the region, nor are they confined to any geologic structures or terrains. Because earthquakes have been detected all over New England, seismologists suspect that a strong earthquake could be centered anywhere in the region, although it is possible that earthquakes tend to re-occur along pre-existing planes of weakness (Kafka, 2020). Generally, USGS seismic hazard maps show that Massachusetts has a low to moderate level of seismic hazard compared to other areas of the country (USGS, 2018a). Peak ground accelerations (PGA) with a 2 percent probability of being exceeded in 50 years are predicted to be higher in the northeast part of the Commonwealth, around 20–30 percent the force of gravity (Figure 5.7-2). Shaking at this level is known to cause some property damage, such as broken chimneys. However, as discussed above and shown in Figure 5.7-1, softer soil types (especially on Cape Cod and the Islands, in the Greater Boston region, and in the Connecticut River Valley) can amplify local ground shaking and thus the impacts from an earthquake.



Source: U.S. Geological Survey (2014).

Figure 5.7-2. USGS seismic hazard map for Massachusetts.

In addition to those originating within the Commonwealth, earthquakes in other parts of New England can affect widespread areas including Massachusetts. This is due in part to the fact that the geologic structures and rock properties in the eastern U.S. allow seismic waves to travel farther than they do in the western U.S. without weakening as much as they do in California. This can amplify an earthquake's intensity and range relative to what is seen for earthquakes on the U.S. West Coast. This characteristic can increase the amount of shaking felt at a distance from smaller seismic events (USGS, 2018b). The result is that large earthquakes in Canada, which is more seismically active than New England, can affect older buildings constructed of unreinforced masonry that are common in Boston and other historic Massachusetts towns (Commonwealth of Massachusetts, 2019; Ebel, 2019).

5.7.2.2.2 Previous Occurrences and Frequency

Previous Occurrences

Although it is well documented that the zone of greatest seismic activity in the U.S. is along the Pacific Coast in Alaska and California, smaller earthquakes are not uncommon in the New England area. According to the Weston Observatory New England Seismic Network's Earthquake Catalog, over 1,800 earthquakes have been recorded in New England and adjacent areas in the last 15 years (NESN, 2022). A few damaging earthquakes have taken place historically in New England, including the 1755 earthquake centered off the coast of Cape Ann, which had an estimated magnitude of 6.2. Historical accounts of the Cape Ann Earthquake depict significant damage to chimneys in Boston, Braintree, and Northampton and report liquefaction in Scituate. The last earthquake with a magnitude above 5.0 that was centered in New England took place in the Ossipee Mountains of New Hampshire in 1940 (Ebel, 2006, 2019).

In 1965, a moderate earthquake shook Nantucket Island, rattling doors, windows, and dishes and slightly damaging fragile objects like ornaments (Commonwealth of Massachusetts, 2019). In 2011, a magnitude 5.8 earthquake centered in Mineral, Virginia, was felt throughout Massachusetts but caused no damage. More recently, in 2021, two small earthquakes—magnitude 1.4 and 1.2—were detected 10 days apart in Peabody. Ground shaking was strong enough to create loud noises and frighten residents, but with no reported damage (McCarthy, 2021).

Frequency

Earthquakes cannot be predicted and may occur at any time. USGS seismic hazard maps are used to determine the likelihood that a given earthquake severity will be exceeded over a defined period (as shown in Figure 5.7-2, which maps the PGA with a 2 percent chance of being exceeded in 50 years). However, these maps are not useful for predicting the timing of individual events.

A 1994 report by USGS, based on a meeting of experts at the Massachusetts Institute of Technology, provides an estimated probability of occurrence for earthquakes above magnitude 5.0. (Earthquakes of this size can cause damage near their epicenters, and in general larger-magnitude earthquakes can cause damage over larger areas.) This report found that the probability of a magnitude 5.0 or greater earthquake centered somewhere in New England in a 10-year period is about 10 to 15 percent, which the Intergovernmental Panel on Climate Change classifies as “unlikely.” This probability rises to about 41 to 56 percent for a 50-year period. Larger earthquakes have lower probabilities of occurrence.

Meanwhile, small earthquakes (magnitude 1 to 1.5) like those experienced in Peabody in 2021, typically occur once or twice a month throughout New England (McCarthy, 2021).

The rate of earthquake occurrence in New England appears to be fairly constant over time in New England (Northeast States Emergency Consortium, n.d.). There is no research indicating any effects of climate change on the frequency or severity of the earthquakes in the Commonwealth.

Potential Effects of Climate Change on Earthquakes

There is no consensus on the effects of climate change on the frequency and severity of earthquakes across the United States or within Massachusetts. Some scientists and researchers have speculated that the effects that sea level rise will have on groundwater levels near the coast may increase the areas exposed to liquefaction risk. Other studies and research have considered the impacts of extreme precipitation events on increased frequency and intensity of earthquakes. While these questions have been raised and some studies are pursuing further information, there is no current consensus on any links between earthquakes and climate change in the Commonwealth or the United States.

5.7.2.2.3 Severity/Intensity

The location of an earthquake is commonly described by its focal depth and the geographic position of its epicenter. The focal depth of an earthquake is the depth from the surface to the region where the earthquake's energy originates (the focus). Globally, earthquakes with focal depths up to about 43.5 miles are classified as shallow. Earthquakes with focal depths of 43.5 to 186 miles are classified as intermediate. The focus of deep earthquakes may reach depths of more than 435 miles. Most earthquakes have focal depths of 20 miles or less. The depth to the Earth's core is about 3,960 miles, so even the deepest earthquakes originate in relatively shallow parts of the Earth's interior. The epicenter of an earthquake is the point on the Earth's surface directly above the focus.

Seismic waves are the vibrations from earthquakes that travel through the Earth and are recorded on instruments called seismographs. The magnitude of an earthquake is a seismograph-measured value of the amplitude of the seismic waves. The most widely known scale for earthquake magnitude is the Richter scale, developed in 1935 as a mathematical device to compare earthquakes. The Richter scale has no upper limit. Importantly, it does not express 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. It is the presence of vulnerable assets and populations near an earthquake epicenter, combined with the earthquake magnitude, that determines the amount of damage and where that damage takes place.

The severity of an earthquake is based on the observed effects of ground shaking on people, buildings, and natural features. Intensity is expressed by the Modified Mercalli Intensity (MMI) scale, which describes how strongly an earthquake was felt at a particular location using values ranging from I to XII. Seismic hazards are also expressed in terms of PGA, which USGS defines as the greatest acceleration that "is experienced by a particle on the ground." More precisely, seismic hazards are described in terms of spectral acceleration, defined by USGS as "approximately what is experienced by a building, as modeled by a particle on a massless vertical rod having the same natural period of vibration as the building" in terms of percent of acceleration force of gravity (percent g).

Table 5.7-1 summarizes the MMI scale, associated damage, and corresponding PGAs and Richter scale magnitudes. Note that the typical comparisons between Mercalli intensity and Richter magnitudes are biased toward the type of earthquakes that happen in California. Smaller magnitude earthquakes can be felt over larger regions in New England, so the Mercalli descriptions for "equivalent"-magnitude earthquakes are not always accurate in this region. For example, a 4.2 magnitude is typically considered to be equivalent to MMI II ("felt only by a few persons"); this may be true on the West Coast, but an earthquake of that magnitude in New England can be felt my many more people over a wide area, sometimes so strongly that people get scared and run out of their buildings (as is typically described for an MMI IV or V earthquake).

Table 5.7-1. MMI and Equivalent PGA and Richter Scale Magnitude

Mercalli Intensity	Equivalent Richter Scale Magnitude	Description	Abbreviated MMI Scale Descriptions	Acceleration (Percent g) (PGA)
I		Detected only on seismographs.	Not felt except by a very few under especially favorable conditions.	< .17
II		Some people feel it.	Felt only by a few people at rest, especially on upper floors of buildings.	.17–1.4
III		Felt by people resting; like a truck rumbling by.	Felt quite noticeably by people indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.	.17–1.4
IV		Felt by people walking.	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.	1.4–3.9
V	< 4.8	Sleeping people awake; church bells ring.	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.	3.9–9.2
VI	< 5.4	Trees sway; suspended objects swing; objects fall off shelves.	Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.	9.2–18
VII	< 6.1	Mild alarm; walls crack; plaster falls.	Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary structures, considerable in poorly built or badly designed structures; some chimneys broken.	18–34

Mercalli Intensity	Equivalent Richter Scale Magnitude	Description	Abbreviated MMI Scale Descriptions	Acceleration (Percent g) (PGA)
VIII		Moving cars are uncontrollable; masonry fractures; poorly constructed buildings damaged.	Slight damage in specially designed structures; considerable damage in ordinary substantial buildings, with partial collapse. Great damage in poorly built structures. Chimneys, factory stacks, columns, monuments, and walls fall. Heavy furniture overturned.	34–65
IX	< 6.9	Some houses collapse; ground cracks; pipes break open.	Considerable damage in specially designed structures; well-designed frame structures thrown out of plumb. Great damage in substantial buildings, with partial collapse. Buildings shifted off foundations.	65–124
X	< 7.3	Ground cracks profusely; many buildings destroyed; liquefaction and landslides are widespread.	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.	>124
XI	< 8.1	Most buildings and bridges collapse; roads, railways, pipes, and cables are destroyed; general triggering of other hazards occurs.	Few, if any (masonry structures remain standing. Bridges destroyed. Rails bent greatly.	>124
XII	> 8.1	Total destruction; trees fall; ground rises and falls in waves.	Total damage. Lines of sight and level are distorted. Objects thrown into the air.	>124

Source: Swiss Seismological Service (n.d.).

[a] USGS (n.d.-b)

Because of the low probability of a significant earthquake in Massachusetts, the entire Commonwealth can be expected to have a low to moderate risk of earthquake damage compared to other areas of the country. However, because the risk of damage from even a moderate earthquake in the region is relatively high, it is more accurate to characterize New England as a “high impact, low probability” earthquake region (Ebel, 2019). Additionally—as described above—impacts at the local level can vary based on types of construction, building density, and soil type, among other factors. This is demonstrated in the Hazus analysis summarized in Section 5.7.2.3. When assessing the likelihood of damage and risk from earthquakes in Massachusetts, it is also important to consider the changes in land use and population since the large earthquake in 1755 and the extent of damage that a similar-magnitude earthquake could cause considering new development, land uses, populations, and aging infrastructure, particularly in the areas where growth has been most significant in the Commonwealth and where the risk of liquefaction and damage to common building types is also highest.

5.7.2.2.4 Warning Time

There is currently no reliable way to predict the day or month when an earthquake will occur in a particular place.

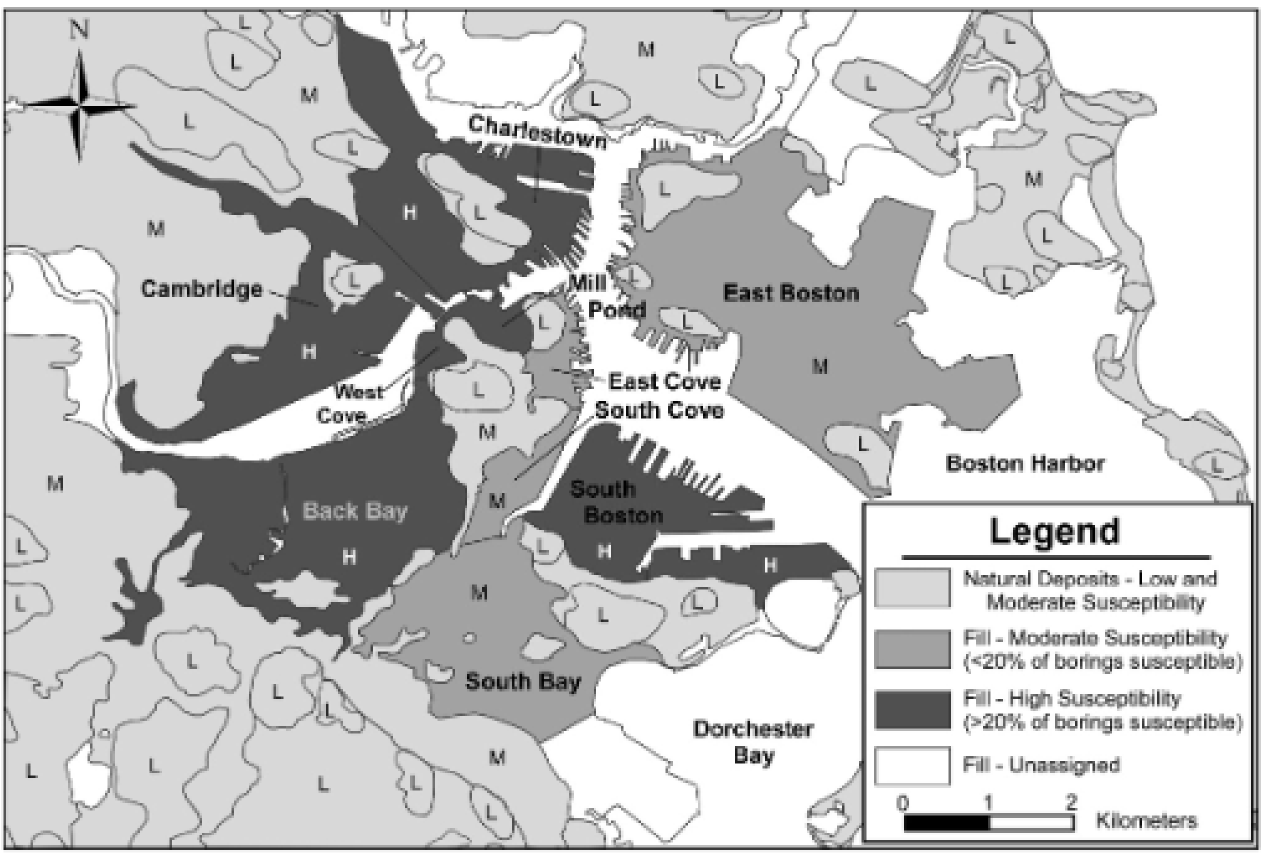
In 2022, USGS released the ShakeAlert mobile app for the West Coast. It can detect energy radiating from an earthquake of magnitude 4.5 or higher and gives around 20 seconds of advanced warning before significant ground shaking occurs. Although the warning time is very short, it could allow immediate safety measures, such as getting under a desk, stepping away from a hazardous material, or shutting down a computer to prevent damage. This early-warning app is only operational in California, Oregon, and Washington; no early-warning system exists on the East Coast, making it difficult for Massachusetts residents to get any warning at all about the imminence of strong earthquake ground shaking (Fowler, 2022; USGS, n.d.-a). Annual drills such as The Great NorthEast ShakeOut help community members learn how to react quickly and reduce their risk of injury in an earthquake scenario. Massachusetts had over 22,000 residents register for the drill in 2022 (Southern California Earthquake Center, n.d.). The lack of warning time makes preparation and mitigation critical for earthquake risk reduction, including building codes, construction methods, and community and agency preparedness.

5.7.2.2.5 Secondary Hazards

All forms of critical infrastructure and assets can face secondary hazards from earthquakes. Examples include fires in residential buildings that can cause injury, loss of life, and significant damage. Earthquakes can also cause large and sometimes disastrous landslides (Section 5.11), tsunamis (Section 5.15), and fires and conflagrations due to ruptured fuel pipelines and other damaged infrastructure (Section 5.7.2.3.3). Dams and levees are susceptible to damage from seismic events, and the impacts of their failures (e.g., flash flooding) can be considered secondary hazards from earthquakes.

Soil liquefaction is a secondary hazard unique to earthquakes that occurs when water-saturated sands, silts, or gravelly soils are shaken so violently that the individual grains lose contact with one another and float freely in the water, turning the ground into a pudding-like liquid. Building and road foundations lose load-bearing strength and may sink into formerly solid ground. Unless properly secured, hazardous materials can be released, causing significant damage to the environment and people. Liquefaction may occur along the shorelines of the ocean, rivers, and lakes, and can also happen in low-lying areas away from water bodies but where the underlying groundwater is near the Earth's surface, as well as areas that were previously wetlands but historically filled to make land such as parts of Boston.

A liquefaction susceptibility mapping study in Boston found that, when saturated, the downtown's non-engineered artificial fill is highly susceptible to liquefaction during an earthquake. Figure 5.7-3 shows that areas of the Back Bay, South Boston, Cambridge, and Charlestown are also highly susceptible to liquefaction in a magnitude 6.0 (PGA = 0.12 g) earthquake. Surrounding towns such as Winthrop, Revere, and Lynn to the north, and Quincy and Hull to the south, also have areas deemed highly susceptible due to being located in areas with artificial fill, beach deposits, or marsh deposits (Brankman & Baise, 2008).



Source: Brankman and Baise (2008).

Figure 5.7-3. Liquefaction susceptibility in Boston, Cambridge, and Charlestown, Massachusetts.

Widespread damage to buildings from liquefaction may be mitigated by certain construction practices, but utilities, roadways, and aging infrastructure and unreinforced masonry buildings are at a high risk of damage from earthquakes (Brankman & Baise, 2008; Kianiard et al., 2017). The city of Boston's Natural Hazard Mitigation Plan recognizes localized risks of liquefaction that could significantly affect the city's underground transportation system and historically significant buildings (City of Boston, 2021).

5.7.2.2.6 Local Context for Hazard and Vulnerability: A Review of Local Plans

The local hazard mitigation plans reviewed revealed a common sentiment that earthquake risk is generally low for the region, although the possibility of a larger earthquake could have serious consequences. Local plans do not typically refer to historical examples of earthquakes, but instead describe projected impacts including economic losses from building damage. Several localities discuss older building stock constructed before the current building codes as a source of vulnerability to earthquake impacts. Local conditions such as soil type and risk of liquefaction, notable especially in Boston, create larger concerns for the earthquake hazard.

Table 5.7-2. Highlight of Local Hazard Mitigation Plans

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
2021 Natural Hazard Mitigation Plan Update, city of Boston, December 2021	• Small earthquakes happen regularly in Boston but often go unnoticed. • The plan flags that a larger earthquake could cause significant impacts (especially in areas built on filled land, which is susceptible to liquefaction).	• Many older and historically significant buildings have high vulnerability to earthquake damage, especially those constructed of unreinforced masonry. Aging transportation infrastructure is also vulnerable.	• Not provided
Town of Hull Hazard Mitigation Plan: 2018 Update, April 2018	• The prominence of older buildings suggests that earthquakes could pose a significant risk to the entire town.	• Older buildings and infrastructure were constructed without specific earthquake-resistant design features. Technological equipment is also at risk of earthquake damage.	• Estimated $184 million in total building damage for a magnitude 5.0 earthquake.
City of Somerville Hazard Mitigation Plan: 2022 Update, January 2022	• No earthquake epicenters have been recorded in Somerville, and the Commonwealth more broadly has a	• Newer construction would be built to seismic standards, but most buildings in Somerville pre-date the current building codes	• Estimated $1.7 billion in total building damage for a magnitude 5.0 earthquake.

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
	low earthquake risk compared to other areas in the U.S. However, a serious earthquake is possible.	and are therefore vulnerable to earthquake damage.	
Town of Erving Hazard Mitigation Plan (draft), October 2019	• Overall, Erving has low vulnerability to earthquakes. However, there are relevant concerns for this hazard related to residents' water supply, the town's sheltering capacity, transportation routes and potential hazardous material spills, and social vulnerabilities.	• People over 65 (19% of the town's population) and those living below the poverty level (8.9% of town's population) are the most vulnerable to earthquake risks. 61% of housing units in town were built prior to the current building codes. Earthquake damage to the Northfield Mountain Hydroelectric Facility could lead to dam failure and flooding in Erving's Village of Farley.	• Not provided

5.7.2.3 Exposure and Vulnerability

The assessment team conducted an exposure and vulnerability earthquake analysis using Hazus 6.0 (risk modeling software from the Federal Emergency Management Agency, updated to improve long-term seismic hazard model data), updated U.S. Census data, and updated structural valuation data to provide better damage estimates compared to previous versions.

The Hazus analysis also incorporates the updated seismic site classification map, shown in Figure 5.7-1, to generate exposure and vulnerability results for each Massachusetts county. This map was developed in 2023 based on the state's surficial geology map and calculations that consider the average overburden velocity, depth to bedrock, and bedrock velocity (Pontrelli et al., 2023). This updated soil characterization map improves on previous versions by incorporating better geologic data, especially shear wave velocity and depth to bedrock.

To estimate the earthquake damage that could occur in Massachusetts, a probabilistic Level 2 analysis was conducted in Hazus for the 100-, 500-, 1,000-, and 2,500-year mean recurrence period (MRP) events based on USGS probabilistic seismic hazard maps. The results of this analysis, discussed later in this section, demonstrate which counties in Massachusetts may experience greater damage from these modeled events. Earthquake vulnerability varies due to local conditions; the Hazus analysis included criteria such as geology, population, land use, and infrastructure. It did not consider other localized impacts in liquefaction-susceptible areas, and damage in these areas would likely be greater than the Hazus estimates show.

Table 5.7-3 summarizes the potential priority impacts and high-consequence vulnerabilities related to earthquakes in the Commonwealth using themes and analysis identified in the 2023 SHMCAP Risk Assessment, the 2022 Massachusetts Climate Change Assessment,[1] and information related to past events in Massachusetts and the U.S.

Table 5.7-3. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Earthquakes

Sector	Priority Impacts and Vulnerabilities
Human	• Emergency service response delays and evacuation disruptions **(most urgent)** • Damage to cultural resources **(urgent)** • Injury and possible loss of life
Governance	• Increase in demand for state and municipal government services **(most urgent)** • Damage to (inland and coastal) state and municipal buildings and land
Infrastructure	• Damage to unreinforced masonry buildings • Damage to roads and rail infrastructure, especially bridges and tunnels **(most urgent)** • Reduction in clean water supply **(urgent)** • Damage to electric transmission and utility distribution infrastructure **(most urgent)**
Natural environment	*None identified*
Economy	• Reduction in the availability of affordably priced housing **(most urgent)** • Economic losses from commercial structure damage and business interruption **(urgent)** • Damage to tourist attractions and recreation amenities **(urgent)**

[1] While the 2022 Massachusetts Climate Change Assessment does not explicitly address earthquake risks, it identifies some priority impacts that are likely to apply to this hazard based on this 2023 MA SHMCAP Risk Assessment and information about past events in the Commonwealth.

5.7.2.3.1 Human

The entire population of Massachusetts is potentially exposed to direct and indirect impacts from earthquakes. 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 type of soil that buildings and infrastructure are built on; and the proximity of these building to the earthquake epicenter. Additionally, the construction type, age, and maintenance of the utilities and infrastructure, including fuel pipelines, that serve these communities can also have a large effect on the risk to people during an earthquake, as fires and toxic releases often occur after earthquakes. In addition, the time of day exposes different sectors of the community and numbers of people to the hazard.

Earthquakes could affect the lives of people across the Commonwealth in many ways. Business interruptions could keep people from working, road closures could isolate populations and delay emergency response, and loss of utilities could affect populations that suffer no direct damage from an event itself but lose access to water, power, or communication. Populations that rely on transit could lose service while systems are assessed for damage—and for longer periods if damage is identified and requires repairs. People, particularly low-income households, and renters, who live or work in older unreinforced masonry buildings or in areas with high susceptibility to liquefaction are more vulnerable to loss of housing, injury, and loss of life. The population of the city of Boston is projected to grow by over 100,000 residents by 2040, potentially putting more people at higher risk of earthquake impacts in the city’s liquefaction zones, especially with rapid residential development in the South Boston Waterfront neighborhood (Boston Planning and Development Agency, n.d.; UMass Donahue Institute, 2018). Due to changes in building codes, newer construction will pose less of a life safety risk than older construction and unreinforced masonry buildings, but damage to building, utilities, and infrastructure in liquefaction zones can still be significant enough to require major retrofits and replacements after an earthquake and result in a loss of housing stock and critical services over extended periods.

Vulnerable Populations

The populations most vulnerable to an earthquake event are those that would have difficulty preparing for, responding to, and recovering from an earthquake. Characteristics of vulnerability include age (over 65 or under five), renter status, low income, linguistic isolation, membership in an underrepresented race/ethnicity, unhoused status, transit dependence, disability, underlying health conditions, or residence in a single-parent household. These characteristics affect many factors, such as a person’s physical and financial ability to react or respond during a hazard, the location and construction quality of their housing, and their ability to be self-sustaining after an incident due to limited resources to find new housing, as well as access to food and freshwater resources directly following an event.

Residents may be displaced or require temporary to long-term shelter if an earthquake damages their homes directly or results in a fire or other secondary hazard. The number of people needing temporary shelter is generally less than the number displaced, as some who are displaced use hotels or stay with family or friends following a disaster event. Impacts on people and households in the planning area were estimated for the 100-, 500-, 1,000-, and 2,500-year MRP earthquakes through the probabilistic Hazus analysis. Table 5.7-4 summarizes the results. Shelter estimates from Hazus are intended for general planning purposes and should not be assumed to be exact. It should also be noted that, in Massachusetts, the season in which an earthquake occurs could significantly affect the number of residents needing shelter. For example, if an earthquake occurred during a winter weather event, more people might need shelter if utility infrastructure damage resulted in a loss of heat in their homes. These numbers should be considered as general, year-round average estimates. Depending on the level of damage, some residents may be permanently displaced from their homes, needing long-term housing replacement. This is a particularly challenging problem due to the high cost of living in Massachusetts, and especially in Boston. Ensuring earthquake-resilient design in new residential developments and infrastructure will help mitigate the need for long-term housing replacement.

Table 5.7-4. Estimated Shelter Requirements: Hazus Probabilistic Scenarios

County	100-Year MRP		500-Year MRP		1,000-Year MRP		2,500-Year MRP	
	Displaced House-holds	Short-Term Sheltering Needs	Displaced House-holds	Short-Term Sheltering Needs	Displaced House-holds	Short-Term Sheltering Needs	Displaced House-holds	Short-Term Sheltering Needs
Barnstable	0	0	0	0	54	22	54	22
Berkshire	0	0	7	3	20	10	20	10
Bristol	0	0	30	16	30	16	378	199
Dukes	0	0	0	0	3	1	3	1
Essex	0	0	0	0	350	191	1,283	701
Franklin	0	0	0	0	13	7	13	7
Hampden	0	0	0	0	163	101	163	101
Hampshire	0	0	14	7	14	7	132	63
Middlesex	1	1	231	108	231	108	2,619	1,229
Nantucket	0	0	0	0	2	1	2	1
Norfolk	0	0	0	0	167	74	606	271
Plymouth	0	0	0	0	99	49	361	179
Suffolk	5	3	5	3	767	428	2,930	1,647
Worcester	0	0	50	26	158	84	562	298
Total	**6**	**4**	**337**	**163**	**2,071**	**1,099**	**9,126**	**4,729**

As part of the development of the 2023 SHMCAP, state agencies were asked in a survey to identify their primary concerns about impacts from earthquakes, related to populations served and potential disproportionate impacts. Examples of their responses are in Table 5.7-5.

Table 5.7-5. Example State Agency Responses: Primary Concerns About Earthquake Consequences to Populations Served and Potential Disproportionate Impacts

Category	Examples of Primary Concerns
Populations served	• People with disabilities • Emergency response workers • Veterans • Environmental Justice populations • Elderly
Potential disproportionate impacts	• Loss of in-person services such as in-home care and meal delivery for elderly or disabled populations • Disproportionate impact to those reliant on public transportation and/or required to work in-person jobs • Delayed emergency response time • Delayed financial benefits to veterans if internet is lost

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Health Impacts

The most immediate health risk presented by the earthquake hazard is trauma-related injuries and fatalities from structural collapse; impacts from nonstructural items; or the secondary effects of earthquakes, such as tsunamis, landslides, and fires. Structural damage to critical facilities, such as hospitals and schools or other institutional settings, may have more significant impacts on human health. Ensuring that critical assets such as hospitals, K–12 schools, emergency response and public safety stations, prisons, shelters, elder care facilities, animal shelters. and large gathering spaces (e.g., arenas, museums, concert halls, and theaters) are designed and located to reduce life safety and injury and remain functional post-disaster is critical. While new construction can be built to new standards that consider soil conditions, older construction should be assessed to determine the need for retrofits to reduce the life and public safety risks associated with earthquakes—particularly for critical assets and large gathering spaces, and particularly in liquefaction zones and other areas with weak soils.

Hazus estimates the number of people who may be injured or killed by an earthquake depending on the time of day the event occurs. Estimates are provided for three times of day, representing periods when different sectors of the community are at their peak: peak residential occupancy at 2:00 a.m.; peak educational, commercial, and industrial occupancy at 2:00 p.m.; and peak commuter traffic at 5:00 p.m. Table 5.7-6 shows the number of injuries and casualties for each county expected for events of varying severity, occurring at various times of the day. Statewide totals for each earthquake scenario and time of day are shown in Table 5.7-7. These results show that an earthquake at midday, when most residents are in commercial or educational buildings, would produce the most injuries and casualties statewide. Across the Commonwealth, Hazus estimates between one and four injuries could occur during a 100-year MRP earthquake, and between 1,221 and 3,167 injuries and casualties in a 2,500-year MRP earthquake, depending on time of day.

Table 5.7-6. Estimated Number of Injuries and Casualties by County: Hazus Probabilistic Scenarios

County	100-Year MRP			500-Year MRP			1,000-Year MRP			2,500-Year MRP		
	2 am	2 pm	5 pm	2 am	2 pm	5 pm	2 am	2 pm	5 pm	2 am	2 pm	5 pm
Barnstable												
Injuries	0	0	0	0	0	0	9	26	16	9	26	16
Hospitalizations	0	0	0	0	0	0	1	3	2	1	3	2
Casualties	0	0	0	0	0	0	0	0	0	0	0	0
Berkshire												
Injuries	0	0	0	1	3	2	3	7	5	3	7	5
Hospitalizations	0	0	0	0	0	0	0	1	1	0	1	1
Casualties	0	0	0	0	0	0	0	0	0	0	0	0
Bristol												
Injuries	0	0	0	5	9	6	5	9	6	52	88	60
Hospitalizations	0	0	0	0	1	1	0	1	1	8	13	9
Casualties	0	0	0	0	0	0	0	0	0	1	2	1
Dukes												
Injuries	0	0	0	0	0	0	1	2	1	1	2	1
Hospitalizations	0	0	0	0	0	0	0	0	0	0	0	0
Casualties	0	0	0	0	0	0	0	0	0	0	0	0
Essex												
Injuries	0	0	0	0	0	0	50	84	57	170	275	190
Hospitalizations	0	0	0	0	0	0	7	12	8	27	46	32
Casualties	0	0	0	0	0	0	1	2	1	5	8	5
Franklin												
Injuries	0	0	0	0	0	0	2	4	3	2	4	3
Hospitalizations	0	0	0	0	0	0	0	0	0	0	0	0
Casualties	0	0	0	0	0	0	0	0	0	0	0	0

County	100-Year MRP			500-Year MRP			1,000-Year MRP			2,500-Year MRP		
	2 am	2 pm	5 pm	2 am	2 pm	5 pm	2 am	2 pm	5 pm	2 am	2 pm	5 pm
Hampden												
Injuries	0	0	0	0	0	0	25	52	33	25	52	33
Hospitalization	0	0	0	0	0	0	3	6	4	3	6	4
Casualties	0	0	0	0	0	0	0	1	1	0	1	1
Hampshire												
Injuries	0	0	0	2	5	3	2	5	3	16	41	26
Hospitalizations	0	0	0	0	1	0	0	1	0	2	7	4
Casualties	0	0	0	0	0	0	0	0	0	0	1	1
Middlesex												
Injuries	0	1	0	32	67	44	32	67	44	304	634	413
Hospitalizations	0	0	0	3	7	5	3	7	5	48	109	73
Casualties	0	0	0	0	1	1	0	1	1	8	19	12
Nantucket												
Injuries	0	0	0	0	0	0	0	1	1	0	1	1
Hospitalizations	0	0	0	0	0	0	0	0	0	0	0	0
Casualties	0	0	0	0	0	0	0	0	0	0	0	0
Norfolk												
Injuries	0	0	0	0	0	0	20	46	30	68	147	96
Hospitalizations	0	0	0	0	0	0	2	5	3	9	22	14
Casualties	0	0	0	0	0	0	0	1	0	1	3	2
Plymouth												
Injuries	0	0	0	0	0	0	16	37	24	54	122	79
Hospitalizations	0	0	0	0	0	0	2	4	3	8	19	12
Casualties	0	0	0	0	0	0	0	1	0	1	3	2
Suffolk												
Injuries	1	3	2	1	3	2	75	265	156	248	1062	610
Hospitalizations	0	0	0	0	0	0	11	43	29	46	225	141
Casualties	0	0	0	0	0	0	2	7	4	9	45	27
Worcester												
Injuries	0	0	0	8	17	11	24	47	31	79	148	98
Hospitalizations	0	0	0	1	2	1	3	5	4	11	22	14
Casualties	0	0	0	0	0	0	0	1	0	2	3	2

Table 5.7-7. Estimated Number of Injuries and Casualties Statewide: Hazus Probabilistic Scenarios

Statewide	100-Year MRP			500-Year MRP			1,000-Year MRP			2,500-Year MRP		
	2 am	2 pm	5 pm	2 am	2 pm	5 pm	2 am	2 pm	5 pm	2 am	2 pm	5 pm
Injuries	1	4	2	49	104	68	264	652	410	1031	2609	1631
Hospitalizations	0	0	0	4	11	7	32	88	60	163	473	306
Casualties	0	0	0	0	1	1	3	14	7	27	85	53
Total	**1**	**4**	**2**	**53**	**116**	**76**	**299**	**754**	**477**	**1221**	**3167**	**1990**

Following a severe earthquake, impacts related to the damage, disruption, or loss of transportation infrastructure and services may result in emergency response delays and difficulty accessing critical facilities such as hospitals, schools, care facilities, and others as described for other hazards. Earthquakes may also result in mental health stressors from the direct impacts as well as the need to respond and recover, particularly if injuries occurred or if access to work and availability of shelter were limited because of the event. If ground movement causes hazardous material (in storage areas or in pipelines) to enter the environment, additional health impacts could result, particularly if surface water, air, groundwater, or agricultural areas are contaminated.

5.7.2.3.2 Governance

All Commonwealth-owned buildings and operations are exposed to earthquake hazards. Hazus does not specifically address earthquake impacts to state-owned government buildings, as these facilities cannot be differentiated from those of other types of government. Therefore, specific exposure analyses or estimates of potential damage cannot be provided for government assets.

Vulnerability of State Assets

Any older government buildings that were constructed of unreinforced masonry or without specific earthquake-resistant design will be at higher risk of damage. State transportation assets, especially highway and railway bridges and tunnels, are at risk of earthquake damage. State assets sited on artificial fill are more vulnerable to the risks of liquefaction. This includes state-owned buildings in Boston. Among the buildings built on loose clay soils are multiple Suffolk County Sheriff Department Prison buildings, several University of Massachusetts Boston buildings, pump stations in the Charles River Reservation, and Massachusetts College of Art and Design buildings.

Earthquake damage to physical assets, especially critical facilities, and lifelines, could hinder government's ability to provide necessary services to people across the Commonwealth, which would result in greater impacts on those populations with characteristics that make them more at risk for earthquakes and those located in areas or in structures more at risk from shaking and liquefaction. A significant earthquake in

Massachusetts would also increase the service demands of public safety workers and first responders during response and recovery efforts.

As part of the 2023 MA SHMCAP state agency survey (ERG, 2023), agencies in Massachusetts were asked to identify vulnerabilities of state assets and services. Many shared concerns about the consequences an earthquake could have on the services they provide. Their responses also included updates and improvements needed to address concerns about earthquake hazards. Examples of the responses are provided in Table 5.7-8 below. While many of the comments focus on emergency response, the need to mitigate the risks to reduce these impacts are also included, such as preparations of critical infrastructure and utilities and a focus on building codes.

Table 5.7-8. Example State Agency Responses: Primary Concerns About Earthquake Consequences to Services and Improvements Needed to Address Concerns

Category	Examples of Primary Concerns
Services provided	• Disruption to 911 services and call centers • Damage to roads, bridges, culverts, traffic lights, and signage; evacuation/emergency routes not available • Inability of compliance officers to reach businesses requiring inspection • Emergency services coordination at the federal, state, and local levels including situational awareness • Potential damage/destruction of foster homes or residential facilities, resulting in a disrupted placement of children in the state's care and the need to find another safe and stable placement
Updates, improvements, or enhancements needed to address concerns	• Work with the carriers to assess vulnerable infrastructure that serves 911, i.e., cell towers • Comply with building codes for earthquake-resistant design; remodel older structures to meet updated codes • Support programs that promote planning for extreme events, particularly for those with special medical needs or physical challenges • Continue to review financial institution preparedness plans

Source: ERG (2023).

Note: The responses to the survey were completed by agency staff and did not go through formal review.

5.7.2.3.3 Infrastructure

While all elements of the built environment in the Commonwealth are exposed to the earthquake hazard, the vulnerabilities and risks vary greatly across Massachusetts based on age, condition, location, type, and function of the assets. All assets within areas exposed to liquefaction risk—such as parts of Boston, Cambridge, Charlestown, Winthrop, Revere, Lynn, Quincy, and Hull—are at greater risk and should be designed and retrofitted to mitigate this increased risk with a particular focus on critical assets, large gathering spaces, historic resources, and lifeline infrastructure. Building types such as unreinforced masonry buildings, buildings constructed before building code updates in the 1970s, and historically significant buildings should be assessed regardless of soil type due to age, condition, and construction methods. Buildings that provide functions that provide health services, emergency and safety services, large gathering spaces, public services, and institutional settings should also be assessed based on the difficulty of evacuating such spaces and the risk of large-scale injuries and casualties, as well the potential loss of cultural and historic assets.

Lifeline infrastructure and other utility and infrastructure networks and systems are also at a greater risk from earthquakes, as these linear systems are only as resilient as their weakest links. As described above, bridges and tunnels can be at greater risk from earthquakes, particularly due to age, condition, and construction methods. Rail lines and runways can be disrupted by minor ground disturbances from earthquakes, resulting in transportation disruption and delays and potentially costly repairs. Based on age, condition, construction type, and function, Massachusetts could consider identifying earthquake risk reduction priorities that focus on the locations, assets, and functions whose damage, disruption, or complete loss due to an earthquake would create the most significant consequences.

Table 5.7-9 and Table 5.7-10 in Section 5.7.2.3.5 below summarize the estimated economic loss related to damaged buildings and transportation and utility infrastructure from earthquake events from a range of return periods. In addition to these direct economic impacts, this damage can cause loss of life, injuries, and mental health effects; lost work hours and increased commute times; impacts to neighborhoods and communities due to housing and business interruptions and displacement; damage to cultural and historic resources; and strains on emergency response and public safety services. There are also secondary hazards to consider: for example, an increased risk of fires raises the risk of hazardous material releases, which can include potentially catastrophic discharges into the atmosphere or nearby waterways and can disrupt services well beyond the primary area of impact. Many of the infrastructure categories described below serve as community lifelines and their temporary or long-term failure poses risks to public health and safety, the environment, and the economy.

Buildings

The Massachusetts State Building Code, first enacted in 1975, includes seismic design provisions, but many towns in Massachusetts have high proportions of older buildings that predate the building codes and are therefore more vulnerable to damage in an earthquake. As one of the oldest cities in the country, Boston is home to many buildings constructed of unreinforced masonry, which is highly susceptible to earthquake damage. There are about 19,000 unreinforced masonry buildings in the city of Boston—and over 100,000 in the Greater Boston area (Kianiard et al., 2017)—many of which are historically and culturally significant. Table 5.7-9 summarizes the estimated economic loss related to buildings damaged in each earthquake scenario modeled from 100- to 2,500-year MRP events.

Energy

Earthquakes often cause physical damage to power plants, gas lines, liquid fuel storage infrastructure, transmission lines, utility poles, solar and wind infrastructure, and other elements of the energy sector. While Hazus results for utility damage (Table 5.7-9) do not predict any damage to energy infrastructure in pipelines under any earthquake MRP scenario, these resources in areas susceptible to liquefaction are at higher risk, and damage to any components of the energy grid can result in widespread power outages.

Telecommunications

Communication systems are critical for coordinating emergency response efforts after a disaster and disseminating warnings about secondary hazards. A significant earthquake could cause physical damage to telecommunication infrastructure, such as telephone poles and cell towers, and those sited in areas susceptible to liquefaction are at higher risk. Electricity is necessary to support many communication systems, so any impacts to the electric grid that cause power outages can subsequently induce mobile communication breakdown. Damage to these systems can be expensive and time-consuming to repair (El Khaled & Mcheick, 2019).

Public Health

Hospitals and other medical and health facilities can experience damage and direct losses from earthquakes, which would limit their ability to serve patients and put the patients that they are already serving at significant risk. Health care facilities can be incredibly challenging to evacuate due to patient conditions and equipment and medication requirements and needs. Even if a building is designed to withstand an earthquake, damage to medical equipment is possible if it is not properly secured. Boston is a major healthcare industry hub; its 25 hospitals and 20 community health centers could be at risk from liquefaction based on their location. Additionally, a significant earthquake would likely result in many injuries that would increase the demand for health services and hospitals (Table 5.7-6 and Table 5.7-7). Release of hazardous materials in the air, soil, or water from damaged infrastructure could cause widespread public health impacts; see Section 5.7.2.3.1 above for more information about potential impacts to human health.

Public Safety

Police stations, fire stations, and other critical public safety infrastructure and services are also at risk from damage, disruption, and loss from earthquakes, which could affect their ability to operate at the needed capacity to respond to an earthquake event. Direct damage to stations and equipment would make it much more difficult for public safety providers to serve the surrounding community. Damage to transportation and communication infrastructure components could also impair emergency response efforts.

Transportation

Earthquakes can affect many aspects of the transportation sector, including causing damage to roads, railways, airports, vehicles, and storage facilities and sheds. Bridges and tunnels are often among the most vulnerable types of transportation structures, along with rail networks and airport runways (which can be affected by small ground displacements). Damage to road and networks, bridges, and runways can cause widespread disruption of services and impede disaster recovery and response. Some of the Commonwealth's most valuable transportation components run underground through Boston; these subway and highway tunnels are uniquely vulnerable to the effects of liquefaction in the city and disruption to these transportation services would have broader impacts throughout Massachusetts and New England (City of Boston, 2021; Massachusetts Department of Transportation, 2015). In 2023, 8.6 percent of the Commonwealth's bridges (446 out of 5,168) were found to be structurally deficient, putting them at higher risk of damage from an earthquake (Massachusetts Department of Transportation, 2023). Economic losses from transportation are included in Table 5.7-10

Water Infrastructure

Due to their extensive networks of aboveground and belowground infrastructure—including pipelines, pump stations, tanks, administrative and laboratory buildings, reservoirs, chemical storage facilities, and treatment facilities—water and wastewater utilities are vulnerable to earthquakes (U.S. EPA, 2018). Additionally, sewer and water treatment facilities are often built on ground that is subject to liquefaction, increasing their vulnerability. Earthquakes can cause ruptures in storage and process tanks, breaks in pipelines, and building collapse, resulting in loss of water, loss of pressure, and contamination and disruption of drinking water services. Damage to wastewater infrastructure can lead to sewage backups and releases of untreated sewage into the environment (U.S. EPA, 2018). Based on Hazus results, the largest utility-related infrastructure damage in Massachusetts is likely to be to potable water facilities.

5.7.2.3.4 Natural Environment

Earthquakes affect natural resources and the environment primarily through secondary impacts, such as landslides, liquefaction, fires, slope failure, or flash flooding. Flora and fauna are unlikely to be directly harmed by ground shaking in a Massachusetts earthquake, although disruption to the physical foundation of an ecosystem can lead to localized species loss. Longer-term disruptions to species balance could leave the area more vulnerable to the spread of invasive species [Section 5.10 (Invasive Species)]. Contamination of water sources from released hazardous materials could have longer-term impacts on the natural environment. Fires that break out as a result of earthquakes can also cause ecosystem damage, as described in Section 5.16 (Wildfires).

Any of these impacts to the natural environment could have similar impacts on the Commonwealth's agriculture sector. For example, groundwater changes or flooding due to liquefaction could result in localized loss of crop yields. Livestock animals could also be injured or killed in the collapse of a barn or other structures. Damage to agricultural infrastructure such as irrigation systems would cause additional losses to this sector. Loss of power, communications, and water delivery, as well as damage or disruption to transportation access or port operations. would also have significant impacts on agricultural uses, making it difficult to maintain operations, deliveries, and shipments.

5.7.2.3.5 Economy

Earthquake impacts on other sectors discussed above will have cascading impacts on the economy. Hazus estimates the economic loss associated with each earthquake return period assessed, which includes building and lifeline-related losses (transportation and utility losses) based on the available inventory (facility or GIS [geographic information system] point data only). Given that Massachusetts, especially Greater Boston, is a national economic, financial, and transportation hub, any local impacts could have cascading consequences throughout New England, as well as the country.

Direct building-related loss estimates include the costs to repair or replace the damage to a building, as well as business interruption losses associated with the inability to operate a business because of damage sustained in an earthquake. Business interruption losses also include the temporary living expenses of people displaced from their homes because of the earthquake. Hazus considers these as capital stock losses (structural damage, non-structural damage, contents damage, inventory loss) as well as income losses (relocation loss, capital-related loss, wages losses, and rental income loss). Table 5.7-9 below summarizes the estimated potential building-related losses per earthquake scenario per county.

Table 5.7-9. Building-Related Economic Loss Estimates: Hazus Probabilistic Scenarios

County	100-Year MRP	500-Year MRP	1,000-Year MRP	2,500-Year MRP
Barnstable	$0	$52,922,000	$183,239,000	$732,933,000
Berkshire	$0	$12,584,000	$40,510,000	$150,887,000
Bristol	$0	$40,292,000	$150,558,000	$656,472,000
Dukes	$0	$4,594,000	$16,394,000	$68,942,000
Essex	$62,000	$170,250,000	$659,701,000	$2,640,394,000
Franklin	$0	$7,014,000	$22,991,000	$85,956,000
Hampden	$0	$81,007,000	$252,043,000	$892,380,000
Hampshire	$0	$23,132,000	$72,460,000	$257,611,000
Middlesex	$1,569,000	$356,855,000	$1,264,668,000	$4,946,490,000
Nantucket	$0	$2,919,000	$10,245,000	$42,880,000
Norfolk	$42,000	$79,986,000	$298,424,000	$1,238,848,000

County	100-Year MRP	500-Year MRP	1,000-Year MRP	2,500-Year MRP
Plymouth	$0	$68,228,000	$247,750,000	$1,015,679,000
Suffolk	$9,049,000	$411,737,000	$1,289,836,000	$4,605,463,000
Worcester	$0	$77,370,000	$281,390,000	$1,138,662,000
Total	**$10,722,000**	**$1,388,890,000**	**$4,790,209,000**	**$18,473,597,000**

Lifeline-related losses include the (estimated) costs to repair damaged transportation and utility system components. Transportation components include roadway or rail segments, bridges, and tunnels, as well as facilities for the state's highway, railway, light rail, buses, ports, ferries, and airports. Utility systems include the facilities and pipelines providing potable water, wastewater, oil systems, natural gas, electric power, and communication resources. A summary of these losses is presented in Table 5.7-10. In all cases, transportation losses are estimated to be significantly larger than utility losses in the Commonwealth. According to Hazus, the only utility losses are likely to be related to potable water infrastructure; however, other utility resources in liquefaction-susceptible areas may be at higher risk of damage than Hazus predicts. Suffolk County is likely to experience the largest economic losses from transportation and utility damage in an earthquake, and a large portion of Suffolk County's transportation losses are attributed to light rail facilities. Localized impacts could be greater in some areas due to liquefaction, which is not included in this analysis.

Table 5.7-10. Transportation and Utility Loss Estimates: Hazus Probabilistic Scenarios

County	100-Year MRP	500-Year MRP	1,000-Year MRP	2,500-Year MRP
Barnstable	$50,000	$3,567,000	$9,365,000	$23,914,000
Berkshire	$5,000	$238,000	$628,000	$1,755,000
Bristol	$24,000	$2,621,000	$7,487,000	$20,313,000
Dukes	$8,000	$1,080,000	$3,130,000	$8,262,000
Essex	$495,000	$23,998,000	$57,722,000	$137,275,000
Franklin	$4,000	$211,000	$604,000	$2,067,000
Hampden	$27,000	$1,171,000	$2,961,000	$8,509,000
Hampshire	$4,000	$286,000	$984,000	$3,530,000
Middlesex	$164,000	$8,099,000	$23,697,000	$70,533,000
Nantucket	$4,000	$297,000	$805,000	$2,053,000
Norfolk	$174,000	$6,127,000	$14,503,000	$33,063,000
Plymouth	$80,000	$4,893,000	$11,890,000	$28,584,000
Suffolk	$9,007,000	$22,310,000	$468,151,000	$986,595,000
Worcester	$24,000	$1,751,000	$5,074,000	$14,905,000
Total	**$10,070,000**	**$76,649,000**	**$607,001,000**	**$1,341,358,000**

Chapter 5. Risk Assessment and Hazard Analysis

Flooding from Precipitation and Assessment of Dam Overtopping

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5.8 Flooding from Precipitation and Assessment of Dam Overtopping

5.8.1 Flooding from Precipitation Problem Statement

Flooding from Precipitation

Flooding in urban areas can be exacerbated by climate change, which is predicted to alter the intensity, duration, extent, and possibly frequency of precipitation. Additionally, changing land uses and increasing development are leading to a reduction in permeable surfaces, causing increased risk of flooding. Urban or other areas with reduced permeable surfaces depend on drainage systems to manage stormwater, especially during periods of high-intensity precipitation, precipitation when the ground is frozen, or rain-on-snow events. The ability of stormwater systems to provide sufficient drainage capacity can be reduced as groundwater levels rise due to reduced capacity for infiltration and runoff. Sea level rise and riverine flooding can reduce drainage capacity in areas that depend on gravity to direct water flow if sea water enters and overwhelms sewer systems. In combined sewer and stormwater systems, the high influx of stormwater can result in sewer overflows (in areas with or without combined sewer overflows, or CSOs), leading to environmental contamination. The impacts from precipitation flooding in connection with stormwater drainage systems are felt in developed areas throughout the entire state, especially in urban areas prone to flooding. Flooding also affects the natural environment (e.g., streams) due to increased polluted runoff, untreated sewage overflows, and higher volumes and higher velocity of stormwater, which could result in impacts to habitat and vegetation. Housing, businesses, and assets in low-lying areas or areas with undersized drainage systems are especially vulnerable to flooding. Below-ground and at-grade living quarters, utilities, and critical and sensitive assets are at significant risk from precipitation and stormwater drainage flooding. Under-resourced and overburdened communities are most at risk from the high consequences of this type of flooding inundating homes, businesses, and critical assets.

Dam Failure

When reservoir inflows exceed the capacity of a dam's spillway, rising reservoir water levels can result in increased rates of seepage outflow, destabilization of embankment slopes, and/or dam failure due to overtopping. Climate change increases the risk of dam overtopping or dam failure due to the predicted changes in intensity, extent and frequency of storms and rainfall events. These events can put pressure on a dam and lead to dam failure. A dam failure event may occur rapidly with limited warning time, making maintenance, preventive measures, and early warning systems critical. There is also need for data on people who live downstream from dams who may be affected from dam failures and flooding. According to Title 302 of the Code of Massachusetts Regulations, Chapter 10, the owner of any “Significant and High Hazard Dam” must have an Emergency Action Plan that is updated annually. Copies of these plans must be kept with the Massachusetts Office of Dam Safety and the Massachusetts Emergency Management Agency. Not all dams are considered “Significant and High Hazard Dams.” For most dams, even if the dam owner is required to understand the impacts of a potential breach, this information is not available for downstream residents. Dam failure can also result in release of accumulated sediment, causing degradation of downstream habitats including the scour of intact stream banks and floodplains, and in-channel sedimentation. In many dams near waterbodies that are contaminated, sediments that build up behind dams also could be contaminated. For additional information on high hazard dams, please refer to the List of High Hazard Dams in Massachusetts section.

5.8.2 Flooding from Precipitation Risk Assessment

5.8.2.1 General Background

Extreme precipitation events can result in flooding, which can damage vulnerable infrastructure; affect ecosystems; and cause injury, disease, or death. Flooding associated with extreme precipitation is sometimes categorized as “inland flooding” to distinguish it from coastal flood hazards, because coastal floods often result from different phenomena and involve a different suite of risk mitigation actions. Coastal flooding is discussed in more detail in Section 5.5 (Coastal Flooding). As noted below, some phenomena, such as hurricanes and extratropical storms (nor’easters), are multi-hazard events that include extreme rainfall, high winds, coastal storm surge, and damaging ocean waves. Flooding from precipitation can also affect coastal areas. For example, coastal ecosystems can be affected by bursts of freshwater or polluted runoff. This section addresses the risks associated with flooding from high precipitation events, which include convective storms (thunderstorms or other typically sudden and extreme precipitation events), nor’easters, and hurricanes.

Risk from floods associated with extreme precipitation is growing as a result of changes in housing and population density (Wing et al., 2018), and as a result of changes in the frequency and intensity of precipitation patterns due to climate change (Davenport et al., 2021; Wobus et al., 2019). In particular, and as described in more detail in Section 5.8.2.2.3, atmospheric scientists expect that there will be more rain overall in Massachusetts, on an annual basis and in most years, as higher temperatures in the future increase the moisture-holding capacity of the atmosphere. Days of precipitation will be less frequent, but on the days when it does rain or snow, there will be more, leading to increased overall flooding. There are also important differences in projected precipitation patterns by season: the largest and most widespread precipitation increases are expected in winter, and more often as rain rather than snow. In summer there could be increases in precipitation over Cape Cod, decreases in the area southwest of Boston, and decreases in the Berkshires and Hilltowns and Greater Connecticut River Valley regions in western Massachusetts.

This section addresses three major types of flooding from precipitation: riverine flooding (also called fluvial flooding), stormwater flooding (also called pluvial or urban drainage flooding, though it is not confined to urban areas), and dam overtopping. This section also refers to a multi-hazard phenomenon known as ice jams, which can be exacerbated through co-occurrence with high precipitation events.

Riverine Flooding

Riverine flooding occurs when excessive rainfall over an extended period collects across a watershed and causes a river to exceed its natural drainage capacity. Heavier downpours can result in more extreme flooding, affecting human health and safety, property, infrastructure, and ecosystems. Areas of the state with high slopes and minimal soil cover (such as found in western Massachusetts) are particularly susceptible to flash flooding caused by rapid runoff that occurs in heavy precipitation events and in combination with spring snowmelt. Frozen ground conditions can also contribute to low rainfall infiltration and high runoff events that may result in riverine flooding.

Some of the worst riverine flooding in Massachusetts's history was caused by strong Nor'easters and tropical storms (e.g., Hurricanes). Tropical storms can produce very high rainfall rates and volumes of rain that generate high runoff when soil infiltration rates are exceeded. Inland flooding in Massachusetts is forecast and classified by the National Weather Service's (NWS's) Northeast River Forecast Center as minor, moderate, or severe based on the types of impacts that occur or could occur. Minor flooding causes impacts such as road closures and flooding of recreational areas and farmland. Moderate flooding can cause land with buildings to become inundated. Major flooding is a widespread, life-threatening event. NWS makes river forecasts at locations in the state where there are U.S. Geological Survey (USGS) river gauges that have established flood elevations and levels corresponding to each of the degrees of flooding.

Stormwater Drainage Flooding

A second type of inland flooding is caused by high-intensity rainfall in combination with high amounts of impervious surface area that prevents infiltration. This causes stormwater drainage systems to reach a state of over-capacity, rather than rain causing a river system to exceed its capacity. Drainage systems are designed to remove surface water from developed areas as quickly as possible to prevent localized flooding on streets and other urban areas. They make use of conveyance systems that channel water away from developed areas to surrounding streams, bypassing natural processes of water infiltration into the ground, groundwater storage, and evapotranspiration (plant water uptake and respiration). Since drainage systems reduce the amount of time that rainfall takes to reach surrounding streams, riverine flooding in developed areas can be exacerbated and may occur more quickly and reach greater depths than less densely developed areas. In addition, undersized, poorly maintained, or clogged drainage systems increase the frequency and/or severity of this type of flooding. In coastal areas, drainage capacity may also be reduced by multi-hazard combinations of high precipitation and storm tides if the system is not designed to accommodate these conditions, which can also worsen as sea levels rise in the future. Another potential multi-hazard threat is related to changes in groundwater levels, which can limit infiltration and drainage capacity. Elevated groundwater levels also are linked to rising sea levels in coastal areas; see Section 5.3 (Changes in Groundwater) for more details.

In developed areas, below-grade building structures, roads, and other infrastructure can experience significant flooding damage due to poor or insufficient stormwater capacity and a significant percentage of impervious surfaces in the watershed. Flooding associated with the failure of stormwater drainage is also expected to worsen over time as a result of aging undersized infrastructure, additional land development, variability in precipitation frequency, and increases in intensity due to climate change.

Stormwater drainage flooding can also have impacts when the conveyance system works as planned but (because stormwater and sewage systems are combined, as they are in some places) the wastewater treatment facility's capacity is overwhelmed. The result, known as a CSO, can lead to the spread of untreated sewage during high rainfall events. This can in turn lead to adverse human health and ecosystem effects. CSOs are in urbanized areas, so related flooding is confined to urban areas. In Massachusetts, there are CSOs in Greenfield, Holyoke, Chicopee, Springfield, Indian Orchard, Worcester, Fitchburg, Lowell, Lawrence, Haverhill, Gloucester, Lynn, Somerville, Cambridge, Boston, Taunton, Fall River, and New Bedford.

Ice Jams

An ice jam is an accumulation of ice that acts as a natural dam and restricts the flow of a body of water. There are two types of ice jams: a freeze-up jam and a breakup jam. A freeze-up jam usually occurs in early to mid-winter during extremely cold weather when super-cooled water and ice formations extend to nearly the entire depth of the river channel. This type of jam can act as a dam and begin to back up the flowing water behind it. The second type, a breakup jam, forms because of the breakup of the ice cover at ice-out: large pieces of ice move downstream, potentially piling up at culverts, around bridge abutments, and at curves in river channels. Breakup ice jams occur when warm temperatures and heavy rains cause rapid snowmelt. The melting snow, combined with the heavy rain, causes frozen rivers to swell. The rising water breaks the ice layers into large chunks, which float downstream and pile up near narrow passages and obstructions (bridges and dams). Ice jams may build up to a thickness great enough to raise the water level and cause flooding upstream of the obstruction.

The Ice Jam Database, maintained by the Ice Engineering Group at the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory, currently consists of more than 230 historical records of ice jam occurrence in Massachusetts since water year 1869.

A report from this database that lists historical ice jam events in Massachusetts is included as an appendix to this hazard section.

Dam Failure

As dams are used to impound water by controlling water flow, changes in precipitation intensity and duration can affect dam performance and safety. When reservoir inflows exceed the capacity of a dam's spillway, rising reservoir water levels can result in increased rates of seepage outflow, destabilization of embankment slopes, and/or dam failure due to overtopping. The projected increase in the frequency of extreme precipitation events will increase the frequency and severity of dam overtopping and will increase the risk of dams failing.

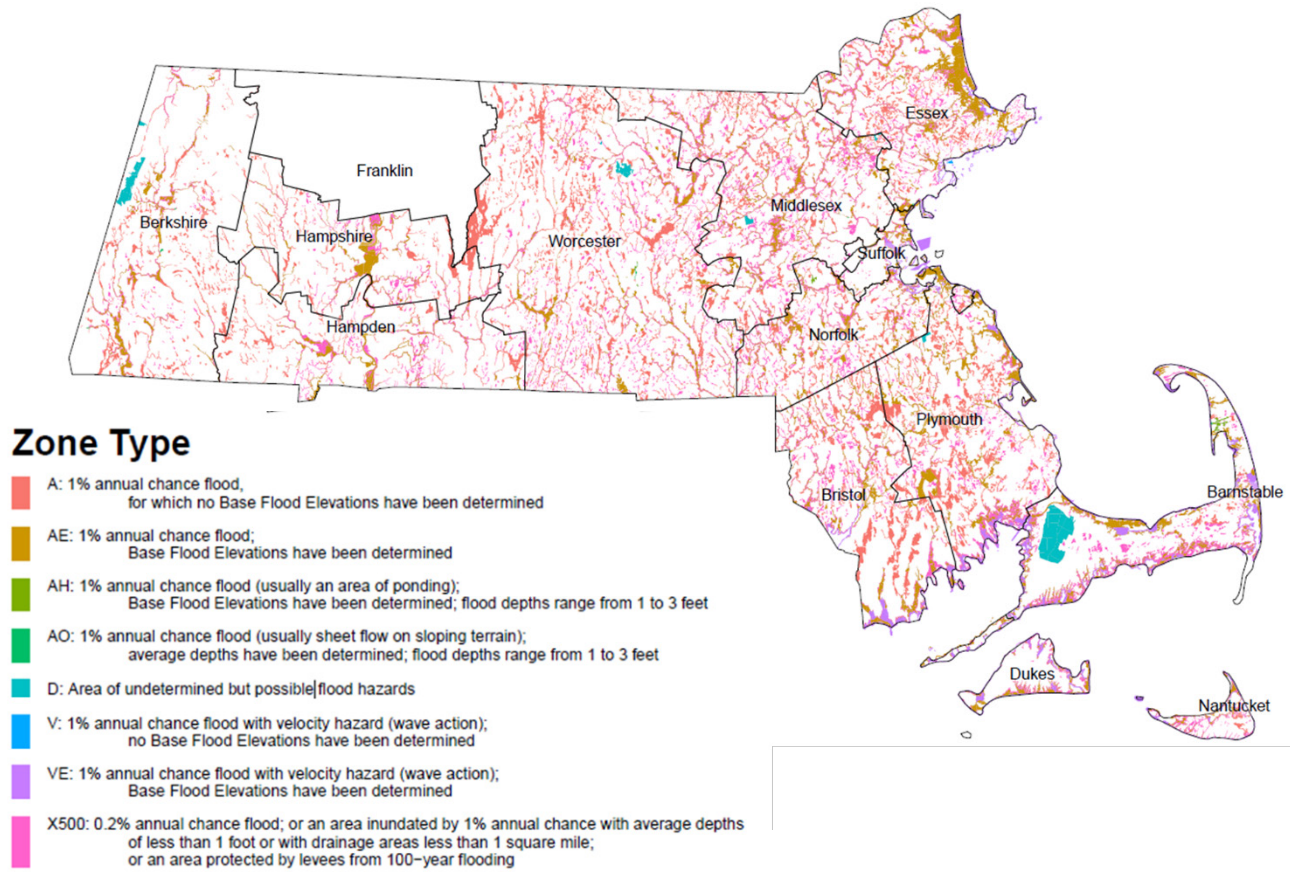
5.8.2.2 Hazard Description

Flooding from precipitation in Massachusetts includes inland flood events caused by extreme rainfall events, riverine overtopping, overwhelmed stormwater systems, ice jams blocking drainage, and dam failure or overtopping.

5.8.2.2.1 Location

Flooding from precipitation includes riverine flooding, stormwater flooding, urban drainage flooding, flooding from groundwater rise, dam overtopping, and combined rainfall and coastal storm events near the coast. The Federal Emergency Management Agency (FEMA) characterizes the current hazard using floodplain boundaries, as shown in Figure 5.8-1. These data include the locations of:

- The FEMA flood zones
- The 1 percent annual chance event (also sometimes referred to as 100-year flood) zones, including both A Zones and V Zones
- The 0.2 percent change event (or 500-year flood) zones



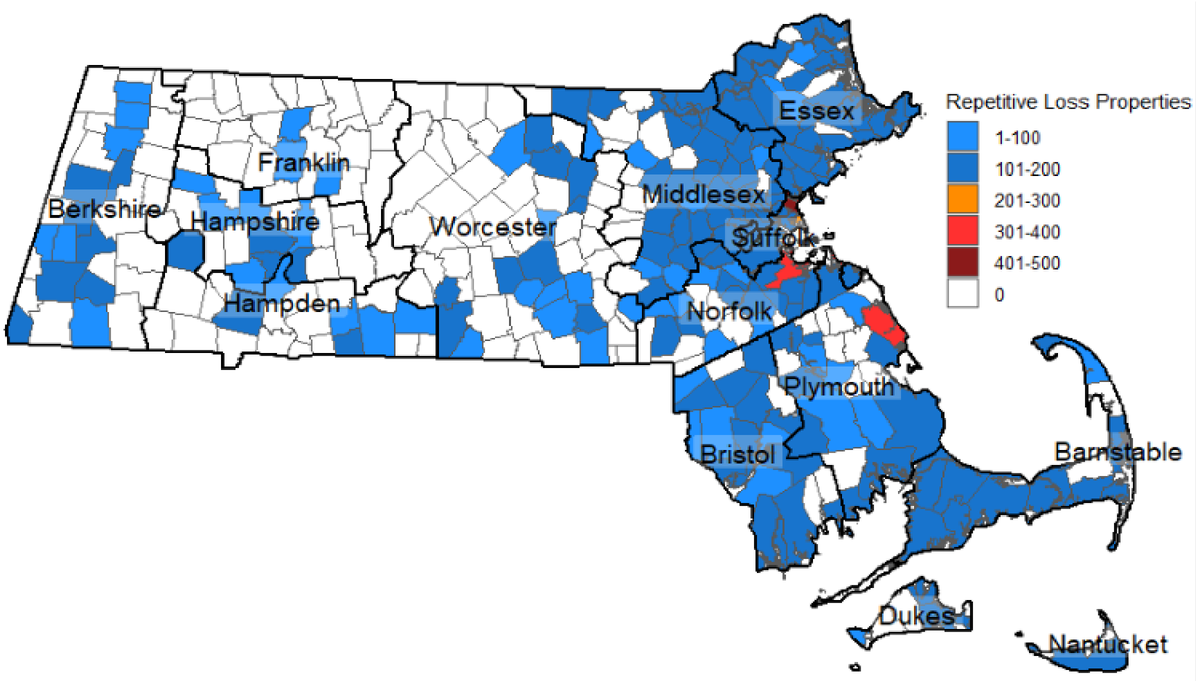
Types of current flood zones designated by the Flood Insurance Rate Map (FIRM) databases. Note that there is no data available for Franklin County, as the FIRM maps have not been digitized for this county.

Figure 5.8-1. FEMA inland flood risk zones.

5.8.2.2.2 Previous Occurences and Frequency

Previous Occurrences

The newest data from the FEMA Flood Insurance Rate Maps (FIRMs) are shown in Figure 5.8-1. These FIRMs are used to support floodplain regulations and mandatory purchase of flood insurance for federally backed mortgages. Insurance claims data are a useful indicator of historical flood risk, but they are incomplete: many property owners without federally backed mortgages are not required to and/or choose not to purchase flood risk insurance. Additionally, these data do not address potential damage from stormwater drainage flooding, as stormwater flooding can occur outside the floodplain. Some properties with National Flood Insurance Program (NFIP) insurance have already experienced two or more flood events that caused them to file claims of $1,000 or more, making these properties of particular interest for high flood risk. These properties, referred to as “repetitive loss properties,” are shown in Figure 5.8-2. Note that coastal flooding claims cannot be extracted from these data, which include coastal and inland flooding claims together.



Source: ERG analysis using data from FEMA (2022b).

A repetitive loss property is a property for which NFIP has paid two or more flood insurance claims of more than $1,000 within any 10-year period since 1978.

Figure 5.8-2. Count of NFIP repetitive loss properties per town.

Frequency

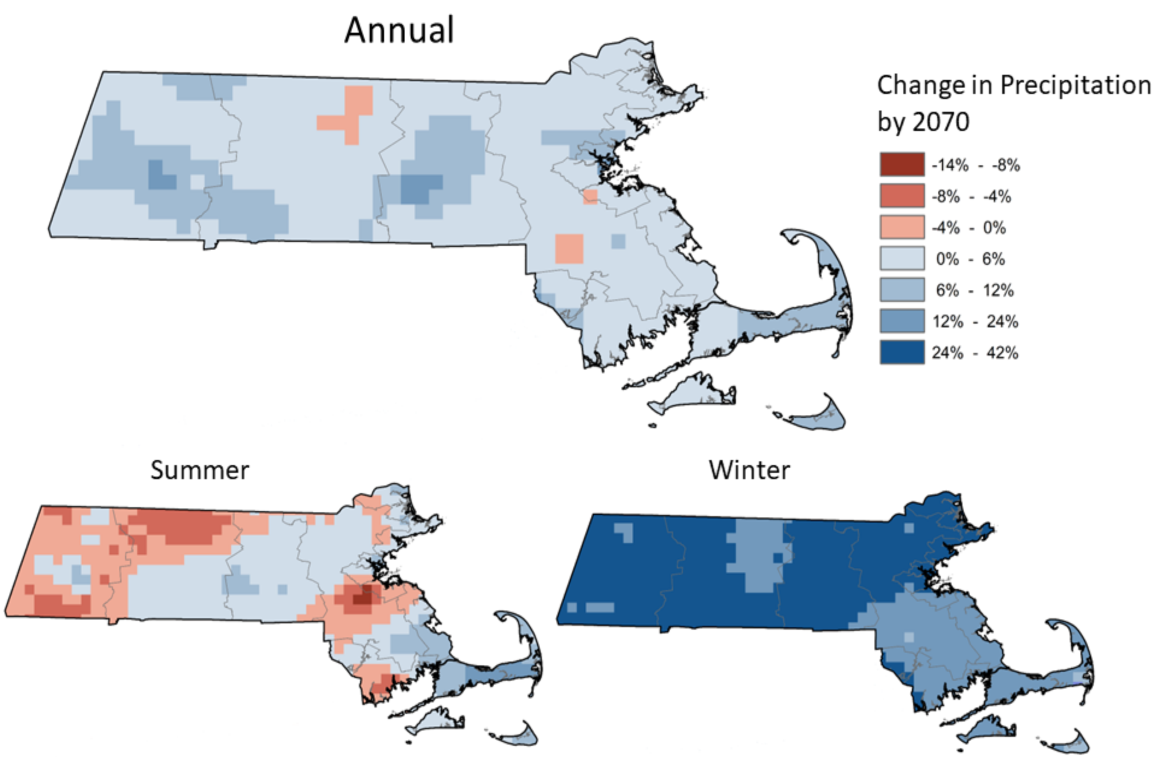
Climate change is projected to affect precipitation patterns that lead to inland flooding, according to analysis conducted for the *2022 Massachusetts Climate Change Assessment* (MA Climate Assessment). For example, the current 24-hour 10-year return period historical precipitation (about 3 inches) could double in frequency by 2050 in western and central Massachusetts and triple in frequency in coastal regions. Consequently, extreme river flow events are projected to increase, raising the probability of damaging floods. The MA Climate Assessment analysis uses National Oceanic and Atmospheric Administration (NOAA) Atlas 14 data as a baseline and adjusts these intensity-duration-frequency data for future warming and the resulting increase in the moisture-holding capacity of the atmosphere.

Potential Effects of Climate Change on Extreme Precipitation

Forecasting precipitation under climate change is complex, but scientists expect that there will be more precipitation overall in Massachusetts, on an annual basis and in most years: higher temperatures will mean the moisture-holding capacity of the atmosphere increases, but also that evaporation rates are higher. Patterns to date suggest that annual precipitation is likely to be more variable, and fall over few days, but that precipitation will be more intense on days when it does rain or snow. According to climate projections for Massachusetts, annual precipitation will increase and will fall more intensely at the daily to weekly scale. Climate change is also projected to bring longer and deeper periods of drought and/or reduced precipitation. The drought and low precipitation aspects of climate change are discussed in Section 5.6 (Drought).

By 2070, most areas of Massachusetts are projected to have small increases in annual total precipitation but a substantial change in seasonal precipitation patterns. Figure 5.8-3 below shows the locations of these anticipated changes. In most locations, the increase in annual precipitation (shown in blue) is less than 8 percent per year; in a few locations, small decreases in annual precipitation (shown in red) of less than 4 percent are expected. Western and southeastern Massachusetts are projected to see significantly drier summers, and much of the state is expected to experience between 24 and 42 percent more winter precipitation—primarily in the form of rain on frozen ground. These data are the median of a broad range of climate projection models from the Stochastic Weather Generator

(SWG) (Steinschneider et al., 2019). There is agreement among most climate forecast models concerning these future precipitation patterns.



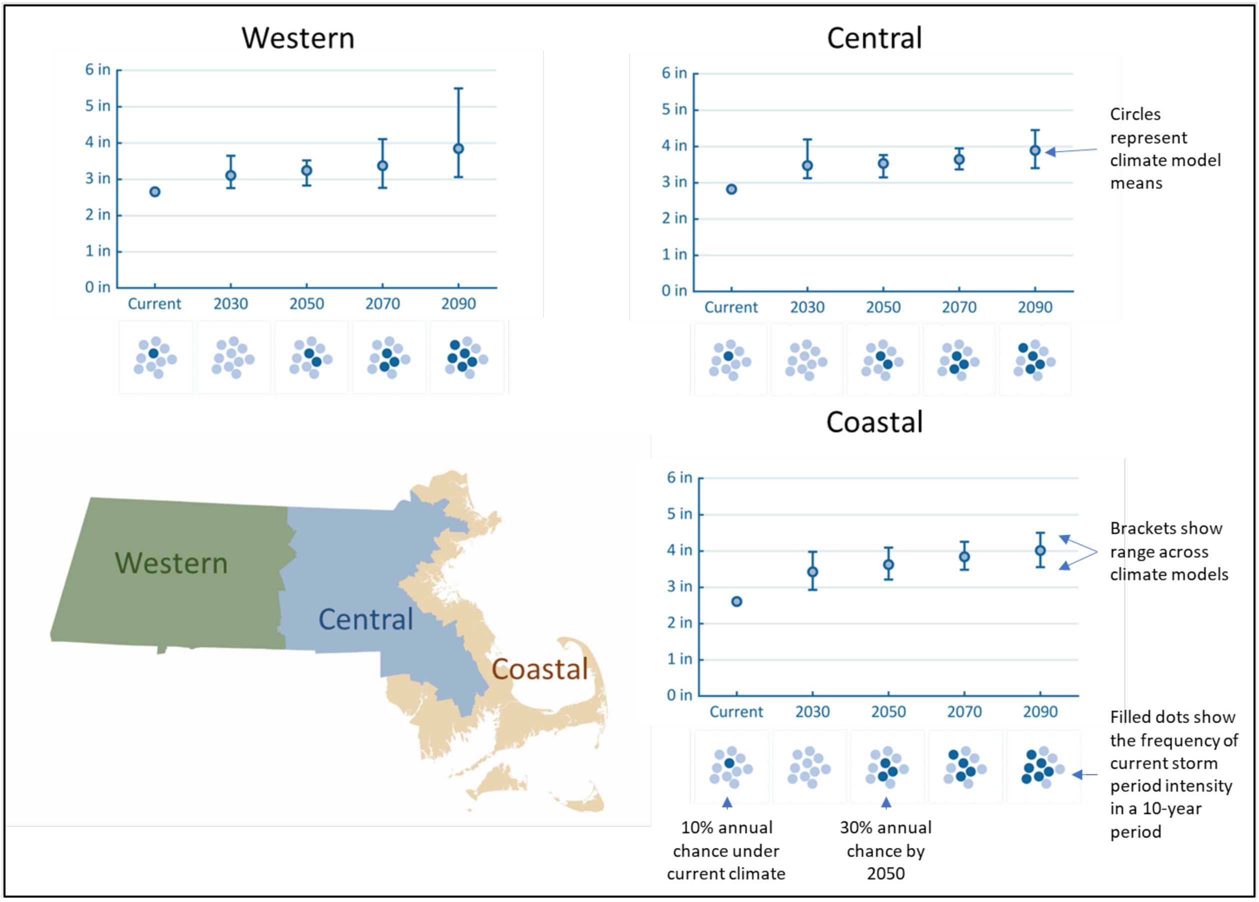
Source: Commonwealth of Massachusetts (2022), using SWG data.
Differences between the 50th percentile of projections for 2060–2080 and a baseline of 1986–2005.

Figure 5.8-3. Change in annual, summer, and winter season precipitation in 2070 compared to current climate.

5.8.2.2.3 Severity/Intensity

Increases in intensity and duration of rainfall on rainy days can lead to flooding, stress on built infrastructure and ecosystems, and consequent impacts on human health.

Figure 5.8-4 below shows projected precipitation intensity and frequency over time across Massachusetts regions. The graphs show changes in the expected size of a 10-year return period rainstorm (i.e., a storm, defined in terms of equal or greater precipitation within 24 hours, that has 10 percent chance of occurring in a given year) and the expected frequency of rainstorms that would meet the current 10-year return period size.



Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022).

A 10-year size indicates a 10 percent chance of equal or greater precipitation within 24 hours in a given year. Bar charts show the projected size of 10-year return period events, and filled dots show the anticipated frequency of storms that would exceed current 10-year return period events.

Figure 5.8-4. Change in intensity and frequency of 10-year return period precipitation events.

Under the current climate, the 10-year return period event is roughly 3 inches for all regions of the Commonwealth (although the implications of a 3-inch rainfall event differ greatly by context—see Section 5.8.2.4 below for more detail). By the end of the century, the intensity of the 10-year return period event is expected to increase by one third, to

4 inches in a day. The frequency of the current 10-year return period event is expected to increase by the end of the century by a factor of five for the western and coastal regions of the Commonwealth, and by a factor of four in the Central region.

5.8.2.2.4 Warning Time

Due to the sequential pattern of meteorological conditions needed to cause serious flooding, it is unusual for a flood to occur without warning. Flash flooding, which occurs when excessive water fills either normally dry creeks or riverbeds or dramatically increases the water surface elevation on currently flowing creeks and river, can be less predictable. However, areas at risk can be warned of potential flash-flooding danger on a time scale of days to hours. NWS issues flash flood watches and warnings, as well as small stream flood advisories, on a county scale on a continuous basis; these are available at the NOAA Storm Prediction Center.

Flooding is more likely to occur due to a rainstorm when the soil is already wet and/or streams are already running high from recent previous rains. NOAA's Northeast River Forecast Center provides flood warnings for Massachusetts, relying on monitoring data from the USGS stream gauge network. Notice of potential flood conditions is generally available five days in advance. State agency staff also monitor river, weather, and forecast conditions throughout the year. Notification of potential flooding is shared among state agency staff, including the Massachusetts Emergency Management Agency (MEMA) and the Office of Dam Safety. NWS briefs state and local emergency managers and notifies the public via traditional media and social networking platforms. MEMA also distributes information on potential flooding to local emergency managers, the press, and the public.

5.8.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

The local hazard mitigation plans reviewed by the Risk Assessment team acknowledge the considerable impact of flooding from precipitation in many Massachusetts towns, especially those near or on major rivers such as the Connecticut River. Review of municipal vulnerability preparedness (MVP) program planning reports reveal that flooding is a primary concern for many Massachusetts residents across the Commonwealth. Table 5.8-1 provides some examples of location-specific hazard and vulnerability information from local plans.

Table 5.8-1. Highlight of Local Plans and MVP Program Planning Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Town of West Stockbridge Hazard Mitigation Plan, January 2022	West Stockbridge has significant floodplain areas spread across the town, with about 1,050 acres of floodplain covering approximately 8.8% of the town's total land mass.	About 7.14% of the town's total number of road miles travel through the 100-year floodplain.	Not provided.
Town of Shutesbury Hazard Mitigation Plan, January 2022	About 1.35 percent of the town, including an estimated 7.4 acres of developed residential land are in the 100-year floodplain.	About 3.6% of the total population of Shutesbury lives in a flood hazard area. Many of Shutesbury's residents rely on private wells, placing them at risk during prolonged power outages caused by extreme weather. Flooding may compromise water quality.	Average assessed value of residential land use in flood hazard area: $3,715,233.
Auburn Hazard Mitigation Plan Update, September 2018	Flood-prone areas in Auburn are closely associated to the course of Kettle Brook and associated tributaries as well as the Worcester Diversion Tunnel.	Sections of evacuation routes, including Routes 12 and 20, are within the 100-year flood zone. There are several identified critical infrastructures within the 100-year flood zone, but the locations have not been affected by flooding in the past.	Total estimated property damage from 100-year flood event: $31,190,000.

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Springfield Community Resilience Building Workshops: Summary of Findings, June 2018	Vulnerable neighborhoods: Brightwood, Memorial Square, Liberty Heights, Metro Center, South End, Old Hill, Upper Hill, Bay, McKnight, Six Corners, Indian Orchard.	Inland flooding identified as the top hazard by most participants.	Not provided.

Actions that some local governments have identified or already undertaken to reduce risk include:

- The Resilient Mystic Collaborative (with partners mostly in Middlesex County and some in Suffolk County) modeled the effects of active reservoir management on natural stormwater storage capacity and precipitation-based flood risk in the Upper Mystic River watershed (Resilient Mystic Collaborative, 2021).
- The city of Northampton in Hampshire County designed a series of projects to implement nature-based solutions, including bioswale installation, stream channel restoration, and bioretention basin design, to reduce stormwater flooding and runoff into the nearby Connecticut River (GZA, 2019).
- The city of Lowell's *Claypit Brook Climate Resilience Stormwater Management Capital Improvement Plan* (Middlesex County) addresses storm-driven flooding due to poor drainage via hydraulic and hydrologic modeling and green infrastructure design and costing (City of Lowell, 2021).

5.8.2.3 Secondary Hazards

Secondary hazards associated with flooding from precipitation include health impacts, disruption of emergency services, changes in the position of river channels due to extreme flooding, and associated erosion. Riverbank erosion from flooding during Hurricane Irene caused an excess of $23 million in damage along Route 2 (Commonwealth of Massachusetts, 2022).

Erosion caused by flooding from precipitation is especially prevalent in the upper courses of rivers with steep gradients, where floodwaters can scour the banks, edging buildings and structures closer to the river channel or causing them to fall in. Landslides (see Section 5.11, Landslides/Mudflows) can occur following flood events when high precipitation oversaturates soils on steep slopes, causing them to fail.

Roadways, culverts, and bridges are affected when floods undermine or wash out supporting structures. Underground infrastructure, including roadway tunnels and utility and communications infrastructure, may also be vulnerable to flooding from precipitation. Flooding has also affected water supplies in the past, temporarily closing wells, pumps, or other supply infrastructure or facilities. Dams may be damaged or fail, compounding flood hazards for downstream communities and ecosystems.

During floods, hazardous material tanks can overflow or overtop and hazardous waste containers can dislodge, causing wastewater treatment plants to fail and release untreated wastewater or hazardous materials directly into storm sewers, rivers, or the ocean.

In areas with combined sewer systems, flooding from precipitation can lead to CSOs that release untreated sewage into surface waters and have severe impacts on ecological and public health in addition to other economic and quality of life concerns.

5.8.2.4 Exposure and Vulnerability

To estimate the population exposed to the 1 percent and 0.2 percent annual chance flood events, the Risk Assessment team overlaid flood hazard boundaries on the 2020 U.S. Census block population data. Because census blocks do not follow the boundaries of the floodplain, the portion of the census block within the floodplain was used to approximate the population contained. For example, if 50 percent of a census block of 1,000 people was within a floodplain, the estimated population exposed to the hazard would be 500. Table 5.8-2 below lists the estimated population within the 1 percent riverine floodplain and the incremental additional population within the 0.2 percent flood zone. Section 5.5 (Coastal Flooding) includes an analysis of exposure to all forms of coastal flooding, including exposure to V Zones.

Table 5.8-2. Estimated Population Exposed to the 1 Percent and 0.2 Percent Annual Chance Inland A-Zones Flood Events

County	Total 2020 Population	1% Annual Chance Flood Event "A" Zone		0.2% Annual Chance Flood Event (Increment to 1% Annual Chance Results)	
		Vulnerable Population	% of Total in County or Statewide	Additional Vulnerable Population	% of Total in County or Statewide
Barnstable	213,505	4,875	2.3	14,053	6.6
Berkshire	125,927	34	0.0	3,201	2.5
Bristol	563,301	79,426	14.1	27,582	4.9
Dukes	17,430	—	0.0	1,888	10.8
Essex	787,038	34,754	4.4	22,597	2.9
Franklin	70,529	NA	NA	NA	NA
Hampden	466,647	49,062	10.5	44,601	9.6
Hampshire	161,361	506	0.3	2,662	1.6

County	Total 2020 Population	1% Annual Chance Flood Event "A" Zone		0.2% Annual Chance Flood Event (Increment to 1% Annual Chance Results)	
		Vulnerable Population	% of Total in County or Statewide	Additional Vulnerable Population	% of Total in County or Statewide
Middlesex	1,605,899	43,235	2.7	43,096	2.7
Nantucket	11,212	4,449	39.7	9,115	81.3
Norfolk	703,740	36,362	5.2	27,812	4.0
Plymouth	518,597	72,063	13.9	21,807	4.2
Suffolk	801,162	450	0.1	10,361	1.3
Worcester	826,655	76,486	9.3	44,351	5.4
Total	**6,873,003**	**401,702**	**5.8**	**273,126**	**4.0**

Source: MA Climate Assessment analysis (Commonwealth of Massachusetts, 2022) using flood event zones from FEMA, downloaded from MassGIS, and block group level population data from the 2020 U.S. Census. The 1 percent chance A Zones reflect all FEMA A Zones, including those in coastal areas. The 0.2 percent chance areas include all FEMA X Zones.

Over 400,000 Massachusetts residents currently live in a 1 percent annual chance (all FEMA A Zone) flood zone; these areas reflect riverine risks in inland counties and both riverine and coastal risks in coastal counties. The three counties with the largest population in this flood zone are Bristol, Worcester, and Plymouth. A larger but unknown number of residents are subject to flooding associated with the combined effects of riverine and stormwater drainage flooding. The FEMA data presented above do not capture the risk of stormwater drainage flooding, but these risks can be substantial.

For example, three extreme precipitation events took place in rapid succession between March 13 and 31, 2010. The events led to a Federally Declared Disaster for large portions of eastern Massachusetts. The combined effects of high river flow and overwhelmed drainage systems, coinciding in many regions with low soil infiltration rates due to frozen ground, included 18,480 disaster claims (93 percent of which were outside the FEMA 1 percent flood zones) and 915 flood insurance claims (40 percent of which were outside the 1 percent zone). The most affected municipalities were clustered around South Boston (Stoughton to Milton) and North Boston (Bedford to Lynnfield). About 87 percent of homes experienced flooding of less than 1 foot; however, residential properties filed for about $38.4 million of disaster assistance, with an average damage claim of $1,900 and a maximum damage claim of $87,600 (Metropolitan Area Planning Council, 2023).

Improving the characterization of stormwater drainage flood risks for the Commonwealth therefore continues to be a high priority for risk assessment and planning of risk mitigation actions.

Population growth through the end of the century is anticipated to place more people at risk of flooding. The greatest population increases in Massachusetts are expected in

Middlesex, Norfolk, Suffolk, and Essex counties (UMass Donahue Institute, 2018). As Table 5.8-2 shows, as much as 5 percent of the population in these counties are vulnerable to 1 percent annual chance floods. Bristol, Nantucket, and Plymouth counties have the greatest rates of vulnerability to 1 percent annual chance floods; all counties are expected to experience population increases by mid-century (UMass Donahue Institute, 2018).

5.8.2.4.1 Human

Inland flood risk affects a large area of Massachusetts. However, the capacity to prepare and mitigate risks is not equal among Massachusetts residents. Those with lower capacity to adapt are experiencing more impacts and have higher costs of recovery. These lower-capacity groups include environmental justice and other priority populations. The Risk Assessment uses the Commonwealth's definition of environmental justice populations; priority populations are people or communities who are disproportionately affected by climate change due to life circumstances that systematically increase their exposure to climate hazards or make it harder to respond. Additional factors such as physical ability, access to transportation, health, and age can indicate whether someone or their community will be disproportionately affected by climate change. This is driven by underlying contributors such as racial discrimination, economic disparities, or accessibility barriers that create vulnerability. The term "priority populations" acknowledges that the needs of people with these experiences and expertise must take precedence when developing resilience solutions to reduce vulnerability to climate change. Environmental justice and other priority populations are shown to be disproportionately affected by health impacts associated with extreme storms—more specifically, with flooding, associated power outages, etc.—in the 2022 MA Climate Assessment (Commonwealth of Massachusetts, 2022).

In addition, the potentially elevated risk of complications associated with chronic obstructive pulmonary disease (COPD), renal disease, respiratory conditions, and pregnancy—which have been shown to lead to health effects corresponding to a variety of flood and emergency response delays that occur during extreme flood events—means populations with high baseline prevalence of these conditions are particularly vulnerable. In addition, populations that rely on electricity for medical devices have a high vulnerability to power outages associated with flood risk.

The incidence of mold-related impacts from floods also disproportionately affects people, especially children, with pre-existing respiratory disease, such as asthma or COPD.

Studies have found elevated rates of emergency room visits for gastrointestinal illness in Massachusetts in the two-week period following flooding and sewer overflows (Jagai et al., 2015, 2017; Wade et al., 2014), but research on a broader range of storm- and flood-related health impacts in the state is lacking. The literature provides qualitative links for many of the additional health effects stemming from inland flooding and power outages, but it should be clarified that these are part of a class of indirect effects of inland flooding. A few studies in Massachusetts have measured emergency room visits for gastrointestinal illness following flooding and sewer overflow events, both of which can lead to increased exposure to contaminated water. One such study found an 8 percent increase in the rate of emergency room visits for gastrointestinal illness in the four days following flood events (Wade et al., 2014). A similarly constructed study, focused instead on sanitary sewer overflows, found a 9 percent increase in the rate of emergency room visits for gastrointestinal illness 10–14 days following events (Jagai et al., 2017).

Gaps in knowledge and data prevented a comprehensive analysis as part of this Risk Assessment, but the team applied the relative risk estimates from the study cited above to generate excess risks during storm events. In Massachusetts, an estimated 780 storm-related medical incidents occur annually. By the end of the century, this number is expected to increase by more than 400 incidents. Current estimates are based on statistical modeling of storm frequency under current climate, rather than health surveillance data. Only the incremental change was estimated using relative risk estimates from Kintziger (2019).

"Storm-related medical incidents" are defined in this discussion as injuries from external forces or substances including "mechanical, thermal, electrical, chemical, or radiant exposures, or submersions" (Kintziger, 2019). Costs of illness were not estimated, but literature suggests potentially significant direct (morbidity and mortality) and indirect (lost productivity) costs of more than $13,000 per case for unintentional carbon monoxide poisonings (Hampson, 2016) and more than $136,000 per case for treatment and rehabilitation of other major injuries (Peterson et al., 2021)). Costs of this magnitude, particularly for injuries, could mean incremental increases in the monetary impacts of climate change of roughly $4 million by 2030, $28 million by 2050, and $50 million by 2070. However, there is a high degree of variability in specific injury costs, which could be much lower for minor injuries, and a high degree of uncertainty on the specific types of injury associated with extreme events. The main driver of these additional incidents is extreme rainfall events, which are expected to increase across the Commonwealth. Additional indirect health impacts include respiratory disease, including respiratory tract symptoms, wheezing, and asthma in people with existing respiratory conditions due to mold (Institute of Medicine, 2011). Repeated flood events increase the risk of mold production.

As part of the 2023 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP) process, Massachusetts state agencies completed a survey in which they identified their primary concerns for populations served and potential disproportionate impacts from floods. Table 5.8-3 below lists impacts on Massachusetts populations, including disproportionate impacts.

Table 5.8-3. State Agency Responses: Primary Concerns About Flooding from Precipitation's Impacts on Populations Served and Potential Disproportionate Impacts

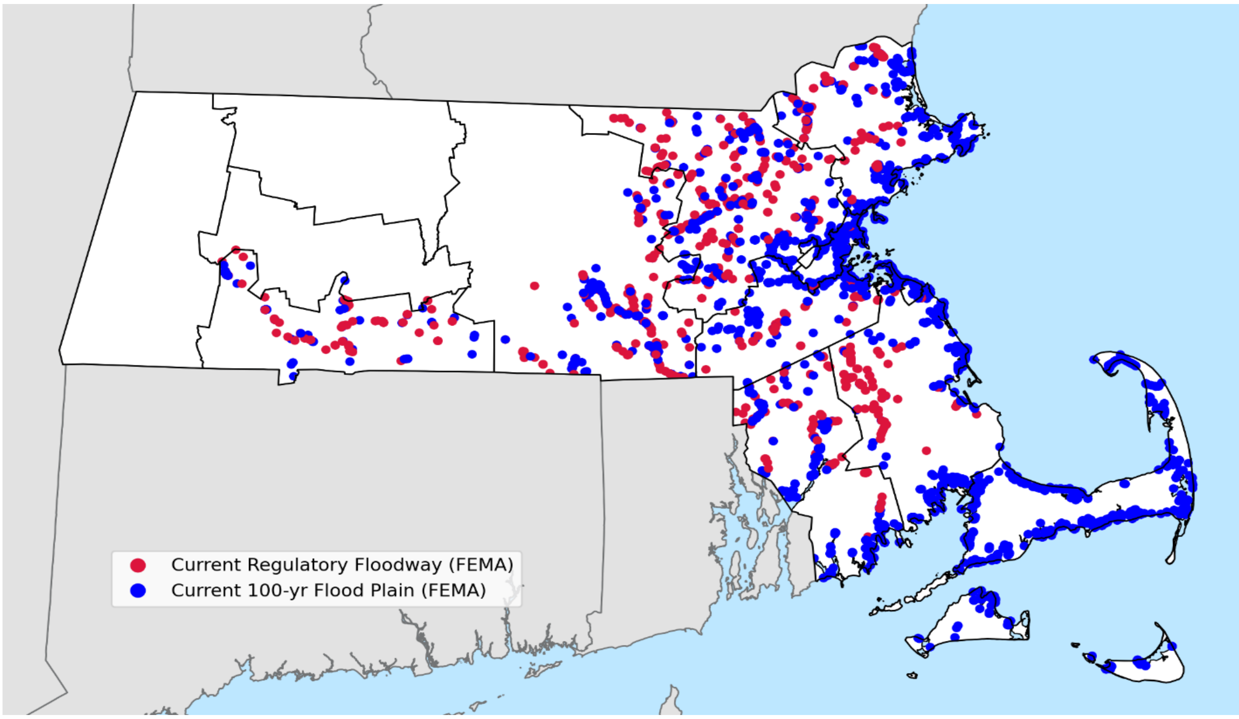
Category	Primary Concerns
Populations served	• All Massachusetts residents, businesses, and municipalities (priority populations may experience amplified impacts) • All municipal, campus, hospital, and environmental police and deputy sheriffs • Injured workers
Disproportionate impacts	• Impacts could be disproportionate for priority populations, environmental justice populations, and those with limited capacity to evacuate or respond, such as the elderly and mobility impaired. • People reliant on public transportation could be disproportionately affected if access to mobility is impaired. • Impacts would likely depend on the severity and location of the event; everyone on the Socially Vulnerable Population index is proven to be disproportionately affected by disaster as they are typically located in less safe, more undesirable areas and have a harder time bouncing back from disasters.

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Cultural Resources

Using spatial data on cultural heritage sites, historic places, and other sites with cultural importance and/or archives and inland flooding data identifies specific locations that may be at risk of flooding. The Massachusetts Historical Commission maintains the Massachusetts Cultural Resource Information System (MACRIS), an inventory of over 200,000 cultural resources and historical sites in the Commonwealth. Figure 5.8-5 below shows the sites in this list that fall within FEMA's current 100-year inland flood zone. About 8,000 sites and resources are within a currently designated FEMA floodplain and over 6,000 other sites and resources could be at risk of inundation during a 100-year flood by 2050. The MACRIS includes water-based resources and sites such as footbridges and fish runs. Not all these resources will be vulnerable to flooding.



MACRIS sites and FEMA floodplains from MassGIS, coastal flooding layer from the Massachusetts Coastal Flood Risk Model (MC-FRM). See Section 5.5 (Coastal Flooding) for details.

Figure 5.8-5. MACRIS sites and resources in the 100-year floodplain or regulatory floodway.

5.8.2.4.2 Governance

Flooding from precipitation may also affect Commonwealth governance. Two aspects of state governance are examined here: the extent to which state buildings may be subject to precipitation flooding (which can jeopardize their continued use by employees or state residents) and the vulnerability of affordable housing to flooding (which could put more pressure on state agencies to ensure provision of safer affordable housing). Other governance impacts may include an increased demand for emergency medical response and law enforcement deployment during emergency flood events.

Table 5.8-4 summarizes an analysis of state buildings and assets in the Massachusetts Division of Capital Asset Management and Maintenance (DCAMM) database exposed to riverine flooding. As noted in the table, 53 of the 1,977 state-owned major buildings (or about 3 percent) are in the FEMA 100-year floodplain (1 percent annual probability) for non-coastal counties.[1]

Table 5.8-4. State-Owned Major Buildings in Inland Counties Potentially at Risk from Riverine Flooding

County	All DCAMM Major Buildings		State-Owned Buildings		Buildings in Floodplain	
	Count	Replacement Value (Million $)	Count	Replacement Value (Million $)	Count	Replacement Value (Million $)
Berkshire	80	$1,123	58	$938	10	$56
Franklin	31	520	29	489	0	0
Hampden	122	3,836	109	3,492	21	318
Hampshire	293	7,730	175	4,920	0	0
Worcester	288	8,241	247	7,282	12	314
Total	**814**	**21,450**	**618**	**17,122**	**43**	**$689**

Sources: ERG analysis of FEMA floodplain (Wobus et al., 2021), inland flood damage estimation, and DCAMM state asset database.

The DCAMM database lists major buildings by region. Buildings include state-owned buildings, state-owned buildings in the floodplain, and state-owned buildings both in the current FEMA floodplain and subject to annual expected damage as large as 0.5 percent annually, as compared to the baseline climate scenario (1986–2005). Future impacts are presented for four periods identified in the table by their central year: 2030 (near-term, 2020–2039), 2050 (mid-century, 2040–2059), 2070 (mid-late century, 2060–2079), and 2090 (end of century, 2080–2099). This analysis presents risk from riverine flooding in inland counties.

A guideline commonly used for property managers recommends that annual maintenance and repair costs of all types for a property be no less than about 1 percent of the total structure value to maintain long-term; some data put this value as 2 percent annually.

Statewide, only two state-owned buildings in 2030, and seven in 2050 or later, could have expected flood damage of 0.5 percent annually. Of the seven buildings identified as potentially at greatest risk, three are owned by the Department of Conservation and Recreation and are recreation facilities sited along bodies of water, two are former mill buildings that are part of the University of Massachusetts Lowell, and two are owned by the Essex County Sheriff's office in Lawrence. Note that, while Essex County has a

[1] The 100-year flood is the flood that has a 1 percent chance of being equaled or exceeded each year. The 100-year flood is the standard used by most federal and state agencies. For example, NFIP uses it to guide floodplain management and determine the need for flood insurance. Additionally, it should be noted that riverine flooding is also experienced in coastal counties.

considerable amount of coastline, the town of Lawrence in Essex County sits on the Merrimack River, which poses a risk for riverine flooding.

While buildings identified in this analysis might see a substantial increase in maintenance costs to respond to and repair flood damage, the analysis suggests that the number of state-owned buildings exposed to moderate riverine flood risks is low. This holds when considering future conditions, including impacts from climate change. Note that this analysis addresses only the risk of state-owned buildings to riverine flood risk—data currently are not available to assess risk to stormwater drainage flooding. The analysis presented in Table 5.8-4 includes information for inland counties only. The results from coastal counties cannot be isolated to flooding from precipitation or riverine flooding. For information on state-owned buildings exposed to coastal flooding risk in coastal counties, see Section 5.5 (Coastal Flooding).

The FEMA floodplain may not reflect all possible impacts of flooding from precipitation to commercial structures because it omits risk of stormwater drainage flooding. Consideration of stormwater drainage flood risks would increase the estimates presented, but the magnitude of consequence for stormwater drainage flooding of state-owned structures is currently unknown.

The MA Climate Assessment also found that precipitation flooding's effects on state-owned buildings are likely to have limited disproportionate impact. The number of major buildings owned by the Commonwealth that are potentially at risk of inland flooding is estimated to be small, and none of those buildings are in Commonwealth-designated environmental justice block groups—though that analysis excluded impacts from stormwater drainage flooding, due to lack of data (Commonwealth of Massachusetts, 2022).

In general, users of the governmental services provided through potentially affected buildings are expected to be particularly vulnerable, and users seeking income, food, or health assistance through state-owned buildings could be particularly vulnerable to flood impacts on these services—although no quantitative data are yet available to characterize the prevalence of this type of impact.

5.8.2.4.3 Infrastructure

The impacts of flooding from precipitation on infrastructure and the built environment include damage to residential buildings, commercial and industrial buildings, energy production, and culverts and bridges.

Areas of the built environment, including housing and businesses, may experience varying levels of risk to flooding. Factors that are related and can influence exposure and risk to flooding include proximity to flood zones, wetlands, and hydrologic features; soil and slope conditions; and physical and spatial characteristics of buildings (Metropolitan Area Planning Council, 2023).

As illustrated in Figure 5.1-4 in the Risk Assessment Introduction, the Commonwealth is experiencing an increase in construction and changes in development in regions exposed to flooding. Coastal areas have continued to grow at a rapid pace and are projected to experience continued development. Additionally, regions along the Connecticut River valley, especially between Amherst and Springfield and Worcester, are projected to experience the highest concentration of new construction in the near future, as estimated by construction permits for projects to be constructed between 2023 and 2030 (Metropolitan Area Planning Council, n.d.).

Priority populations and environmental justice groups are likely to experience higher exposure to risk of riverine flooding. In addition to experiencing higher risk, priority populations experience additional challenges in preparing for and responding to impacts from flooding events. For example, the MA Climate Assessment found that populations living in environmental justice block groups defined as census blocks where:

- Low-income populations reside in buildings that have 24 percent higher rate of structural damage from riverine flooding compared to the rest of the Commonwealth. This disparity is particularly apparent in two regions: Greater Connecticut River Valley and Eastern Inland, where the rates of structural damage are over 50 percent higher in block groups that meet the low-income criterion. In all other regions of the state, no disproportionate impact results in aggregate—but it is also true that many communities have specific environmental justice block groups that are affected by flooding from precipitation.
- Language-isolated populations reside in buildings that have a 39 percent higher rate of structural damage from riverine flooding than those in the rest of the Commonwealth. The disparity is most apparent in two regions: Greater Connecticut River Valley and Eastern Inland, where the rate of structural damage is over 350 percent and 91 percent higher, respectively, in block groups that meet the language isolation criterion.

Information on vulnerability of priority populations from flooding impacts on bridges and culverts is not currently available. Prior riverine and stormwater drainage flooding events, however, have shown higher levels of fluvial erosion and impacts on bridge scour and culvert capacity in the elevated terrain of western Massachusetts, for example in the Greater Connecticut River Valley region. It is therefore reasonable to expect that disproportionate impacts may be like those reported above for residential properties, as the vulnerable areas for residential properties are similar to those for culverts and bridges.

The data presented above exclude two aspects of flooding that are also important in this section: incidence of stormwater drainage flooding, which results from high precipitation events coupled with inadequate drainage, and impacts to commercial structures. Available qualitative information suggests that pluvial flooding may be associated with impacts in environmental justice block groups. The infrastructure, utilities, and commercial and business properties within communities made up of environmental justice and priority populations are more vulnerable to exposure to inland flooding, as these communities are disproportionately located in areas most vulnerable to flooding.

Recent events such as Hurricane Harvey (characterized by extreme rainfall) have reinforced the social inequities associated with stormwater drainage flood risk and impacts, particularly identifying racial and income inequities. Chakraborty et al. (2019) analyzed whether the spatial distribution of flooding effects was inequitable with respect to race, ethnicity, and socioeconomic status, after controlling for relevant explanatory factors (Chakraborty et al., 2019). A similar study found that Hispanic, Black, and other racial/ethnic minority households were subject to more extensive flooding, and that households with lower income faced more extensive flooding than higher-income households (Collins et al., 2019). Lu (2017) finds that for Houston, Texas, and other areas, socioeconomic status and racial characteristics correlate with low elevation above coastal and inland water bodies (Lu, 2017). While these results were generated for other parts of the U.S. where extreme flooding has recently been experienced, the insights could be more broadly applicable, as historical settlement patterns have tended to push environmental justice and other priority populations into higher-risk flood zones. The U.S. Global Climate Change Research Program’s 2016 Climate and Health Assessment also found, at a national scale, that people living in floodplains are more vulnerable not only to extreme weather, but also to social and economic stressors that can occur simultaneously or consecutively and accumulate over time (Gamble et al., 2016).

Flooding from precipitation could have impacts on commercial and industrial buildings, which represent locations where Commonwealth economic activity is focused. Both the direct impacts of floods on the need for repair and the indirect impacts on business interruptions can be important. According to the MA Climate Assessment, a comparison of risk of direct structural damage to nearby commercial and industrial buildings for individuals living in environmental justice block groups defined on the basis of:

- Environmental justice and priority populations live near commercial and industrial buildings that have a 57 percent higher risk of flood-related damage than the rest of the Commonwealth.
- Environmental justice and other priority populations live near commercial and industrial buildings that have a 148 percent higher risk of flood-related damage than the rest of the Commonwealth.

Residential Buildings

Damage from riverine flooding to residential properties is evaluated at the Census block group level. The data presented here consider both future climate change and increases in value of vulnerable structures over time, but do not yet consider highly uncertain forecasts of new development that may be in the floodplain (Wobus et al., 2021). Note that expected annual economic damage results presented in the MA Climate Assessment rely on the same methods and data, but with one important difference: the prior results assumed constant property values.

The data used in the Wobus analysis includes flooding for return intervals of two years (an event with a 50 percent chance of occurring each year) through 500 years (an event with a 0.2 percent chance of occurring each year). Study authors calculate a damage function known as a “frequency-loss curve” (which expresses structural damage for each type of flood event) for each property. From this curve, the estimated annual damages can be calculated. Data are not reported at the property level but the block group level. The data do not address flooding events associated with poor or inadequate drainage, quantifying only riverine floods. As a result, the quantified results in this impact category are limited to riverine floods; other types of flooding events such as stormwater drainage flooding in urban areas are considered qualitatively.

The methodology estimates the baseline annual EAD using current structure characteristics (e.g., ground-level floor elevation, replacement cost, market value), the flood depths associated with baseline conditions for varying return periods, and depth-damage functions available from FEMA’s Hazus documentation (FEMA, 2022a; First Street Foundation, 2020; Wobus et al., 2021). Impacts are projected under a “no additional adaptation” scenario.

Using the methods described above, baseline annual economic damage of riverine flooding to residential structures, before climate change, are estimated to be $116 million statewide. Unfortunately, those results are not available at a detailed spatial scale.

Annual economic flood damage is estimated to increase by $9.3 million statewide by 2030 as a result of climate change, with some regions experiencing a decline in impacts and others an increase because of differences in the pattern of precipitation changes and the configuration of local river systems to which runoff flows. By 2050, all regions are projected to experience an increase in damage, totaling over $64 million statewide annually (a 55 percent increase over baseline), with over half of the impacts in the Eastern Inland region. By 2090, total damage is roughly 2.7 times the baseline damage, because of much higher annual precipitation leading to higher riverine flows affecting residential buildings. These estimates omit consideration of stormwater drainage flood impacts, as well as impacts to commercial and industrial buildings, but are consistent with the climate scenarios chosen for the MA Climate Assessment and the 2023 MA SHMCAP, as well as estimates in the literature on economic impacts of inland flooding (Wobus et al., 2021).

Table 5.8-5. Annual Economic Impact Increase of Riverine Flooding to Residential Buildings Due to Climate Change

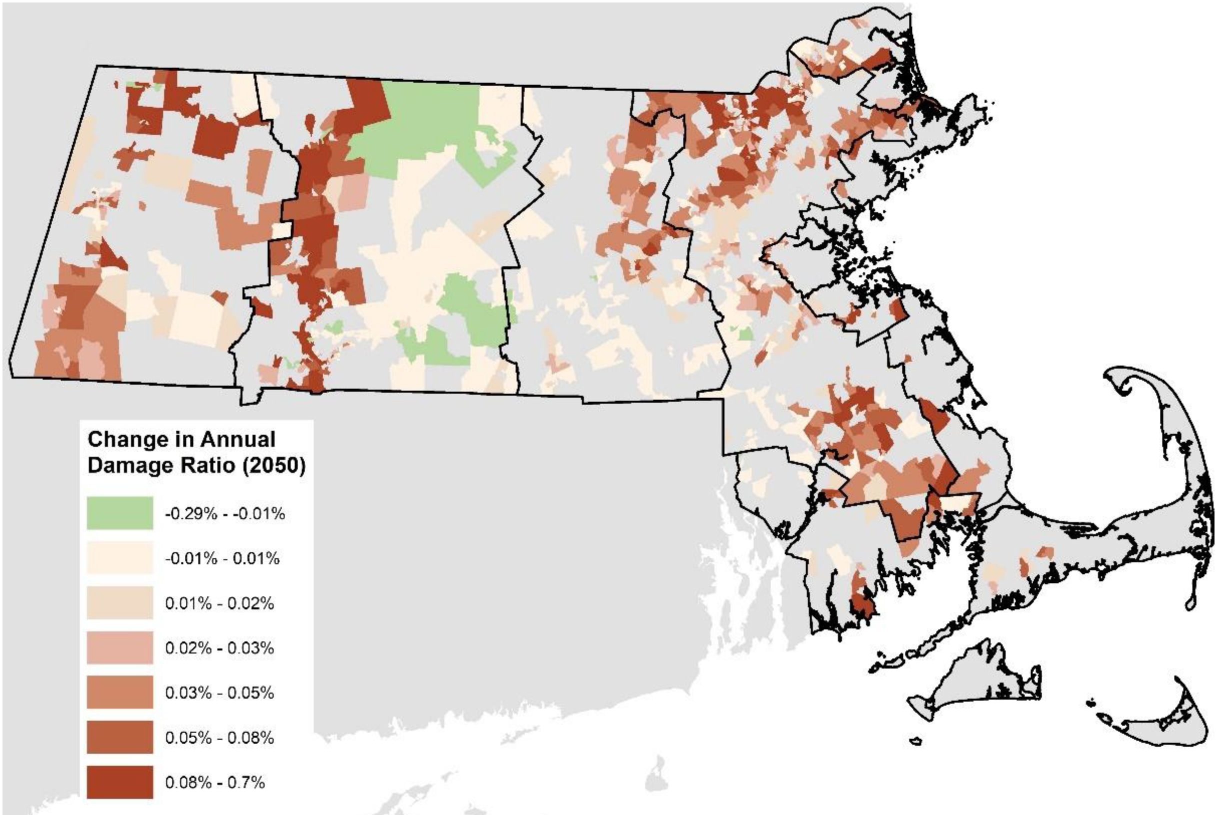
Region	Annual Increase in Damage from Riverine Flooding to Residential Structures Due to Climate Change (Million $)			
	2030	2050	2070	2090
Berkshires and Hilltowns	$5.0	$4.2	$8.8	$16
Greater Connecticut River Valley	$12.8	$12	$237	$42
Central	-$2.0	$3.1	$5.3	$6.6
Eastern Inland	-$4.4	$33	$64	$93
Boston Harbor	$1.0	$5.9	$12	$18
North and South Shores	-$3.5	$3.7	$11	$19
Cape, Islands, and South Coast	$0.4	$1.8	$2.8	$3.5
Statewide	**$9.3**	**$64**	**$130**	**$200**

Source: Derived from Wobus et al. (2021), U.S. EPA data at www.epa.gov/CIRA, and the MA Climate Assessment (Commonwealth of Massachusetts, 2022).

Economic impacts are defined as annual economic impact as compared to the baseline climate scenario (1986–2005). Future impacts are presented for four periods identified in the table by their central year: 2030 (near-term, 2020–2039), 2050 (mid-century, 2040–2059), 2070 (mid-late century, 2060–2079), and 2090 (end of century, 2080–2099). Values may not sum due to rounding. Estimates do not include impacts to commercial or industrial buildings or impacts from stormwater drainage flooding.

Table 5.8-5's results for the 2030 period may seem unusual. The negative values for that period represent temporary reductions in flood risk (relative to current flood risk) in some regions, associated with drying conditions in that period relative to the current climate. These regional reductions in flood risk are seen only in the 2030 period: by the 2050 period and afterward, damage at regional scale increases relative to current levels of flood and continues to increase steadily over time.

Figure 5.8-6 shows summary information on the annual residential structure damage ratio, in 2050, by block group. As the map shows, many of the areas expected to see the most severe inland flooding impacts trace the Connecticut River valley, the northern part of Berkshire County, and more isolated areas of the eastern part of the state in multiple regions. Reductions in damage could occur in the eastern part of the Greater Connecticut River Valley region, in smaller subbasins east of the main stem of the Connecticut River itself, associated with changes in circulation patterns and drying conditions leading to reduction in river flow in that area for the 2050 period. Most of this area is less populated than the areas that see increases in flood risk in other parts of the region and statewide, as shown in the map.



Sources: U.S. EPA data (available at www.epa.gov/CIRA) and MA Climate Assessment (Commonwealth of Massachusetts, 2022).

The structure damage ratio at the block group level is the annual expected damage in the 2050 period divided by the total block group residential structure value. Red areas show an increase in damage relative to baseline climate; green areas show reduction in damage.

Figure 5.8-6. Changes in annual residential structure damage ratio in 2050.

Commercial and Industrial Buildings

For the Risk Assessment, damage to commercial properties from riverine flooding and damage to all properties from stormwater drainage flooding were examined at a statewide level. The assessment used estimates of impacts to commercial structures by First Street Foundation; note that those estimates were provided only for combined multi-hazard flooding (i.e., tidal, storm surge, urban drainage, and riverine), and only statewide and for the Boston area (First Street Foundation & Arup, 2021). These results are examined in more detail in Section 5.5 (Coastal Flooding). The coastal flooding analysis shows that baseline structural damage to commercial properties from all flood hazards might increase by 25 percent (from an annual expected direct damage average of $115 million statewide, only for commercial properties) over the next 30 years, excluding indirect damage, but 75 percent of that damage would be in Boston, leading to the conclusion that damage to commercial structures in the First Street Foundation analysis is mostly from coastal rather than inland flooding.

Solar Electricity Production

Inland floods also put energy production resources at risk. For example, within the solar category of clean energy production, the MA Climate Assessment examines the potential of inland flooding to temporarily or permanently reduce electric energy supply. Flood risk profiles for inland flooding described above are used, as well as the following data and geographic information system (GIS) sources:

- The FEMA National Flood Hazard Layer
- The Massachusetts Department of Energy Resources' Production Tracking System (PTS) Solar Photovoltaic Report (as of February 2022)[2]
- A GIS file developed by Clark University professor John Rogan that documents the physical outlines of solar installations in the Commonwealth[3]

The results of this overlay analysis, shown in Table 5.8-6, reveal that while 26 percent of current solar production is located in a FEMA 100-year floodplain, not all of that production is likely to experience flooding, according to available flood risk modeling. Using forecast flood risk modeling, the amount of currently deployed production at risk in future years could be as high as 4 percent of total current annual solar electricity production. Note that the method is based on flooding at ground level, not at the level of the solar panel installation: it assumes that ground-level flooding can damage the ground-level components of an installation, such as connections to the grid.

Table 5.8-6. Annual Solar Electric Production at Risk from Inland and Coastal Flooding Associated with Climate Change

Region	Production in 100-Year Floodplain (Gigawatt Hours)	Production at Risk of Flooding from 100-Year Flood: Inland and Coastal Flood Risk Combined (Gigawatt Hours)			
	Current	2030	2050	2070	2090
Berkshires and Hilltowns	15	15	0.3	0.3	14
Greater Connecticut River Valley	60	12	0.6	0.4	8
Central	240	15	2	5	3
Eastern Inland	430	60	1	2	65
Boston Harbor	33	16	0.2	0.3	31
North and South Shores	60	25	17	18	4
Cape, Islands, and South Coast	64	11	0.8	4	4

[2] PTS data are available at https://www.masscec.com/production-tracking-system-pts.

[3] Solar installation outlines were obtained via personal communication with Dr. Rogan. The data set is described at https://clarknow.clarku.edu/2021/04/21/geography-research-documents-solar-farms-negative-effects-on-landscape/.

Region	Production in 100-Year Floodplain (Gigawatt Hours)	Production at Risk of Flooding from 100-Year Flood: Inland and Coastal Flood Risk Combined (Gigawatt Hours)			
	Current	2030	2050	2070	2090
Statewide	**900**	**160**	**22**	**30**	**130**
Statewide as % of current production	26%	4%	1%	1%	4%

Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022) analysis of data provided by Dr. John Rogan of Clark University.

This table presents estimates of current solar electric production in the 100-year return period inland and coastal floodplain, as well as total annual solar electric production that may be at elevated risk of flooding based on currently available flood modeling. Future impacts are presented for four periods identified in the table by their central year: 2030 (near-term, 2020–2039), 2050 (mid-century, 2040–2059), 2070 (mid-late century, 2060–2079), and 2090 (end of century, 2080–2099). Values may not sum due to rounding.

Flood damage to other types of energy infrastructure in the Commonwealth, such as fossil-fuel-fired production, wind turbines, and transmission and distribution infrastructure, can be substantial but is currently incompletely assessed.

Culverts

High-river-flow events may overwhelm culverts' capacity to convey water under a road or railway, causing damage to the road, the culvert itself, and the surrounding environment. A recent Commonwealth-sponsored analysis of vulnerability of culverts (defined as road crossings with spans of 10 feet or less) and small bridges (defined as road crossings with spans of 10 to 20 feet) provides specific case studies and links to resources for local-scale vulnerability assessment, case studies of culvert and small bridge replacement projects, and potential sources for project financing (Massachusetts Culverts and Small Bridges Working Group, 2020). The report also references a framework and limited-scale demonstration project for identifying culvert vulnerabilities to high-river-flow events, taking climate change into account. The following components were reviewed: risk of failure, climate change and associated impacts, disruption of emergency medical services, ecological disruption, and transportation vulnerability. These factors were used to develop a transportation vulnerability and ecological disruption score for each crossing to identify an overall prioritization rating—though the framework has not yet been applied throughout the Commonwealth (Sturdevant Rees et al., 2018).

Bridges

Some estimates exist to characterize impacts of inland flooding on the road and rail bridge network. Early estimates assessed the impacts of high-river-flow events on bridge support scour and the need to incur extraordinary repair costs; these estimates suggest that up to 25 percent of bridges of all types that span water (including road and rail network bridges) in the New England region may be vulnerable to this effect but did not provide estimates specific to Massachusetts. The analysis applied a uniform assumption to the amount of increase in peak flow that would make a bridge vulnerable; it is not a substitute basin-level hydraulic analysis. The bridge analysis presented here is drawn directly from the MA Climate Assessment, whose discussion on infrastructure sector impacts includes definitions and more details and information on methods. Preliminary insights from ongoing research suggest that the potential for bridge scour and the potential for overtopping of bridge decks exists at over 1,000 bridges (road and rail) in Massachusetts. These conditions might increase the average annual maintenance cost per bridge by about $5,000 to $7,000. These impacts could be much greater if bridges are not regularly maintained (Wright et al., 2012; Dr. Kenneth Strzepek, personal communication).

Lifelines

Flooding from precipitation affects a number of community lifelines, including:

- Water quality, particularly stormwater drainage events that involve contamination from sewage. If wastewater treatment plans fail (as discussed above), hazardous materials can be introduced to water supplies.
- Food supply chains (as discussed in Section 5.8.2.4.5).
- Power grid by reducing the production of solar electricity (as discussed above).
- Hydroelectric dams and power generation (as discussed in Section 5.8.3) and the introduction of hazardous materials if wastewater treatment plants fail (as discussed above).

Table 5.8-7 outlines examples of state agency responses to the 2023 SHMCAP survey related to their primary concerns about flooding from precipitation and activities undertaken/planned to address flooding from precipitation. Of note, the responses to the survey were completed by agency staff and did not go through formal review.

Table 5.8-7. State Agency Responses: Primary Concerns About Flooding from Precipitation's Effects on Services, with Suggested Improvements

Category	Concerns/Improvements
Services provided	• Emergency services coordination at the federal, state, and local levels, including situational awareness, could be affected. • Telecommunications systems failures would adversely affect business and government services. • Transportation services could be affected. • Recreational boating and fishing access could be temporarily lost. • Parks and open space/recreation could be damaged. • Dams, culverts, and bridges are susceptible to overtopping, erosion, washout, or failure.

Category	Concerns/Improvements
Updates, improvements, or enhancements to address concerns	• Conduct a study to mitigate flooding. Are any public safety answering points in a flood zone? Is there vulnerable infrastructure that services 911 (e.g., cell towers)? • Make infrastructure improvements in potential flood zones. • Create site-specific designs for maintenance facilities to address drainage, remove debris from culverts, elevate track in low-lying areas, and flood-proof vulnerable roads to permit bus and paratransit service. • Move IT infrastructure to more resilient and redundant third-party facilities and cloud solutions. • Install backup power generators to power sump pumps.

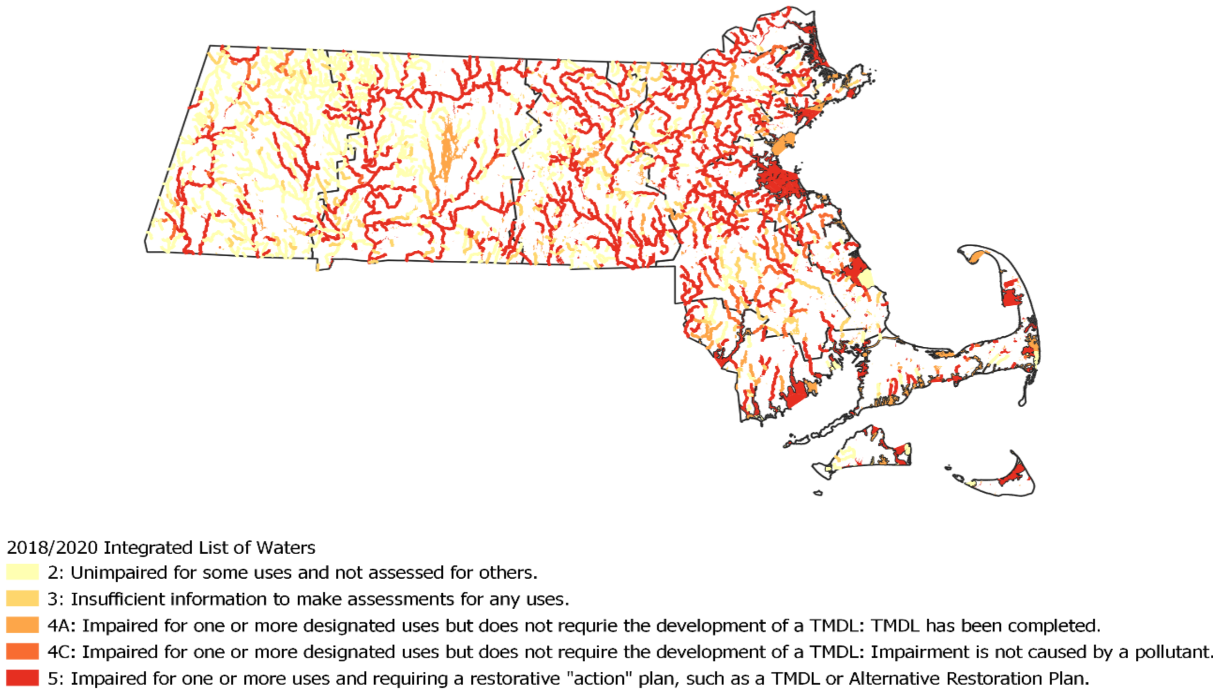
Source: ERG (2023).

5.8.2.4.4 Natural Environment

Intense precipitation and associated flooding threaten freshwater ecosystems through increased sediment delivery, nutrient loadings and contaminants, and scouring of riverbeds, which could increase with climate change. Freshwater ecosystems are critical assets to the Commonwealth. Rivers, streams, lakes, ponds, and freshwater wetlands provide habitat to a variety of fish, birds, invertebrates, and other species, and provide other ecosystem services such as water supply, wildlife viewing, fishing, climate resiliency, and recreational opportunities.

Intense precipitation events scour and erode stream channels and increase nutrient and contaminant concentrations in freshwater bodies. This is magnified in watersheds with high levels of impervious cover, which increase the amount of stormwater runoff. As noted above, the frequency of extreme rainfall events is expected to increase in the eastern parts of the Commonwealth (the Eastern Inland; Boston Harbor; North and South Shores; and Cape, Islands, and South Coast regions). Many of the same regions have the highest concentration of impaired waters requiring restoration action plans (Figure 5.8-7).[4] These areas, which also have some of the highest percentages of impervious surfaces, are particularly at risk for further impairment under a changing climate. In future years, the combination of increasing climate stress and potentially increasing development could lead to significant changes in runoff patterns.

[4] The Massachusetts Department of Environmental Protection (MassDEP) compiles the Integrated List of Waters every two years, in compliance with Section 303(d) of the Clean Water Act. Impaired waters on this list are surface waterbodies that are not expected to meet surface water quality standards after the implementation of technology-based controls. See the MassDEP website for details on the evaluation and listing process.



Developed by MassDEP Division of Watershed Management.

Figure 5.8-7. Waters in Massachusetts by impairment category.

In addition, increased freshwater flow could affect coastal environments. High freshwater flow laden with contaminated sediment to estuaries, for example, changes the chemistry of the system and impairs the ecosystem function.

The impacts of flooding from precipitation on natural environment assets is expected to be focused on freshwater ecosystem structure and function. Water quality issues such as harmful algal blooms (increasing in frequency with warmer water temperatures) and increased nutrient loading (from runoff and combined sewer overflows following extreme precipitation events) could affect sensitive populations and opportunities to recreate in reservoirs, lakes, ponds, and water-adjacent natural systems (Chapra et al., 2017; Jagai et al., 2015). Human populations are affected by changes to natural environment, particularly those who rely on natural resources for their livelihoods or who live in areas of degraded environments, water quality and air quality. Population groups that interact with flooded natural ecosystems will be more exposed to hazards such as polluted waters, contaminated debris, dangerous conditions, loss of healthy natural areas, and other disruptions from flooding events. Populations that are sensitive to environmental conditions, including people with pre-existing conditions may also be more exposed to experience health effects if flooding events displace contaminants. Population groups that depend on water ecosystems for income may also experience impacts from the disruption of certain ecosystem services such as recreational services, fishing, and other water-based activities.

5.8.2.4.5 Economy

Inland flooding could affect the availability of affordably priced housing in the Commonwealth in multiple ways, including through inland flood damage that can affect both publicly owned housing and the market for affordable housing. An increase in demand for high-quality housing and a decrease in supply worsens the scarcity of affordably priced housing. Increasing demand for affordably priced housing can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures (“climate gentrification”). The supply of affordably priced housing is reduced by direct physical damage from climate impacts and potentially higher construction costs for all housing to improve resiliency to threats from climate. Both demand and supply effects raise rental and ownership prices, which can limit options for affordably priced housing.

Flooding from precipitation impacts on affordable housing disproportionately affects low-income populations. Analysis from the MA Climate Assessment supports this conclusion: that report found that exposure to this impact is highly disproportionate. Populations living in environmental justice block groups defined on the basis of:

- Low-income populations are more likely to live in housing located in areas that experience 59 percent higher flood impacts than the rest of the Commonwealth
- Language-isolated populations are more likely to live in housing located in areas that experience 88 percent higher flood impacts than the rest of the Commonwealth

High rates of disproportionality are seen in the 2030s time period: during that period, 12 block groups statewide have a severe annual damage ratio of 0.5 percent or higher for housing that is affordable, but 58 percent of these block groups are environmental justice block groups, and 48 percent of the 106 block groups projected to see a 0.1 percent annual damage ratio are environmental justice block groups. In other words, it is expected that people living in environmental justice block groups will experience the most immediate impacts of intense flooding.

This quantitative analysis cannot forecast indirect impacts from climate gentrification, but the literature universally acknowledges that the complex market effects of climate gentrification disproportionally impact low-income populations, who are least able to afford the higher housing and rental prices that climate gentrification causes.

Table 5.8-8 below provides a summary of results for flood risk to lower structure value per household block group in the Commonwealth. The results show an increase in impacts from $44 million to $150 million statewide from 2030 to 2090.

Table 5.8-8. Estimated Impact of Flooding on Affordable Housing: Residential Buildings in the 25th Percentile for Median Per Household Structure Value

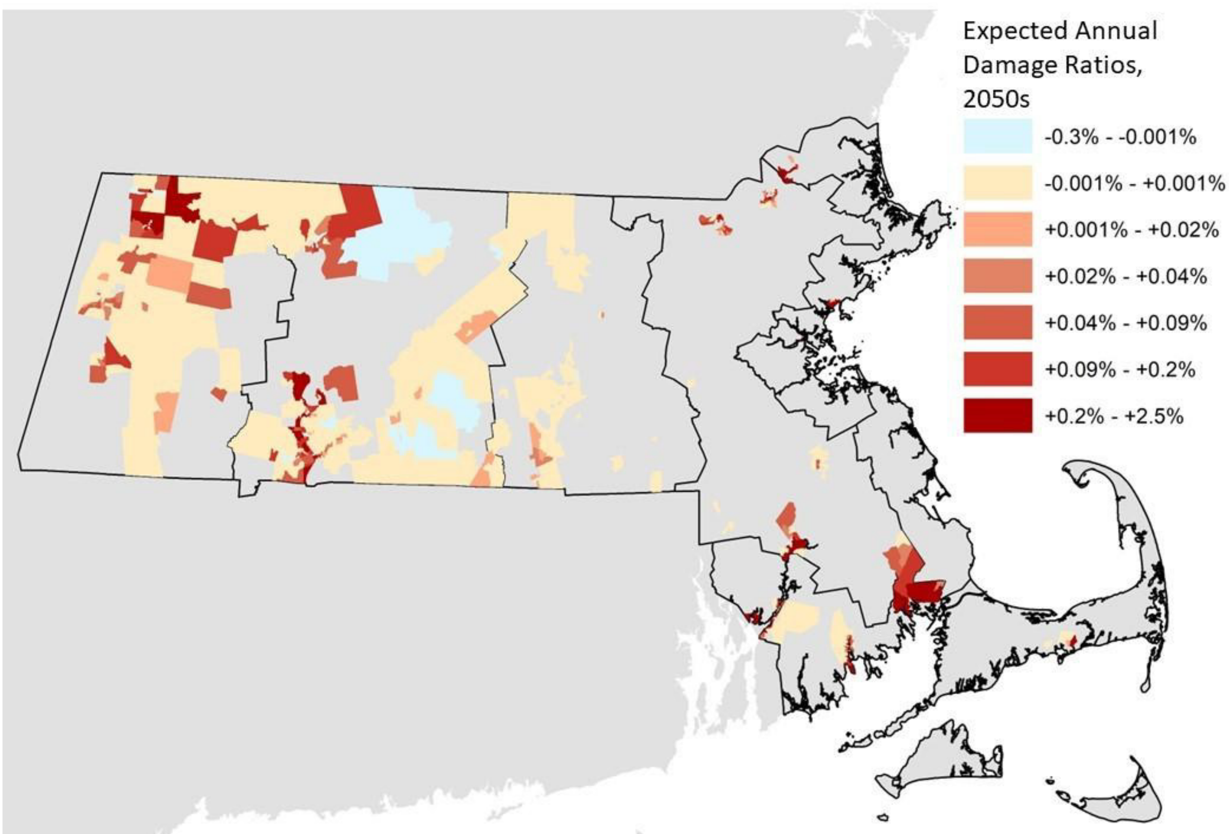
Region	Current Total Residential Structure Value (Million $)	Annual Total Expected Damage from Inland Flood Risk (Million $)			
		2030	2050	2070	2090
Berkshires and Hilltowns	$11,000	$5	$4	$7	$10
Greater Connecticut River Valley	$48,000	$13	$10	$17	$29
Central	$31,000	-$0.8	$0.1	-$0.2	-$0.4
Eastern Inland	$22,000	$3	$14	$19	$25
Boston Harbor	$1,000	$0.4	$0.8	$2	$3
North and South Shores	$3,600	$7	$14	$19	$25
Cape, Islands, and South Coast	$23,000	$16	$25	$40	$54
Statewide	**$140,000**	**$44**	**$68**	**$100**	**$150**

Sources: ACS property and structure value, U.S. EPA data (available at www.epa.gov/CIRA), and MA Climate Assessment analysis (Commonwealth of Massachusetts, 2022).

This table presents current total residential structure value for properties in the 25th percentile of block groups for median household structure value, as well as estimated impact of climate change on EAD from inland and coastal flooding. Future impacts are presented for four periods identified in the table by their central year: 2030 (near-term, 2020–2039), 2050 (mid-century, 2040–2059), 2070 (mid-late century, 2060–2079), and 2090 (end of century, 2080–2099). All results are in millions of 2020 dollars. Totals may not sum due to rounding. Negative values represent reductions in projected residential flood risk relative to current damage ratios.

The spatial distribution of the results shows damage is largest in the Cape and Islands/South Coast, Greater Connecticut River Valley, and Eastern Inland regions. As a percentage of the total current residential structure value in these regions, however, the largest effects are on the Cape and Islands/South Coast region (see Figure 5.8-8 below; the greatest impacts are in the South Coast portion of this region). Large impacts in the Greater Connecticut River Valley and Eastern Inland regions are associated with an increase in inland flood risks. In the Central region, a projected decrease in river flows in the 2030, 2070, and 2090 time periods in the relevant 25th percentile structure value block groups could result in a slight decrease in expected damage.

Figure 5.8-8 shows a map of all the 25th percentile block groups and their EAD ratios (damage as a percentage of total structure value) in the 2050s. Although it appears there are few block groups of interest in the Cape, Islands, and South Coast region, the relevant 25th percentile block groups are small and densely populated and concentrated in the South Coast portion that includes Fall River and New Bedford. Other concentrations of interest in Figure 5.8-8 are in the Greater Connecticut River Valley region, particularly the Springfield area but also near the Vermont border, and in mostly northern portions of the Berkshire and Hilltowns region.



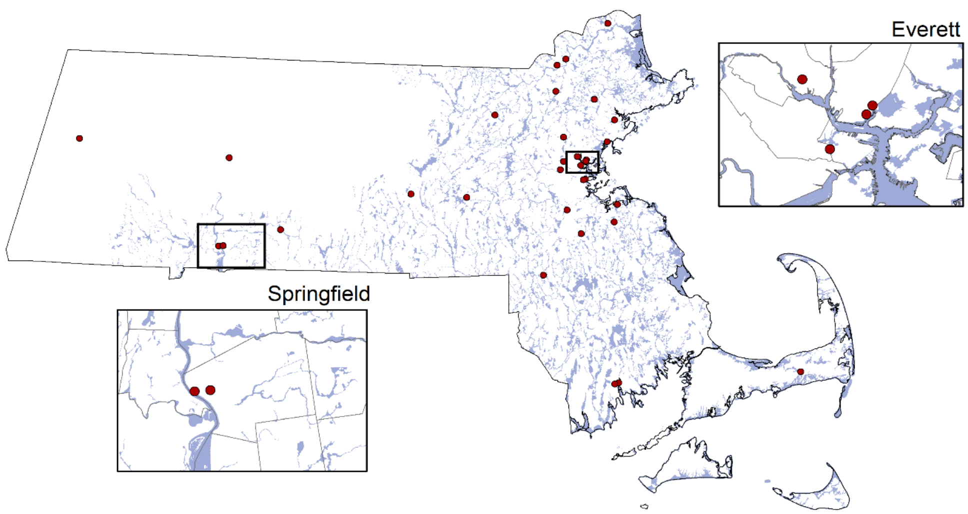
Source: U.S. EPA data (available at www.epa.gov/CIRA) and MA Climate Assessment analysis (Commonwealth of Massachusetts, 2022).

Map shows the EADs for block groups falling within the 25th percentile of housing value in the 2050s. Negative values represent reductions in projected residential flood risk relative to current damage ratios.

Figure 5.8-8. Map of EAD ratios in the 2050s relative to current ratios for housing that is affordable.

Flooding from precipitation could also affect the sometimes complex national and international supply chains of Massachusetts businesses. For example, flooding can damage manufacturing sites, wholesale distribution centers, raw material extraction operations, or transport links. Disruptions to supply chains for energy, raw materials, and intermediate goods essential to manufacturing can affect Massachusetts businesses' ability to meet customer orders and keep their workforce fully engaged. The U.S. Fourth National Climate Assessment identified the link between climate change and supply chain reliability in 2018, highlighting it as a key message in the "Climate Effects on U.S. International Interests" chapter (Smith et al., 2018). That chapter also noted that there is a lack of research on this topic; however, recent supply chain disruptions have made supply chain risk assessments a priority for businesses that depend critically on reliable and timely supply chain delivery for their operations.

One potential supply chain vulnerability involves the resilience of major food distribution centers throughout Massachusetts to impacts from a flood-related shutdown of a major distribution facility. Such a shutdown might temporarily—but perhaps severely—affect local food availability during and after the event. Figure 5.8-9 below shows the major wholesale food distribution centers in Massachusetts, based on industry trade group research, with their locations plotted in proximity to the FEMA 100-year floodplain.[5] Four of the 32 centers on the list are located within the FEMA 100-year floodplain; 29 are within 1,000 meters of it. The map shows two of these, along with others, in the Everett/Chelsea and Springfield areas, which may be both vulnerable to flood risk and may be important in supplying groceries in Commonwealth-designated environmental justice population areas. See Section 5.1.5.2 of the Risk Assessment Introduction for more discussion on Priority Communities and MA Environmental Justice block groups. While no flood modeling is yet available to more comprehensively assess inland flood risks to these facilities and their operations, the critical role of distribution centers suggests more detailed inland flood risk analysis may be needed to understand the effects on communities and workers who rely on local services and employment. Interruptions to businesses and work may also cause loss of wages, which would likely disproportionately affect environmental justice and other priority populations working in this market.



Sources: Food distribution locations from FoodCoDirectory; FEMA flood layer from MassGIS.

Red dots show the locations of major wholesale food distribution centers—see text for source. Blue-shaded areas are the current FEMA 100-year floodplain. Insets show two centers near Springfield, and four near Everett, which are among those within and/or nearest to the current 100-year floodplain.

Figure 5.8-9. Locations of major wholesale food distribution centers in Massachusetts relative to the current FEMA 100-year floodplain.

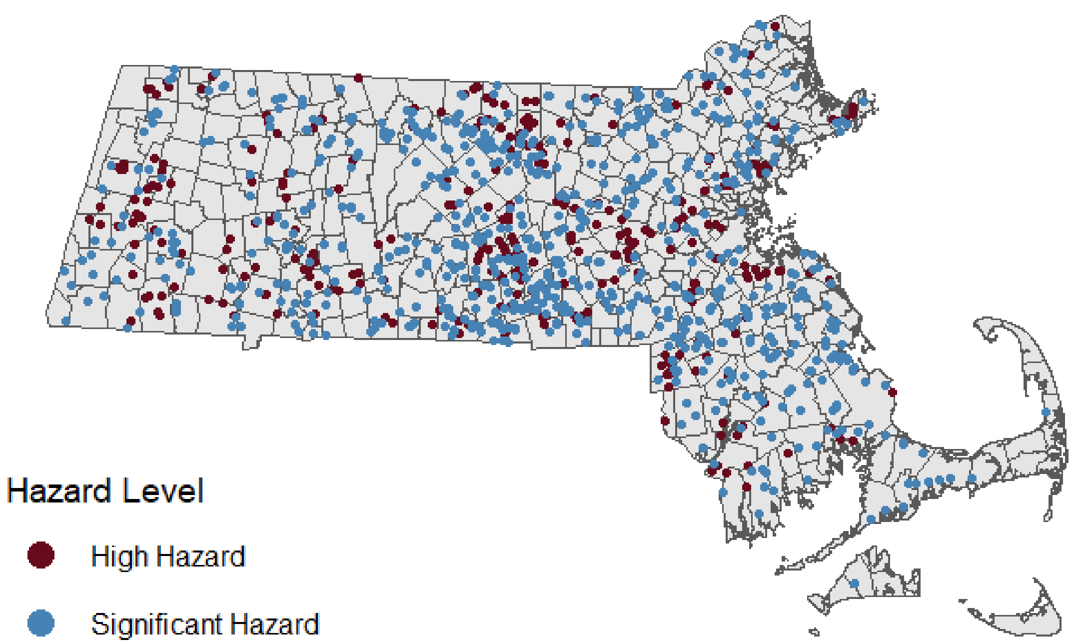
[5] List available at https://www.foodcodirectory.com/2020/09/wholesale-food-distributors-in_31.html.

5.8.3 Assessment of Dam Overtopping

This section is a supplement to the Risk Assessment hazard Section 5.8, titled "Flooding from Precipitation." It is drawn from the analysis, data, and findings from the MA Climate Assessment.

5.8.3.1 Hazard Description

In Massachusetts, over 1,400 dams fall under the jurisdiction of the state dam safety program, and over 900 of those are classified as high or significant hazard under state dam safety regulations (see Table 5.8-9 for regulatory definitions). Over two-thirds of the high and significant hazard dams are publicly owned. Other high and significant hazard dams exist within Massachusetts that fall under the jurisdiction of federal regulatory agencies. Figure 5.8-10 below illustrates the locations of high and significant hazard dams in the Commonwealth. (Table 5.8-13 in Section 5.8.3.5 provides a full list of high hazard dams in the Commonwealth.) One notable historical dam failure took place with the Whittington Pond Dam in Taunton, Massachusetts, in 2005, when an extreme rain event put the 170-year-old dam at high risk of collapse. The town was evacuated as a preventive measure and repairs by emergency response teams were estimated at $1.5 million. This event catalyzed state-level attention to dam safety and was followed by a series of legislative actions to address risk from high hazard dams.



Source: MassGIS (2022).

Figure 5.8-10. Location of dams and their hazard significance levels.

Climate change effects are projected to change rainfall storm patterns: for example, the current 24-hour 10-year return period historical rainstorm (about 3 inches) could double in frequency by 2050 in western and central Massachusetts and triple in frequency in coastal regions. These changes to precipitation can alter river flow upstream of dams due to changes in rainfall patterns that accumulate in the water system. Dam failures can cause damage upstream and downstream, and the probability of this happening is expected to increase with climate change over time.

5.8.3.2 Exposure and Vulnerability

Historically, there have been few documented dam failure events in Massachusetts, particularly events with reported damage to building, infrastructure, and natural and open space areas. However, Massachusetts is projected to see a tenfold increase in the frequency of high-river-flow events over the century, which in turn could increase dam-related damage (see the MA Climate Assessment, drawing on work by Fant et al., 2017).

Exposure to dam failure impacts is heavily influenced by capital expenditure and the allocation of funding toward risk mitigation. Depending on responsibility for the dam and availability of funding, the burden can sometimes fall on communities with limited funding and capacity. Due to the availability and reliability of data and information, the scope of dams evaluated is limited to those specifically defined by the Massachusetts Department of Conservation and Recreation (DCR) as Significant and High Hazard Dams under dam safety program regulations.

Dams are classified for the purpose of establishing inspection schedules and adherence to design criteria, in accordance with their potential for damage to life or property in the downstream area of the dam in the event of failure of the dam or appurtenant facilities. Dams are classified based on their size and hazard potential. The classifications are determined as follows, summarized in Table 5.8-9.

Table 5.8-9. Summary of Size and Hazard Classifications in Massachusetts Dam Safety Regulations

Panel A: Size Classification Table		
Category	**Storage (Acre-Feet)**	**Height (Feet)**
Non-jurisdictional[a]	Not in excess of 15 regardless of height	Not in excess of 6 regardless of storage capacity
Small	≥15 and <50	≥6 and <15
Intermediate	≥50 and <1000	≥15 and <40
Large	≥1000	≥40

Panel B: Hazard Potential Classification Table	
Hazard Potential Classification	**Definition**
High hazard potential (Class I)	Dams located where failure will likely cause loss of life and serious damage to home(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).
Significant hazard potential (Class II)	Dams located where failure may cause loss of life and damage to 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 potential (Class III)	Dams located where failure may cause minimal property damage to others. Loss of life is not expected.

Source: Hazard classification definitions and other information contained in 302 CMR 10.6(3), available at https://www.mass.gov/regulations/302-CMR-1000-dam-safety.

[a] For dams not in excess of 6 feet in height or having maximum impounding capacity not in excess of 15 acre-feet, the Commissioner shall make jurisdictional determination by taking into consideration factors or combination of factors such as height, type of structure, volume of the impoundment, extent of downstream development, and other factors deemed appropriate by the Commissioner.

Populations at Risk

Populations potentially at risk were examined near 128 high hazard potential (Class I) dams for which location and other information is available through MassGIS. The extent of the exposure due to a dam breach was estimated based on a sample of emergency action plans for five high hazard dams, which were publicly available and included summaries of dam breach flood risk modeling. Because population density varies near these dams, the estimated population residing with the potential area of flood influence varied between 35 and 62 persons per dam. The total estimated population potentially at risk (residing near these dams) was 5,400, distributed spatially across the Commonwealth as shown by the red color-coded locations in the map above. The exact locations of these dams, and other information about them, are included in an appendix to this section.

Local Adaptation Planning and Highlight from Review of Local Plans

Multiple local governments in the Commonwealth have recognized the potential risk of dam failure and have proactively taken steps to mitigate these risks. Most local planning efforts identified the names and number of dams in their communities. Some municipalities identified information gaps in dams that were privately owned. Below are select highlights of risks and local plans:

- The towns of Charlton and Spencer in Worcester County assessed future climate change flood risk upstream and downstream from dams in their *Integrated Water Infrastructure Vulnerability Assessment and Climate Resiliency Plan* (Fuss & O'Neill, 2019).
- In its *Climate Change Vulnerability Assessment* report, the city of Cambridge considered the future effects of climate change on storm surge protection offered by dams on the Mystic and Charles Rivers (City of Cambridge, 2015, 2017).
- The *City of Springfield: Local Natural Hazards Mitigation Plan* includes an assessment of the flood risk to people, infrastructure, and natural resources posed by potential dam failures at sites in and around the city (Springfield Natural Hazards Mitigation Planning Committee & Pioneer Valley Planning Commission, 2016).
- The *Town of West Stockbridge Hazard Mitigation* completed a Phase 1 Dam inspection in 2020 and found the one dam in West Stockbridge to be in "Satisfactory Condition". The town has an Emergency Action Plan for dams on file with the town which was recently updated for the Shaker Mill Pond Dam (Foresight Land Services, 2021).
- The *Town of Shutesbury Hazard Mitigation Plan Update* identifies Lake Wyola Dam, the Atkins Reservoir Dam, and Dudleyville Pond Dam as high hazard dams in Shutesbury. Because the outflows of this dam are located close to Shutesbury's western border with Leverett, impacts from a dam failure would affect residents along North Leveret road and residents in Leveret (Shutesbury Hazard Mitigation Planning Team & Franklin Regional Council of Governments, 2021).
- The *Auburn Hazard Mitigation Plan* highlighted risks from the Leesville Pond Dam as significant. The dam lies upstream from Auburn in the City of Worcester. The town is impacted when the Worcester Diversion Tunnel gate at Leesville Pond is raised/lowered (Menard et al., 2018).

There have also been recent pledges from state and federal government agencies to invest in dam repair and flood control projects (MacCormack, 2021, 2022). These investments are targeted at reducing the projected impact of damage across the state.

The primary estimated impact of dam failure across the commonwealth is quantified below with respect to vulnerabilities within the infrastructure sector.

Infrastructure

Table 5.8-10 below provides a ratio of the frequency of 1 percent or 0.25 percent annual chance river flow events by county and dam hazard level relative to the historical current frequency. Values less than 1 indicate a reduction in frequency in the future, and values greater than 1 indicate an increase in frequency. Dam hazard levels and location data are from [MassGIS](). Estimation of future river flow future is based on simulations of daily river flows using Global Climate Models (Fant et al., 2017). Future impacts are presented for four periods and two annual flood chance levels, identified in the table by their central year: 2030 (near-term, 2020–2039), 2050 (mid-century, 2040–2059), 2070 (mid-late century, 2060–2079), and 2090 (end of century, 2080–2099) and the two annual flood chance levels of 1 and 0.25 percent. Average percent probabilities were calculated by taking event probabilities, at HUC8 spatial resolution, linking those to individual dams at the two hazard levels. Then the event probabilities were averaged across the county to achieve the values in the table. Statewide values reflect averages of event probabilities across the state for the two designated dam hazard levels.

Table 5.8-10. Change in Frequency of 1 Percent and 0.25 Percent Annual Chance River Flow Flood Events at Dam Locations

County	Haz Level	Dam Count	2030		2050		2070	
			1% Event	0.25% Event	1% Event	0.25% Event	1% Event	0.25% Event
Barnstable	High	0	—	—	—	—	—	—
	Sig	11	0.3	0.2	0.6	0.6	0.6	0.6
Berkshire	High	40	2.8	4.3	0.3	0.2	0.5	0.5
	Sig	41	3.1	4.8	0.4	0.3	0.6	0.6
Bristol	High	25	2.1	2.7	5.3	9.9	2.3	2.7
	Sig	44	2.1	2.6	5.2	9.8	2.2	2.7
Dukes	High	0	—	—	—	—	—	—
	Sig	1	0.3	0.2	0.6	0.6	0.6	0.6
Essex	High	33	7	12.7	7.3	11.3	4.6	5.9
	Sig	57	10.8	21.9	6.3	9.6	4	5.0
Franklin	High	15	2.1	2.6	0.5	0.4	0.5	0.5
	Sig	42	1.6	1.8	0.4	0.3	0.5	0.4
Hampden	High	24	3.1	4.8	0.50	0.4	0.7	0.7
	Sig	52	3.0	4.6	0.5	0.4	0.7	0.6
Hampshire	High	19	2.8	3.6	0.6	0.5	0.5	0.5
	Sig	31	2.6	3.3	0.6	0.5	0.5	0.5
Middlesex	High	43	5	8.3	5	7.4	3.3	4.2
	Sig	82	9	18.0	3.6	5.1	2.5	3.0
Nantucket	High	0	—	—	—	—	—	—
	Sig	0	—	—	—	—	—	—
Norfolk	High	17	4	4.6	7.7	12.0	4.8	6.3
	Sig	52	3.2	4.2	7.1	11.5	4.2	5.4
Plymouth	High	11	0.9	1.0	2.1	3.5	1.1	1.2
	Sig	76	1.3	1.5	3	5.3	1.5	1.8
Suffolk	High	1	3.7	4.9	8.1	12.7	5.1	6.6
	Sig	0	—	—	—	—	—	—

County	Haz Level	Dam Count	2030		2050		2070	
			1% Event	0.25% Event	1% Event	0.25% Event	1% Event	0.25% Event
Worcester	High	102	1.3	1.3	1	1.1	0.6	0.5
	Sig	249	1.2	1.1	1	1.0	0.6	0.5
Statewide	**High**	**330**	**2.9**	**4.4**	**2.7**	**4.1**	**1.7**	**2**
	Sig	**738**	**3.3**	**5.5**	**2.5**	**3.8**	**1.5**	**1.8**

Source: ERG analysis using data from MassGIS (2012, 2017).

Methodology Used to Estimate Impacts of Dam Failures

The impacts of dam failures conducted for the MA Climate Assessment were calculated by estimating baseline economic costs of repair and replacement of dams, and an estimate of the likelihood of a damaging dam failure, adjusted for the economic value of surrounding homes and infrastructure. Estimates of the probability of future flood events and damage from those events was used to calculate damage associated with dam overtopping and failure projected into the future, which are compared to the baseline economic costs.

Historical records from the Stanford National Performance of Dams Program (NPDP) and the Association of State Dam Safety Officials' Dam Incident Database (DID) were used to guide reasonable assumptions about the engineering standards that could apply to the set of dams analyzed to estimate the future likelihood of dam overtopping and breach events. Impacts were analyzed for 1,075 high and significant hazard dams, as identified by DCR. Site analyses for flood damage, which in many instances have been conducted for Massachusetts dams, are not publicly available for a comprehensive sample of Commonwealth dams. This analysis instead used a downscaled version of projected streamflow results of the Hydrologic and Water Quality System, as outlined by Fant et al. (2017), to simulate future hydrologic conditions at each dam site and assess the frequency of potential dam failure modes.

Impacts Considered and Data Sources Used for Estimates

Economic impacts representing flood damage to nearby buildings and infrastructure are based on four elements of data for each dam site: (1) an average estimated area of influence for flooding associated with an overtopping event, (2) the average county level building value per acre in the area surrounding each dam in Massachusetts, (3) standard U.S. Army Corps of Engineers depth damage functions for Massachusetts that are used to estimate building damage associated with a certain freshwater flood height, and (4) estimates of the cost of dam repairs necessary after an overtopping or breach event. Dams may fail for reasons other than high precipitation or river flow events, such as poor maintenance and construction. However, according to the broader dam event databases examined in this analysis, high flow events tend to be triggering events which reveal or exacerbate underlying maintenance and construction deficiencies.

Estimates of the cost of dam repairs necessary after an overtopping or breach event are developed based on NPDP[6] and DID[7] reports of dam safety incidents, characteristics, and estimated economic damage. Fifty-six and five incidents were reported in the NPDP and DID databases, respectively, from Massachusetts. Incidents recorded occurred between 1848 and 2015, with a majority occurring before the year 2000. Only two incidents in the DID have occurred since Office of Dam Safety regulation (302 CMR 10) came into effect in 2017. The DID does not have estimates of economic damage, and only one entry from the NPDP had an economic damage estimate of $1 million.

Estimating Area Affected and Depth of Potential Flooding

To estimate potential area affected and depth of potential flooding, available inundation flood modeling that estimates flood area and depth of inundation for Massachusetts dams or other potentially comparable dams in the hypothesized event of dam breach or failure was researched. Two readily available Emergency Action Plans for dams in Massachusetts that include such analysis were reviewed. The results indicated that, in a breaching event, up to 36 structures might be affected by flooding, with depths of approximately 2.0 feet.

To conduct this analysis, the project team reviewed two publicly available emergency action plans: *Emergency Action Plan for Foster's Pond Dam*, Andover, Essex County, Massachusetts, national I.D. number MA00153, state ID number 5-5-9-10, dam location 42.61361º N / 71.14146º W; and *Emergency Action Plan for Forge Pond Dam*, East Bridgewater, Plymouth County, Massachusetts, national I.D. number MA00427, state ID number 7-12-83-3, dam location 42.0368º N / 70.9595º W. This analysis assumes all non-structural damage to properties would be approximately equal to the damage to structures, consistent with the total damage from the readily available emergency action plan. Non-structural damage could include damage to roads or other infrastructure, local response and cleanup costs beyond structure damage, business interruption, and traffic delays.

This analysis also examined overtopping events, which are not always strictly defined as a dam failure event in the Commonwealth regulations. Dam overtopping occurs where high flow does some damage to the dam, requiring emergency response and repair, and leads to unusually high flow downstream of the dam, but does not drain the impoundment. This event is most like a dam breach, defined in the Commonwealth dam safety regulations as "an eroded or failed section opening through a dam which drains the impoundment," but is more minor in consequence because the release does not drain the impoundment.

[6] The NPDP Dam Incident Consequences Database is available at http://npdp.stanford.edu/consequences. Results are based on a search of the database for all reported incidents in Massachusetts.
[7] The DID is available at https://damsafety.org/incidents. Results are based on a search of the database for all reported incidents in Massachusetts.

Events such as these have been described in the DID event database: the most serious consequence is usually the cost to repair damage to the dam or associated structures associated with the overtopping, and/or to restore areas washed out downstream as a result of the higher-than-usual downstream flow.

Based on U.S. Department of Agriculture design standards, it was assumed that dams in Massachusetts were designed to the 1,000-year (0.01 percent annual likelihood) event for overtopping and the 5,000-year (0.02 percent) event for dam breaching. These standards differ from those in Massachusetts—for example, for high hazard dams that are intermediate or large, the design storm is half of the "probable maximum flood" (½ PMF). Unfortunately, it was not possible to estimate the ½ PMF for the 330 high hazard and 738 Significant Hazard dams analyzed here. By comparing the number of times the flow exceeds the assumed overtopping or dam breaching threshold in the historical period with the same estimates for the future period, an estimate was obtained of the change in expected annual impacts for the future period. For example, if a flow event in the historical period is a 1 percent flood event, and these same flows occur with 2 percent per year frequency in the future projection, annual expected damage for the future projection would be double the baseline annual expected damage.

These thresholds, which were established for new dams, may be more or less strict than standards to which the full universe of dams in the Commonwealth were built or are maintained, and as noted do not correspond directly to the regulatory design storms in the Massachusetts regulatory code (302 CMR 10.14), but unfortunately comprehensive information on specific dam construction standards and condition is not currently available.

Table 5.8-11 shows the annual estimated future impacts of climate change (difference from the baseline) from overtopping and breaching events for the 738 significant hazard dams and 330 high hazard dams evaluated. For the purposes of this analysis, and based on existing incident reports, the cost of repairs and other damage from *overtopping* events is estimated to be just less than $200,000 per event. The economic impact of the potentially more serious and hazardous *breaching* events varies by location but averages slightly more than $2.9 million per event.

Table 5.8-11. Annual Economic Impact of Overtopping and Breaching of Significant and High Hazard Dams due to Climate Change

Region	Baseline	Annual Incremental Economic Impact of Overtopping and Breaching (Million $)			
		2030	2050	2070	2090
Berkshires and Hilltowns	$0.2	-<$0.05	$2.3	$2.0	$2.1
Greater Connecticut River Valley	$0.3	$0.9	$4.3	$4.5	$4.7
Central	$0.4	$0.6	$4.1	$3.3	$3.4
Eastern Inland	$0.5	-$0.2	$1.1	$1.4	$1.4

Region	Baseline	Annual Incremental Economic Impact of Overtopping and Breaching (Million $)			
		2030	2050	2070	2090
Boston Harbor	$0.1	-<$0.05	$0.2	<$0.05	<$0.05
North and South Shores	$0.2	$0.3	$0.6	$2.6	$2.7
Cape, Islands, and South Coast	$0.1	$0.3	$0.3	$2.6	$2.7
Statewide	**$1.7**	**$1.9**	**$13**	**$16**	**$17**

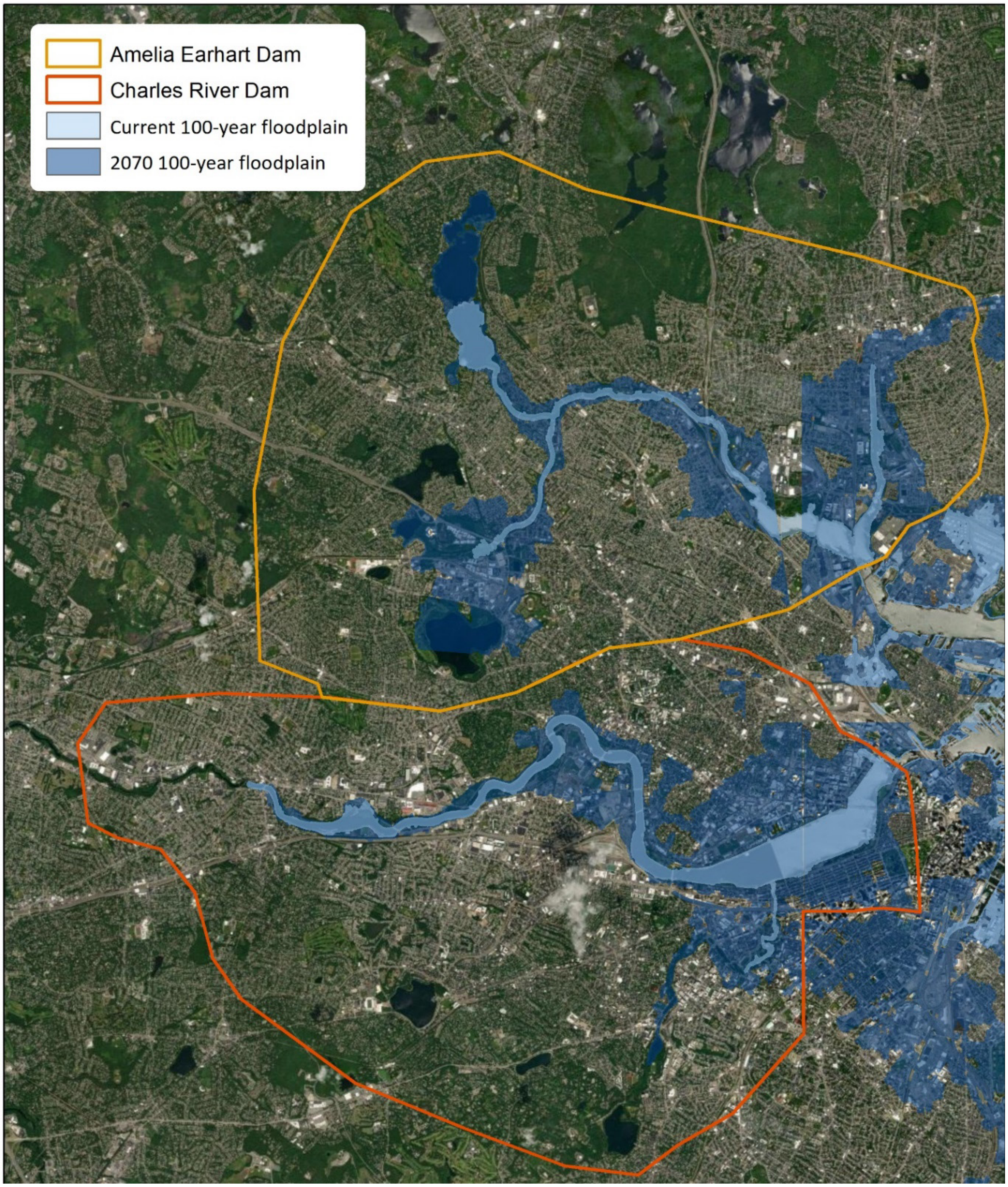
Source: MA Climate Assessment analysis of MassGIS data and climate-induced streamflow data from Fant et al. (2017).

Annual economic impacts are defined as compared to the baseline climate scenario (1986–2005). Future impacts are presented for four periods identified in the table by their central year: 2030 (near-term, 2020–2039), 2050 (mid-century, 2040–2059); 2070 (mid-late century, 2060–2079), and 2090 (end of century, 2080–2099). Values may not sum due to rounding.

Impacts are generally predicted to increase over time for Massachusetts. The spatial distribution of outcomes is skewed toward regions (Greater Connecticut River Valley and Central) with a higher number of significant and high hazard dams. Across Massachusetts, annual expected baseline period damage is $1.65 million and expected to have an incremental increase of $11 to $16 million by the end of the century. Negative values represent temporary reductions in flood risk for the 2030 period, in some regions, relative to current flood risks, associated with drying conditions in that period relative to current climate. These region-scale reductions in flood risk, however, are seen only in the 2030 period: by the 2050 period and afterward, damage at the region scale increases relative to current levels of flooding, and it continues to increase steadily over time.

Note that the impacts summarized above exclude consideration of dams classified as low hazard, and also do not consider climate stresses to dams in coastal regions that result from sea level rise or coastal storm surge. Two examples of dams that are classified as low hazard but potentially affected by coastal hazards are the Amelia Earhart Dam (spanning the Mystic River between Somerville and Everett) and the Charles River Dam in Boston. Coastal flood risk information from the Massachusetts Coastal Flood Risk Model (MC-FRM), described in detail in Section 5.5 (Coastal Flooding) characterizes the risk to properties from flanking or overtopping of these dams that results from periodic coastal storm surge.

The areas vulnerable to exposure near these dams are shown in Figure 5.8-11 below. As shown, the effect of sea level rise over time is to expand all of the current floodplains considerably (the figure shows only the 1 percent annual chance floodplain, but most other annual chance floodplains also expand over time).



Map developed by ERG, showing land that would flood due to overtopping or flanking of either dam. Data from MassGIS (2012, 2017).

Figure 5.8-11. Areas at risk of flooding near Amelia Earhart Dam and Charles River Dam.

Table 5.8-12 shows estimates of the potential damage to buildings on the upstream side of the Charles River and Amelia Earhart dams that could result from flanking or overtopping of these dams associated with period storm surge. As shown in the table, the present period damage (roughly corresponding to 2008) is relatively small, about $100,000 annually, but sea level rise is expected to greatly expand this risk and lead to larger damage in future years. By 2070, the total risk could exceed $240 million on average each year, if no further action is taken to fortify or raise the dam; elevate vulnerable properties; or otherwise contain the storm surge to the riverbanks and buffer areas.

Table 5.8-12. Expected Annual Damage to Buildings Attributable to Coastal Storm Surge Resulting in Flanking or Overtopping of Dams

	Total EAD (Million $)			
	Present	2030	2050	2070
Charles River Dam	$0.1	$9.1	$41.2	$196.8
Amelia Earhart Dam	$0.0	$12.7	$33.1	$48.3
Total	$0.1	$21.9	$74.3	$245.1

Source: ERG analysis of areas at risk of flooding; MA Climate Assessment (Commonwealth of Massachusetts, 2022) analysis of potential damage to buildings from flooding events.

5.8.3.3 Secondary Hazards

Dam failure can contribute to several secondary hazards, including the following:

- Dam failure could disrupt freshwater ecosystems in front of and behind dams.
- Residential and commercial buildings behind dams could be vulnerable if a dam fails; this could result in loss of life.
- Government buildings and land behind dams could be vulnerable to dam failure.
- Agricultural assets (including animals) behind dams could be vulnerable to dam failure.

5.8.3.4 Summary of Data Used to Understand High Hazard Potential Dams

The low reported incidence of dam failure events in Massachusetts, in available national and Commonwealth dam incidence reporting inventories, suggests that the existing dam safety program is well adapted to current climate and flow event occurrence. Estimates of future incidence of high flow events suggest that in aggregate, significant increases in risks from dam failures may not be experienced until mid-century. While many of Massachusetts' dams are old, the existing inspection, monitoring, and emergency preparedness program appears to be effective in reducing incidence to a low level.

Data used in this analysis include the following:

- **Dam hazard designations and locations available through MassGIS.** As shown in the appendix, this also includes information on dam ownership (over 1,600 of the roughly 2900 dams for which MassGIS provides information are privately owned) and an indication of the date of the most recent inspection. This publicly available source does not include information on dam height, age, condition, or impoundment size.
- **Selected emergency action plans for high hazard dams across the Commonwealth.** All these plans include summaries of nearby infrastructure, residences, and natural resources that may be vulnerable to flooding during a dam failure event. Some also include summaries of hydrologic and hydraulic modeling, including potentially affected infrastructure and potential depths of inundation, which are used to characterize scenarios of damage when high or significant hazard dams overtop or breaches.
- A range of modeled annual chance baseline and projected future (with climate change) riverine flow results from Fant et al. (2017). These were used to estimate potential risks from dam failure under high flow events, with reference to their assumed or attributed construction standards.

Key limitations of the data employed in this section include the following:

- The analysis assumes that dams in Massachusetts are built and maintained to their stated design standards. Additionally, the analysis assumes regular inspections and monitoring is performed for dams in Massachusetts. For Massachusetts, that means significant and high hazard dams are designed to the 1,000-year flow event (0.1 percent annual likelihood event) standard for overtopping and the 5,000-year flow event (0.02 percent) standard for breaching. In some cases, the actual design standards and performance characteristics of these dams may differ from the required design standards.
- Costs per event are based on the available information from a review of Massachusetts emergency action plans and the available data from NPDP and the DID. Detailed, project-level estimations of flood damage that are unique to each dam would improve the estimate of cost but would require a significantly expanded level of effort.
- Data on the construction specifications were not available. Some are built for flood control or water supply, and some are built for recreation or aesthetics. The design specifications would provide better estimates of damage from a dam failure. For example, the Amelia Earhart Dam was designed for flood control and is close to large urban development areas near the shore. The dam is therefore susceptible not only to fluvial flooding but also to ocean flooding such as storm surge worsened by rising sea levels, increasing the probability of overtopping and failure. The compounding effects of fluvial and ocean flooding, including sea level rise, are notably complex and were

not considered in this analysis. If the dam were to fail, the damage would be much higher than the effects of fluvial or ocean flooding alone.

- Estimating occurrence probabilities of 1,000- to 5,000-year events with 20 years of data, as done for this assessment, can result in less reliable solutions. Streamflow simulated at the project scale with bootstrapping (a statistical method for generating an artificial time series of flows based on a short period of record, enabling the creation of a longer time series) would improve the estimation of event occurrence for both the historical period and the future period, but would also require a significantly expanded level of effort.
- The analysis conducted here focuses on potential downstream effects of dam failure and addresses upstream effects only qualitatively. Upstream effects after a dam breach can include upstream flooding, bank erosion, and other impacts that compromise road crossings or other infrastructure. Existing information to characterize these effects' frequency or severity is limited.

5.8.3.5 List of High Hazard Dams in Massachusetts

Table 5.8-13 below lists high hazard dams in Massachusetts, their ownership, and their town and county locations.

Table 5.8-13. List of High Hazard Dams in Massachusetts

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00202	Buckley-Dunton Lake Dam	DCR—Dept. of Conservation & Recreation	Becket	Berkshire
MA00205	Palmer Brook Dam	Private	Becket	Berkshire
MA01051	Indian Lake Dam	Private	Becket	Berkshire
MA01063	Egypt Reservoir	Town of Dalton	Dalton	Berkshire
MA00223	Ashmere Lake Dam	DCR—Dept. of Conservation & Recreation	Hinsdale	Berkshire
MA00224	Belmont Reservoir Dam	Town of Hinsdale	Hinsdale	Berkshire
MA00225	Cleveland Brook Reservoir Dam	City of Pittsfield	Hinsdale	Berkshire
MA00226	Plunkett Reservoir Dam	Town of Hinsdale	Hinsdale	Berkshire
MA00227	Upper Sackett Reservoir Dam	City of Pittsfield	Hinsdale	Berkshire
MA00263	Laurel Lake Dam	Private	Lee	Berkshire

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00265	Leahy (Upper) Reservoir Dam	Town of Lee	Lee	Berkshire
MA00018	Lower Root Reservoir	Town of Lenox	Lenox	Berkshire
MA00019	Upper Root Reservoir	Town of Lenox	Lenox	Berkshire
MA00249	Lake Garfield Dam	Town of Monterey	Monterey	Berkshire
MA00256	Thousand Acre Lake Dam	DCR—Dept. of Conservation & Recreation	New Marlborough	Berkshire
MA00281	Windsor Lake Dam	City of North Adams	North Adams	Berkshire
MA00282	Mount Williams Reservoir Dam	City of North Adams	North Adams	Berkshire
MA00283	Notch Reservoir Dam	City of North Adams	North Adams	Berkshire
MA00279	Eclipse Dam	City of North Adams	North Adams	Berkshire
MA00308	Otis Reservoir Dam	DCR—Dept. of Conservation & Recreation	Otis	Berkshire
MA00016	Onota Lake Dam	City of Pittsfield	Pittsfield	Berkshire
MA00309	Pontoosuc Lake Dam	DCR—Dept. of Conservation & Recreation	Pittsfield	Berkshire
MA00843	Pecks Lower Pond Dam	Private	Pittsfield	Berkshire
MA01061	Bel Air Dam	Private	Pittsfield	Berkshire
MA00288	West Lake Dam	DCR—Dept. of Conservation & Recreation	Sandisfield	Berkshire
MA00305	Abbey Lake Dam	DCR—Dept. of Conservation & Recreation	Sandisfield	Berkshire
MA00307	North Silver Lake Dam	DCR—Dept. of Conservation & Recreation	Sandisfield	Berkshire
MA00702	South Silver Dam	DCR—Dept. of Conservation & Recreation	Sandisfield	Berkshire

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA01052	Clam Lake Dam	DCR—Dept. of Conservation & Recreation	Sandisfield	Berkshire
MA00022	Stockbridge Bowl Dam	Town of Stockbridge	Stockbridge	Berkshire
MA00312	Goose Pond Dam	Goose Pond Dam Maintenance District	Tyringham	Berkshire
MA00313	Ashley Lake Reservoir	City of Pittsfield	Washington	Berkshire
MA00314	Farnham Reservoir Dam	City of Pittsfield	Washington	Berkshire
MA00318	Washington Mountain Lake Dam	DCR—Dept. of Conservation & Recreation	Washington	Berkshire
MA02561	October Mt. Lake Dam	DCR—Dept. of Conservation & Recreation	Washington	Berkshire
MA02588	Schoolhouse Lake Dam	DCR—Dept. of Conservation & Recreation	Washington	Berkshire
MA03281	October Mt. Lake Dike	DCR—Dept. of Conservation & Recreation	Washington	Berkshire
MA00732	Shaker Mill Pond Dam	Town of West Stockbridge	West Stockbridge	Berkshire
MA00844	Williamstown Reservoir Dam	Town of Williamstown	Williamstown	Berkshire
MA00841	Windsor Reservoir Dam	Town of Dalton	Windsor	Berkshire
MA01014	New Bedford Reservoir Dam	City of New Bedford	Acushnet	Bristol
MA01288	Manchester Pond Reservoir South Dike	City of Attleboro	Attleboro	Bristol
MA01289	Manchester Pond Reservoir East Dike Embkmt 3 and 4	City of Attleboro	Attleboro	Bristol
MA00860	Manchester Pond Reservoir Dam	City of Attleboro	Attleboro	Bristol

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA01073	Hebronville Pond Dam	Private	Attleboro	Bristol
MA01085	Noquochoke Lake Dam	City of Fall River	Dartmouth	Bristol
MA00793	Muddy Cove Pond Dam	Private	Dighton	Bristol
MA00785	Morse Pond Dam	Private	Easton	Bristol
MA02548	Quequechan Control Structure	City of Fall River	Fall River	Bristol
MA02411	Copicut Reservoir Dam	City of Fall River	Fall River	Bristol
MA03047	Cook Pond Dam	Private	Fall River	Bristol
MA00801	Monument Dam Pond	Private	Freetown	Bristol
MA00802	Terry Brook Reservoir Dam	City of Fall River	Freetown	Bristol
MA02433	Fulton Pond Dam	Town of Mansfield	Mansfield	Bristol
MA00855	Greenwood Lake Dam	FWS—U.S. Fish and Wildlife Service	North Attleborough	Bristol
MA00858	Hoppin Hill Reservoir Dam	City of Attleboro	North Attleborough	Bristol
MA00859	Whiting Pond Dam	Town of North Attleboro	North Attleborough	Bristol
MA00865	Falls Pond Dam	Town of North Attleboro	North Attleborough	Bristol
MA00814	Chartley Pond Dam	Town of Norton	Norton	Bristol
MA00815	Norton Reservoir Dam	Town of Norton	Norton	Bristol
MA02218	Old Grist Mill Pond Dam	Private	Seekonk	Bristol
MA00792	Somerset Reservoir Dam	Town of Somerset	Somerset	Bristol
MA00764	Big Bearhole Pond Dam	DCR—Dept. of Conservation & Recreation	Taunton	Bristol
MA00923	Morey's Bridge Dam	DCR—Dept. of Conservation & Recreation	Taunton	Bristol

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA02410	North Watuppa Pond Dam	City of Fall River	Westport	Bristol
MA00152	Lake Gardner Dam	Town of Amesbury	Amesbury	Essex
MA00744	Putnamville Reservoir West Dike	Salem-Beverly Water Supply Board	Danvers	Essex
MA00745	Putnamville Reservoir Dam	Salem-Beverly Water Supply Board	Danvers	Essex
MA01297	Putnamville Reservoir East Dike	Salem-Beverly Water Supply Board	Danvers	Essex
MA02299	Putmanville Reservoir South Dike	Salem-Beverly Water Supply Board	Danvers	Essex
MA00184	Fernwood Lake North Dam	City of Gloucester	Gloucester	Essex
MA00185	Upper Banjo Pond Dam	Private	Gloucester	Essex
MA00187	Babson Reservoir Dam	City of Gloucester	Gloucester	Essex
MA00155	Haskell Pond Dam	City of Gloucester	Gloucester	Essex
MA00162	Wallace Pond Dam	City of Gloucester	Gloucester	Essex
MA00163	Goose Cove Reservoir South Dam	City of Gloucester	Gloucester	Essex
MA01336	Fernwood Lake East Dam	City of Gloucester	Gloucester	Essex
MA01337	Fernwood Lake West Dam	City of Gloucester	Gloucester	Essex
MA01098	Goose Cove North Dam	City of Gloucester	Gloucester	Essex
MA01099	Goose Cove Northwest Dike	City of Gloucester	Gloucester	Essex
MA01100	Goose Cove Southwest Dike	City of Gloucester	Gloucester	Essex
MA00228	Millvale Reservoir Dam	City of Haverhill	Haverhill	Essex
MA00743	Lawrence Reservoir	City of Lawrence	Lawrence	Essex

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00232	Stevens Pond Outlet Dam	City of Lawrence	Lawrence	Essex
MA00235	Walden Pond East End Dam	City of Lynn	Lynn	Essex
MA00237	Birch Pond Dam	City of Lynn	Lynn	Essex
MA00238	Breeds Pond Outlet Dam #5	City of Lynn	Lynn	Essex
MA03163	Breeds Pond Lantern Rock Dike #4	City of Lynn	Lynn	Essex
MA03164	Breeds Pond Dike #8	City of Lynn	Lynn	Essex
MA03165	Breeds Pond Dike #10	City of Lynn	Lynn	Essex
MA03166	Breed's Pond Dike #11	City of Lynn	Lynn	Essex
MA03167	Breeds Pond Dike #12	City of Lynn	Lynn	Essex
MA00278	Lake Cochichewick Outlet Dam	Town of North Andover	North Andover	Essex
MA00191	Fountain Pond Dam	City of Peabody	Peabody	Essex
MA00726	Winona Pond Dam	City of Peabody	Peabody	Essex
MA00245	Hawkes Pond Outlet Dam	City of Lynn	Saugus	Essex
MA00246	Walden Pond Outlet Dam	City of Lynn	Saugus	Essex
MA00523	Ashfield Pond Dam	Town of Ashfield	Ashfield	Franklin
MA00461	New England Power Co. #3 Dam	Private	Buckland	Franklin
MA00460	New England Power Co. #4 Dam	Private	Charlemont	Franklin
MA01056	Roaring Brook Dam	South Deerfield Water Supply District	Conway	Franklin
MA00848	Turners Falls Canal Headgates	Private	Gill	Franklin
MA00847	Cabot Spillway	Private	Montague	Franklin
MA00849	Turners Falls Dam	Private	Montague	Franklin

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00051	Grandin Reservoir Dam	Private	Northfield	Franklin
MA00840	New England Power Co. #5 Dam	Private	Rowe	Franklin
MA00976	Bear Swamp Pumped Storage—Upper Dam	Private	Rowe	Franklin
MA00464	New England Power Co. #2 Dam	Private	Shelburne	Franklin
MA00508	Atkins Reservoir Dam	Town of Amherst	Shutesbury	Franklin
MA00510	Lake Wyola Dam	Town of Shutesbury	Shutesbury	Franklin
MA00520	West Whately Reservoir Dam	City of Northampton	Whately	Franklin
MA00521	Francis P. Ryan Dam	City of Northampton	Whately	Franklin
MA00528	Provin Mountain Reservoir	City of Springfield	Agawam	Hampden
MA01057	Black Brook Dam	Town of Russell	Blandford	Hampden
MA00968	Littleville Lake Dam	USACE—U.S. Army Corps of Engineers	Chester	Hampden
MA00530	Mountain Lake Dam	Private	Chicopee	Hampden
MA00720	Chicopee Reservoir Dam	DCR—Dept. of Conservation & Recreation	Chicopee	Hampden
MA00067	Borden Brook Reservoir	City of Springfield	Granville	Hampden
MA00068	Cobble Mountain Reservoir Dam	City of Springfield	Granville	Hampden
MA00707	Granville Reservoir Dam	City of Westfield	Granville	Hampden
MA00536	Hamilton Reservoir Dam	Town of Holland	Holland	Hampden
MA00070	Whiting Street Reservoir Dam	City of Holyoke	Holyoke	Hampden
MA00547	Ludlow Reservoir Dam	City of Springfield	Ludlow	Hampden

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00548	Cherry Valley Dam	City of Springfield	Ludlow	Hampden
MA00722	Indian Orchard Dam	Private	Ludlow	Hampden
MA00723	Red Bridge Dam	Private	Ludlow	Hampden
MA00724	Ludlow Manufact. Assoc. Dam	Private	Ludlow	Hampden
MA00551	Zero Manufacturing Company Dam	Private	Monson	Hampden
MA00965	Conant Brook Dam	USACE—U.S. Army Corps of Engineers	Monson	Hampden
MA00734	Westfield Reservoir Dam	City of Westfield	Montgomery	Hampden
MA00562	Diamond International Corp Upper Dam	Private	Palmer	Hampden
MA00569	Watershops Pond Dam	City of Springfield	Springfield	Hampden
MA00571	Lower Van Horn Reservoir Dam	City of Springfield	Springfield	Hampden
MA00604	Arm Brook Dam	City of Westfield	Westfield	Hampden
MA00605	Powdermill Brook Dam	City of Westfield	Westfield	Hampden
MA00610	West Parish Filter #3 Dam	City of Springfield	Westfield	Hampden
MA00063	Factory Hollow Dam	Town of Amherst	Amherst	Hampshire
MA00588	Quabbin Winsor Dam	DCR—Dept. of Conservation & Recreation	Belchertown	Hampshire
MA00058	Upper Highland Lake Dam	DCR—Dept. of Conservation & Recreation	Goshen	Hampshire
MA00598	Lower Highland Lake Dam	DCR—Dept. of Conservation & Recreation	Goshen	Hampshire
MA00969	Knightville Dam	USACE—U.S. Army Corps of Engineers	Huntington	Hampshire

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00753	Roberts Meadow Lower Reservoir Dam	City of Northampton	Northampton	Hampshire
MA00754	Paradise Pond Dam	Private	Northampton	Hampshire
MA00760	Roberts Meadow Upper Reservoir Dam	City of Northampton	Northampton	Hampshire
MA00761	Roberts Meadow Middle Reservoir Dam	City of Northampton	Northampton	Hampshire
MA00583	Mt. Holyoke College Upper Pond Dam	Private	South Hadley	Hampshire
MA00584	Mt. Holyoke College Lower Pond Dam	Private	South Hadley	Hampshire
MA00585	Marcalus Manufacturing Company Dam	Private	South Hadley	Hampshire
MA00586	Leaping Well Reservoir Dam	Town of South Hadley	South Hadley	Hampshire
MA00600	Hillside Beach Dam	Private	South Hadley	Hampshire
MA00973	Holyoke Dam	City of Holyoke	South Hadley	Hampshire
MA00499	Tighe Carmody Reservoir Dam	City of Holyoke	Southampton	Hampshire
MA00590	Quabbin Goodnough Dike	DCR—Dept. of Conservation & Recreation	Ware	Hampshire
MA00595	Pine Island Lake Dam	Private	Westhampton	Hampshire
MA00082	Mountain Street Reservoir Dam	City of Northampton	Williamsburg	Hampshire
MA00771	Arlington Reservoir Dam	Town of Arlington	Arlington	Middlesex
MA00334	Ashby Reservoir Dam	City of Fitchburg	Ashby	Middlesex
MA02518	Damon Pond Dam	DCR—Dept. of Conservation & Recreation	Ashby	Middlesex

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00436	Mill Pond Dam	Town of Ashland	Ashland	Middlesex
MA00437	Hopkinton Reservoir Dam	DCR—Dept. of Conservation & Recreation	Ashland	Middlesex
MA00438	Hopkinton State Park Swimming Pool Dam	DCR—Dept. of Conservation & Recreation	Ashland	Middlesex
MA00439	Ashland Reservoir Dam	DCR—Dept. of Conservation & Recreation	Ashland	Middlesex
MA01121	Mill Pond Dam	Town of Burlington	Burlington	Middlesex
MA01123	Mill Pond South Dike	Town of Burlington	Burlington	Middlesex
MA00337	Framingham #1 Reservoir	DCR—Dept. of Conservation & Recreation	Framingham	Middlesex
MA00338	Framingham #2 Reservoir	DCR—Dept. of Conservation & Recreation	Framingham	Middlesex
MA00339	Framingham Reservoir #3 Dam	DCR—Dept. of Conservation & Recreation	Framingham	Middlesex
MA00340	Central Street Dam	Private	Framingham	Middlesex
MA00740	Lake Cochituate Dam	DCR—Dept. of Conservation & Recreation	Framingham	Middlesex
MA03249	Constance M. Fiske Flood Retarding Dam	DCR—Dept. of Conservation & Recreation	Framingham	Middlesex
MA00808	Lost Lake Dam	Town of Groton	Groton	Middlesex
MA00444	Houghton Pond Dam	Town of Holliston	Holliston	Middlesex
MA00446	Echo Lake Dam	Private	Hopkinton	Middlesex
MA00448	Main Street Dam	Private	Hudson	Middlesex
MA01188	Lowell Reservoir Dam	City of Lowell	Lowell	Middlesex
MA00449	Fort Meadow Reservoir Dam	City of Marlborough	Marlborough	Middlesex

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00451	Williams Lake Dam	City of Marlborough	Marlborough	Middlesex
MA00452	Hager Pond Dam	Private	Marlborough	Middlesex
MA01195	Tyler Dam	DCR—Dept. of Conservation & Recreation	Marlborough	Middlesex
MA00453	South Reservoir Dam	Town of Winchester	Medford	Middlesex
MA00454	Wrights Pond Dam	City of Medford	Medford	Middlesex
MA01278	South Reservoir East Dike	Town of Winchester	Medford	Middlesex
MA01279	South Reservoir West Dike	Town of Winchester	Medford	Middlesex
MA00341	Charles River Dam at South Natick	Town of Natick	Natick	Middlesex
MA01111	Waban Hill Reservoir Dam	DCR—Dept. of Conservation & Recreation	Newton	Middlesex
MA00374	Turner Dam	Private	Pepperell	Middlesex
MA03306	Fells Reservoir Dam—#3	DCR—Dept. of Conservation & Recreation	Stoneham	Middlesex
MA03310	Fells Reservoir Dam—#8	DCR—Dept. of Conservation & Recreation	Stoneham	Middlesex
MA01006	Ames Pond Dam	Private	Tewksbury	Middlesex
MA01296	Ames Pond Dike A	Private	Tewksbury	Middlesex
MA00293	Stony Brook Reservoir Dam	City of Cambridge	Waltham	Middlesex
MA00345	Moody Street Dam	DCR—Dept. of Conservation & Recreation	Waltham	Middlesex
MA00750	Cambridge Reservoir Dam	City of Cambridge	Waltham	Middlesex
MA00782	Norumbega Reservoir Dam No. 1	DCR—Dept. of Conservation & Recreation	Weston	Middlesex

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00784	Schencks Pond Dam	DCR—Dept. of Conservation & Recreation	Weston	Middlesex
MA00798	Weston Reservoir Dam	DCR—Dept. of Conservation & Recreation	Weston	Middlesex
MA01209	Norumbega Reservoir Dike #4	DCR—Dept. of Conservation & Recreation	Weston	Middlesex
MA03314	Norumbega Reservoir East Dike	DCR—Dept. of Conservation & Recreation	Weston	Middlesex
MA00457	North Reservoir Dam	Town of Winchester	Winchester	Middlesex
MA00823	Great Pond Upper Reservoir Dam	Tri-Town Water Board	Braintree	Norfolk
MA00827	Old Quincy Reservoir Dam	DCR—Dept. of Conservation & Recreation	Braintree	Norfolk
MA00828	Great Pond Dam	Tri-Town Water Board	Braintree	Norfolk
MA01292	Smelt Brook Dam	Weymouth/ Braintree Regional Recreation—Conservation District	Braintree	Norfolk
MA03102	Armstrong Pond Dam	Private	Braintree	Norfolk
MA03343	Brookline Reservoir Dam	Town of Brookline	Brookline	Norfolk
MA01280	Aaron River Dam	Town of Cohasset	Cohasset	Norfolk
MA02569	Centennial Dam	DCR—Dept. of Conservation & Recreation	Dedham	Norfolk
MA01112	Rosemary Lake Dam	Town of Needham	Needham	Norfolk
MA00169	Willett Pond Dam	Private Association or other non-profit	Norwood	Norfolk
MA00805	Ellis Pond Dam	Town of Norwood	Norwood	Norfolk

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00826	Blue Hills Reservoir Dam	DCR—Dept. of Conservation & Recreation	Quincy	Norfolk
MA00804	Bird Pond Dam	Private	Walpole	Norfolk
MA02482	Cobbs Pond Dam	Town of Walpole	Walpole	Norfolk
MA03210	Allen Reservoir Dam	Town of Walpole	Walpole	Norfolk
MA00775	Whitmans Pond Dam	Town of Weymouth	Weymouth	Norfolk
MA02492	Iron Hill Dam	Town of Weymouth	Weymouth	Norfolk
MA00423	Thirty Acre Pond Dam	City of Brockton	Brockton	Plymouth
MA00426	Waldo Lake Dam	City of Brockton	Brockton	Plymouth
MA02400	Ellis Brett Pond Dam	City of Brockton	Brockton	Plymouth
MA00392	Russell Pond Dam	Private	Kingston	Plymouth
MA01032	Indian Brook Dam	DOT—Dept. of Transportation	Plymouth	Plymouth
MA00908	Holmes Playground Dam	Town of Plymouth	Plymouth	Plymouth
MA00478	First Herring Brook Reservoir Dam	Town of Scituate	Scituate	Plymouth
MA00027	Mill Pond Dam	DOT—Dept. of Transportation	Wareham	Plymouth
MA00030	Tihonet Pond #2 Dam	Private	Wareham	Plymouth
MA00150	Parker Mills Pond Dam	Town of Wareham	Wareham	Plymouth
MA02560	Rte. #25 #1 Dam	DOT—Dept. of Transportation	Wareham	Plymouth
MA01113	Chestnut Hill Reservoir Dam	DCR—Dept. of Conservation & Recreation	Boston	Suffolk
MA00002	Lower Naukeag Lake Dam	Town of Ashburnham	Ashburnham	Worcester
MA00003	Upper Naukeag Lake Dam	Town of Ashburnham	Ashburnham	Worcester

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00007	Winnekeag Lake Dam	Private	Ashburnham	Worcester
MA00010	Lake Wampanoag Dam	Private	Ashburnham	Worcester
MA00932	Cresticon Upper Dam	Private	Athol	Worcester
MA00934	Crescent Street Dam	Private	Athol	Worcester
MA00147	Auburn Pond Dam	Town of Auburn	Auburn	Worcester
MA00196	Upper Stoneville Reservoir Dam	Auburn Water District	Auburn	Worcester
MA00198	Dark Brook Reservoir Dam	Auburn Water District	Auburn	Worcester
MA00126	Lower Stoneville Pond Dam	Auburn Water District	Auburn	Worcester
MA02730	Eddy Pond Dam	Town of Auburn	Auburn	Worcester
MA00091	South Barre Mill Pond Dam	Private	Barre	Worcester
MA00092	Powder Mill Pond Dam	Private	Barre	Worcester
MA00094	Barre Reservoir Dam	Private	Barre	Worcester
MA00962	Barre Falls Dam	USACE—U.S. Army Corps of Engineers	Barre	Worcester
MA01229	Lester G. Ross Dam	DCR—Dept. of Conservation & Recreation	Berlin	Worcester
MA03263	Wachusett Reservoir South Dike	DCR—Dept. of Conservation & Recreation	Boylston	Worcester
MA00101	Glen Echo Lake Dam	Town of Charlton	Charlton	Worcester
MA00964	Buffumville Dam	USACE—U.S. Army Corps of Engineers	Charlton	Worcester
MA00886	Wachusett Reservoir Dam	DCR—Dept. of Conservation & Recreation	Clinton	Worcester

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA01294	Wachusett Reservoir North Dike	DCR—Dept. of Conservation & Recreation	Clinton	Worcester
MA00200	Whitin Reservoir Dam	Whitin Reservoir Watershed District	Douglas	Worcester
MA00109	Lower Merino Pond Dam	Town of Dudley	Dudley	Worcester
MA00110	Merino Pond Dam	Town of Dudley	Dudley	Worcester
MA00871	Scott Reservoir Dam	City of Fitchburg	Fitchburg	Worcester
MA00872	Lovell Reservoir Dam	City of Fitchburg	Fitchburg	Worcester
MA00875	Greenes Pond Dam	City of Fitchburg	Fitchburg	Worcester
MA00876	Overlook Reservoir Dam	City of Fitchburg	Fitchburg	Worcester
MA00878	Snows Mill Pond Dam	Private	Fitchburg	Worcester
MA00879	McTaggarts Pond Dam	City of Fitchburg	Fitchburg	Worcester
MA01334	Lovell Reservoir Dike	City of Fitchburg	Fitchburg	Worcester
MA01236	Overlook Reservoir Dike	City of Fitchburg	Fitchburg	Worcester
MA02312	Falulah Reservoir Dam	City of Fitchburg	Fitchburg	Worcester
MA00117	Wrights Reservoir Dam	City of Gardner	Gardner	Worcester
MA00118	Cowee Pond Dam	City of Gardner	Gardner	Worcester
MA00119	Perley Brook Reservoir Dam	City of Gardner	Gardner	Worcester
MA00577	Fisherville Pond Dam	Private	Grafton	Worcester
MA00581	Pratts Pond Dam	Private	Grafton	Worcester
MA00619	Holden Reservoir Dam #2	City of Worcester	Holden	Worcester
MA00622	Kendall Reservoir Dam	City of Worcester	Holden	Worcester
MA00623	Pine Hill Reservoir Dam	City of Worcester	Holden	Worcester

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00929	Quinapoxet Reservoir Dam	City of Worcester	Holden	Worcester
MA00960	Holden Reservoir Dam #1	City of Worcester	Holden	Worcester
MA00979	Eagle Lake Dam	Private Association or other non-profit	Holden	Worcester
MA01022	Bickford Pond Dike	City of Fitchburg	Hubbardston	Worcester
MA00977	Kettle Brook Reservoir #2 Dam	City of Worcester	Leicester	Worcester
MA00978	Kettle Brook Reservoir #3 Dam	City of Worcester	Leicester	Worcester
MA00981	Rochdale Pond Dam	Private	Leicester	Worcester
MA00982	Greenville Pond Dam	Town of Leicester	Leicester	Worcester
MA00983	Stiles Reservoir Dam	Stiles Lake Water District	Leicester	Worcester
MA00989	Kettle Brook Reservoir #1 Dam	City of Worcester	Leicester	Worcester
MA00990	Lynde Brook Reservoir Dam	City of Worcester	Leicester	Worcester
MA01290	Lynde Brook Reservoir Dike	City of Worcester	Leicester	Worcester
MA02804	Smiths Pond Dam	Private	Leicester	Worcester
MA00869	Fall Brook Reservoir Dam and Dike	City of Leominster	Leominster	Worcester
MA00870	Notown Reservoir Dam	City of Leominster	Leominster	Worcester
MA00882	Rockwell Pond Dam	City of Leominster	Leominster	Worcester
MA00883	Pierce Pond Dam	Private	Leominster	Worcester
MA00866	Lake Samoset Dam	Private	Leominster	Worcester
MA01240	Notown Reservoir Dike	City of Leominster	Leominster	Worcester
MA00851	Hickory Hills Lake Dam	Private	Lunenburg	Worcester
MA00455	Lake Shirley Dam	Town of Lunenberg	Lunenburg	Worcester

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00145	Ramshorn Pond Dam	Town of Millbury	Millbury	Worcester
MA00996	Cold Harbor Brook Dam	DCR—Dept. of Conservation & Recreation	Northborough	Worcester
MA00998	Hop Brook Dam	DCR—Dept. of Conservation & Recreation	Northborough	Worcester
MA00896	Linwood Pond Dam	Private	Northbridge	Worcester
MA00675	Chimney Pond Dam	Private	Oxford	Worcester
MA00967	Hodges Village Dam	USACE—U.S. Army Corps of Engineers	Oxford	Worcester
MA00677	Kettle Brook Reservoir #4 Dam	City of Worcester	Paxton	Worcester
MA01021	Bickford Pond Dam	City of Fitchburg	Princeton	Worcester
MA00963	Birch Hill Dam	USACE—U.S. Army Corps of Engineers	Royalston	Worcester
MA00970	Tully Lake Dam	USACE—U.S. Army Corps of Engineers	Royalston	Worcester
MA00931	Moulton Pond Dam	Private	Rutland	Worcester
MA00741	Sudbury Reservoir Dam	DCR—Dept. of Conservation & Recreation	Southborough	Worcester
MA00694	Cohasse Brook Reservoir Dam	Town of Southbridge	Southbridge	Worcester
MA00972	Westville Lake Dam	USACE—U.S. Army Corps of Engineers	Southbridge	Worcester
MA00997	Lensdale Pond Dam	Private	Southbridge	Worcester
MA00698	Sugden Reservoir Dam	Town of Spencer	Spencer	Worcester
MA00699	Lake Whittemore Dam	Private	Spencer	Worcester
MA02379	Muzzy Meadow Dam	Private	Spencer	Worcester
MA02583	Moose Hill Pond Dam	DCR—Dept. of Conservation & Recreation	Spencer	Worcester

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00966	East Brimfield Lake Dam	USACE—U.S. Army Corps of Engineers	Sturbridge	Worcester
MA00955	Manchaug Pond Dam	Private	Sutton	Worcester
MA00957	Stevens Pond Dam	Town of Sutton	Sutton	Worcester
MA00627	Lake Maspenock Dam	Town of Hopkinton	Upton	Worcester
MA00935	Rice City Pond Dam	DCR—Dept. of Conservation & Recreation	Uxbridge	Worcester
MA00971	West Hill Dam	USACE—U.S. Army Corps of Engineers	Uxbridge	Worcester
MA02916	Rivulet Village Pond Dam	Private	Uxbridge	Worcester
MA01000	George H. Nichols Multipurpose Dam	DCR—Dept. of Conservation & Recreation	Westborough	Worcester
MA00638	Crocker Pond Dam	Private	Westminster	Worcester
MA00639	Westminster Reservoir Dam	Private	Westminster	Worcester
MA00641	Wyman Pond Compensating Reservoir Dam	City of Fitchburg	Westminster	Worcester
MA00630	Whites Mill Pond Dam	Private	Winchendon	Worcester
MA00631	Lake Monomonac Dam	Town of Winchendon	Winchendon	Worcester
MA00633	Whitney Pond Dam	Town of Winchendon	Winchendon	Worcester
MA02345	Red Dam	Town of Winchendon	Winchendon	Worcester
MA00139	Quinsigamond Pond Dam	City of Worcester	Worcester	Worcester
MA00149	Green Hill Pond Dam	City of Worcester	Worcester	Worcester
MA00120	Coes Reservoir Dam	City of Worcester	Worcester	Worcester
MA00122	Patch Reservoir Dam	City of Worcester	Worcester	Worcester

National Inventory of Dams ID Number	Dam Name	Owner	Town	County
MA00123	Cook’s Pond Dam	Private Association or other non-profit	Worcester	Worcester
MA03341	Patch Pond Dam	City of Worcester	Worcester	Worcester

Source: ERG analysis using data from MassGIS (2012).

Chapter 5. Risk Assessment and Hazard Analysis

Hurricanes/Tropical Cyclones

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5.9 Hurricanes/Tropical Cyclones

5.9.1 Hurricanes/Tropical Cyclones Problem Statement

Hurricanes and tropical storms can affect the entire Commonwealth; however, due to the combination of high winds, tidal surge, and dense development along the coast, coastal areas and habitats are the most exposed to damage based on historical storm paths. The direction, duration, and composition of a storm can have a significant impact on how these events affect the coast. Local coastal infrastructure—such as buried sewer lines, wastewater treatment facilities, and coastal roads—is at high risk of damage. Inland areas in floodplains and low-lying areas—as well as forest dominated by trees with shallow roots and forests along exposed slopes—are also at risk of flooding and wind damage.

Warming ocean temperatures are causing longer and more intense tropical cyclones, which are projected to increase the damage to infrastructure, homes, natural resources, and businesses across the Commonwealth, with disproportionate impacts on sensitive assets and Environmental Justice and other priority populations located along the coast, older construction, and toxic and hazardous materials that could be mobilized during an event. Belowground living spaces and utilities, as well as critical assets on roofs and outside on the ground, are also at greater risk. Additionally, tropical cyclones are likely to disproportionately affect under-resourced and underrepresented communities, who are less able to prepare for, respond to, and recover from a hurricane.

5.9.2 Hurricanes/Tropical Cyclones Risk Assessment

5.9.2.1 General Background

Tropical cyclones (tropical depressions, tropical storms, and hurricanes) form over the warm, moist waters of the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. Tropical cyclones are categorized based on sustained wind speed measured by miles per hour (mph); wind gusts may exceed the sustained winds and cause more severe localized damage (NOAA, 2021).

- A tropical depression is declared when there is a low-pressure center with sustained winds of 38 mph or less.
- A tropical storm is a named event defined as having sustained winds from 39 to 73 mph.

- A storm becomes a hurricane if sustained winds reach 74 mph or greater. The Saffir-Simpson scale ranks hurricanes from Category 1 (74 to 95 mph sustained wind speed) to Category 5 (156 mph or more). Category 3, 4, and 5 hurricanes are considered "major" hurricanes.

The term "tropical" refers both to the origin of these systems, which usually form in tropical regions of the globe, and their formation in maritime tropical air masses. The term "cyclone" refers to such storms' cyclonic nature, with counterclockwise wind flow in the Northern Hemisphere and clockwise wind flow in the Southern Hemisphere.

A tropical storm system is characterized by a low-pressure center and numerous thunderstorms that produce strong winds and heavy rain. Tropical storms strengthen when water evaporates from the ocean and is released as the saturated air rises, resulting in condensation of the water vapor contained in the moist air. These storms are fueled by a different heat mechanism than other cyclonic windstorms, such as nor'easters and polar lows. The characteristic that separates tropical cyclones from other cyclonic systems is that at any height in the atmosphere, the center of a tropical cyclone will be warmer than its surroundings—a phenomenon called "warm core" storm systems.

5.9.2.2 Hazard Description

Hurricanes begin as tropical storms over the warm waters of the Atlantic Ocean, off the coast of West Africa, and over the Pacific Ocean near the equator. As the moisture evaporates, it rises until enormous amounts of heated, humid air are twisted high in the atmosphere. The winds begin to circle counterclockwise north of the equator or clockwise south of the equator. The center of the hurricane is called the eye. When water temperatures are at least 80°F, hurricanes can grow, generating significant amounts of energy that is released in the form of thunderstorms, intense rainfall, and damaging winds. High winds create a dangerous storm surge in which the water rises above the normal astronomical tide. Hurricanes can range from 50 to 500 miles across. Hurricane Allen in 1980 took up the entire Gulf of Mexico.

In the lower latitudes, hurricanes tend to move from east to west. However, when a storm drifts further north, the westerly flow at the mid-latitudes tends to cause the storm to curve toward the north and east. When this occurs, the storm may accelerate its forward speed. This is one of the reasons why weaker hurricanes, tropical storms, or post-tropical systems can cause a variety of impacts across New England.

There are generally two source regions for storms that have the potential to strike New England: (1) off the Cape Verde Islands near the west coast of Africa and (2) in the Bahamas. The Cape Verde–originating storms tend to be very large in diameter, since they have a week or more to grow as they traverse westward along the warm equatorial waters of the Atlantic. The Bahamas-originating storms tend to be smaller, but they can be just as powerful and can reach New England in a day or two.

Storms that reach the Northeast tend to exhibit a pattern wherein areas east of the track of the storm experience limited rain but the worst winds and storm surge. High winds create a dangerous storm surge and water rises above the normal astronomical tide. Intense rainfall and flooding occurs most often to the west of the track of the storm (Vallee, n.d.). An additional threat is the possibility of tornado generation, which generally occurs in the outer bands to the north and east of the storm, from a few hours to 15 hours prior to landfall.

The official hurricane season runs from June 1 to November 30. In New England, these storms are most likely to occur in August, September, and the first half of October due to the considerable amount of time for the waters south of Long Island to warm to the temperature necessary to sustain the storms as far north as Massachusetts. As the region progresses into the fall months, the upper-level jet stream has more dips, meaning that the steering winds might flow from the Great Lakes southward to the Gulf States and then back northward up the Eastern Seaboard. This pattern is conducive for capturing a tropical system over the Bahamas and accelerating it northward.

Recent research has shown that the start of Atlantic hurricane season is trending earlier due to warming ocean temperatures (Truchelut et al., 2022). The 2022 Atlantic hurricane season was the first since 2014 to not have a named storm before June 1 (Donegan, 2022). Four of the seven tropical storms to approach Massachusetts in the last 10 years have occurred in May, June, or July; the earliest tropical storm on record to pass by Massachusetts was Hurricane Ana on May 12, 2015 (NOAA, n.d.-b). An average Atlantic hurricane season has 14 named storms. In 2022, the National Oceanic and Atmospheric Administration (NOAA) predicted an above-average season for the seventh year in a row, due in part to warmer-than-average ocean temperatures (Bray, 2022).

5.9.2.2.1 Location

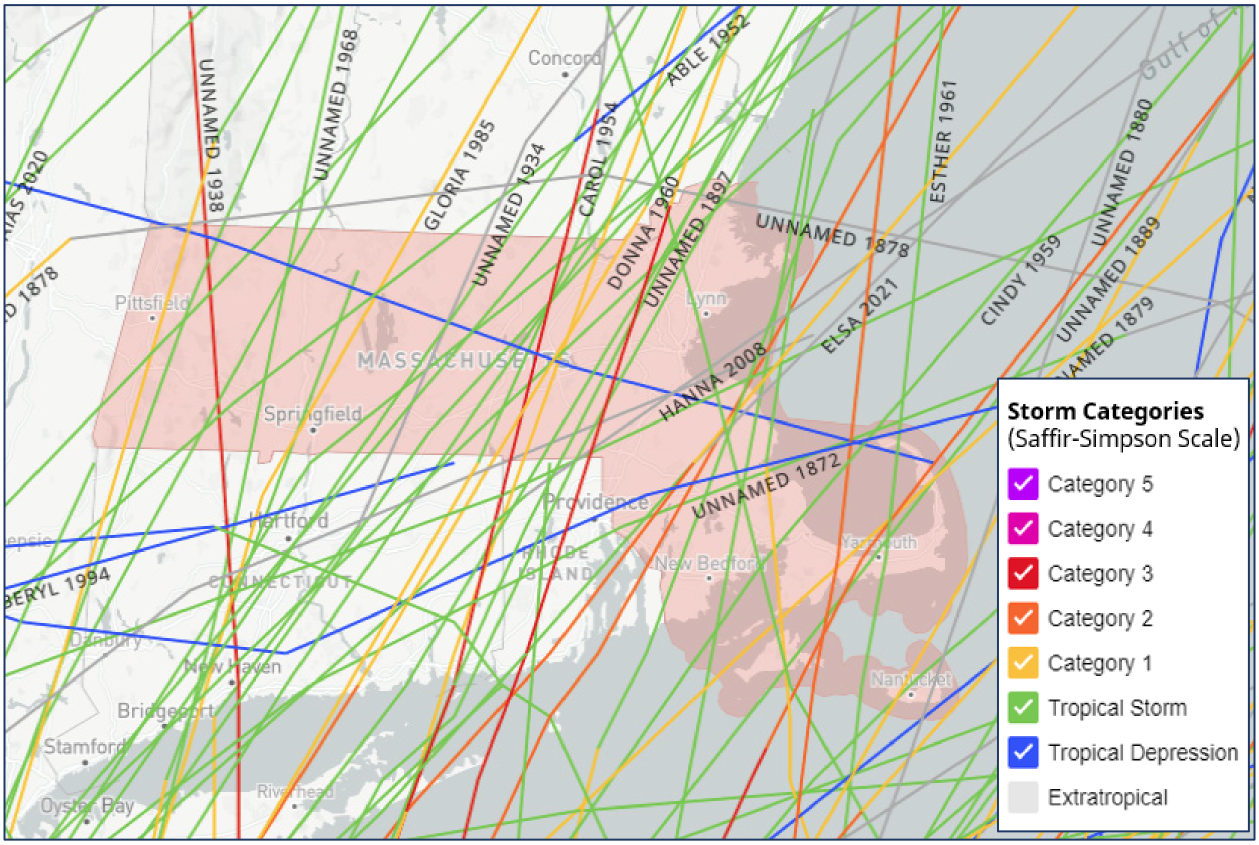
The entire Commonwealth is vulnerable to hurricanes and tropical storms, with the specific areas affected in any single hurricane event depending on the track of a storm. Coastal areas are more susceptible to damage due to the combination of high winds and tidal storm surge. There are several ways to define a "coastal" area in Massachusetts. For example, the Massachusetts Office of Coastal Zone Management serves 78 coastal communities that fall within their defined coastal zone boundary. The *2022 Massachusetts Climate Change Assessment* (MA Climate Assessment) defined coastal regions to include Boston Harbor; the North and South Shores; and the Cape, Islands, and South Coast. The population in these regions makes up nearly 43 percent (3 out of 7 million) of the Commonwealth's total population.

As coastal development continues to increase in Massachusetts, the amount of property and infrastructure exposed to hurricanes and tropical storms will increase, as will the associated damage costs, injuries, loss of life, and disruption to communities and businesses. Inland areas are vulnerable to wind damage from hurricanes, and locations in or adjacent to floodplains, low-lying areas, or historic wetlands are also at risk of flooding from intense rainfall.

NOAA's Historical Hurricane Tracks tool is a public interactive mapping application that displays Atlantic Basin and East-Central Pacific Basin tropical cyclone data. As of 2022, this tool tracks tropical cyclones from 1842 to 2021. Figure 5.9-1 shows that the paths of these storms vary across the Commonwealth but are more likely to occur near the coast. More distant storms can still affect Massachusetts; for example, the track of Hurricane Sandy never came closer than 200 nautical miles to Massachusetts, but still caused moderate coastal flooding and wind damage in the Commonwealth (NWS, n.d.).

The location and path of a tropical cyclone can be a major factor in the severity of its impacts, especially storm surge. Most storm surge happens when the force of the wind, called wind stress, pushes water toward the shore. For hurricanes in the northern hemisphere, this occurs most intensely in the right-front quadrant of the storm, where the winds are strongest due to the combination of a storm's counterclockwise rotation and forward motion.

Because of this pattern, regions in Massachusetts south of Cape Cod are most at risk of flooding from hurricane-induced storm surge, especially in south-facing bays. Storm surge vulnerability is generally higher in Taunton River, Buzzards Bay, the Cape Cod Canal, and Cape Cod Bay (Commonwealth of Massachusetts, 2019). A particularly serious scenario would be if the eye of a major hurricane tracked west of Buzzards Bay. This could produce a potential storm surge of 25 feet or more at the upper part of Buzzards Bay. According to the NOAA National Weather Service, this was most likely the scenario that occurred in the Colonial Hurricane of 1635, which produced a storm surge of 20 feet at the upper part of the Bay. More recent hurricanes that went west or up Buzzards Bay also serve as good examples: the Great New England Hurricane (1938), Hurricanes Edna and Carol (1954), and Hurricane Bob (1991).



Source: NOAA (n.d.-b).

Figure 5.9-1. Historical hurricane tracks in Massachusetts, 1842–2022.

5.9.2.2.2 *Previous Ocurrences and Frequency*

Previous Occurrences

Hurricanes and related events occur somewhat regularly in Massachusetts. Notable events since the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP) include Tropical Depression Henri (2021) and Tropical Storm Elsa (2021). All historical events are listed in Appendix 5.A.

The Commonwealth has not historically been exposed to any Category 4 or 5 hurricanes; however, Category 3 storms have caused widespread damage, disruption, and loss from storm surge, winds, and rainfall. Winds from Category 3 storms have caused extensive damage to homes and other structures, requiring people to relocate or engage in significant repairs and restoration. The Great Hurricane of 1938, for example, brought the strongest winds ever recorded in Massachusetts; it destroyed 8,900 buildings and damaged another 15,000 throughout New England, largely in coastal communities. Hurricane Bob, which reached Massachusetts as a Category 2 storm, caused $39 million in damage in the Commonwealth alone (Massachusetts Office of Coastal Zone Management, n.d.).

According to NOAA's Historical Hurricane Tracker tool, 97 hurricane or tropical storm events have occurred within 65 nautical miles of Massachusetts between 1842 and 2021 (NOAA, n.d.-b). There were no hurricanes in 2022 that came close to Massachusetts (NOAA, n.d.-a). There have been eight hurricanes strong enough to receive Federal Emergency Management Agency (FEMA) emergency or major disaster declarations in Massachusetts since 1954. Most recently, Tropical Storm Henri induced an emergency declaration for the Mashpee Wampanoag Tribe of Massachusetts.

Frequency

Tropical storms and hurricanes have occurred in the proximity of the Commonwealth about once every two years on average. NOAA's National Hurricane Center estimates that a Category 3 hurricane could occur once every 50–60 years (NOAA, n.d.-e).

Potential Effects of Climate Change on Hurricanes and Tropical Cyclones

Both historic events and models of future conditions suggest that climate change will cause the intensity of tropical storms and hurricanes to increase, though uncertainty remains over the relationship between the frequency of tropical cyclones and climate change. The IPCC reports low confidence in observations of long-term changes to tropical cyclone frequency, partly due to inadequate historical data (IPCC, 2021). There is some evidence of a relative increase in the frequency of tropical cyclones in the Atlantic, resulting from a poleward shift in hurricane activity due to warmer temperatures (Shelton, 2022). Together with the increasing intensity and duration of tropical cyclones, these changes are likely to lead to significant changes in this hazard for the Atlantic coast (Dinan, 2017; Marsooli et al., 2019). A recent study of Atlantic tropical cyclones downscaled from climate reanalysis indicates increasing activity over the past 150 years, with a significant uptick since 1990 (Emanuel, 2021). The MA Climate Assessment identifies a possible increase in tropical cyclone frequency of nearly 50 percent by the end of the century (Commonwealth of Massachusetts, 2022).

5.9.2.2.3 Severity/Intensity

Hurricanes are measured according to the Saffir-Simpson scale, described in Table 5.9-1 below, which categorizes hurricanes from 1 (minimal) to 5 (catastrophic) based on their intensity. This is used to estimate the property damage and flooding expected from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf and the shape of the coastline in the landfall region. All winds are assessed using the U.S. one-minute average, meaning the highest wind that is sustained for one minute.

Table 5.9-1. The 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	111–129	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	130–156	Extreme: Extensive damage is done to roofs, windows, and doors; roof systems on small buildings completely fail; and some curtain walls fail.
5	>157	Catastrophic: Roof damage is considerable and widespread, window and door damage is severe, there are extensive glass failures, and entire buildings could fail.

Source: NOAA (n.d.-d).

Tropical storms (39–73 mph) and tropical depressions (38 mph or less), while generally less dangerous than hurricanes, often cause widespread damage, disruption, and injury and loss of life. Tropical storms can produce extremely powerful wind gusts and torrential rain, high waves, damaging storm surge, and tornadoes. These storms develop over large bodies of warm water but can lose their strength as they move over land due to increased surface friction and loss of the warm ocean as an energy source. The heavy rains that are often associated with a tropical storm can produce significant inland flooding, and storm surges can produce extensive coastal and inland flooding up to 25 miles from the coastline. Widespread and lengthy power outages are often a result of these events. For example, after Hurricane Irene passed through the region as a tropical storm in late August 2011, many areas of the Commonwealth were without power for more than five days.

Research from Florida State University has found that, since 1981, the maximum wind speed of the most powerful hurricanes has increased markedly because the warming ocean is providing more energy for storms (Kang & Elsner, 2015). Higher ocean temperatures may cause storm systems to become larger and last longer. Rising global ocean temperatures are thought to be expanding the parts of the world susceptible to hurricanes. Additionally, warmer air can hold more water vapor, which means the rate of rainfall during a hurricane will likely increase with climate change. One study found that hurricane rainfall rates were projected to rise 7 percent for every degree Celsius increase in tropical sea surface temperature (Wang et al., 2017). An assessment of future tropical cyclone climatology estimates the northeastern U.S. could see drastic increases in the joint impacts from extreme rainfall and storm surge by the end of the century; these results hold true even in simulations with no future changes in frequency of tropical cyclone events (Gori et al., 2022). The IPCC states it is likely that the global proportion of Category

3–5 events has increased and rapid intensification events have become more frequent in the past 40 years (IPCC, 2021). Section 5.5 (Coastal Flooding) will also exacerbate the impact of storm surge from storms of all severities, with increased flood heights in low-lying coastal areas and, therefore, floodwaters reaching further inland.

5.9.2.2.4 Warning Time

The National Hurricane Center issues tropical cyclone advisory updates at least every six hours once a storm has formed in the Atlantic. A tropical storm warning is issued when tropical storm conditions (sustained winds of 39 to 73 mph) are expected in a specified area within 36 hours. A hurricane warning is issued when hurricane conditions (sustained winds of 74 mph or greater) are expected in a specified area; for hurricanes, the warning is issued 36 hours in advance of the arrival of tropical-storm force winds. A hurricane or tropical storm watch means that hurricane or tropical storm conditions are possible in a specified location; a watch is issued 48 hours in advance of the anticipated onset of tropical-storm force winds (NOAA, n.d.-c).

In order to reduce damage, disruption, and loss, all preparations that are possible to carry out in the Commonwealth should be completed by the time a storm is at the latitude of North Carolina. Outer bands containing squalls with heavy showers and wind gusts can occur 12 to 24 hours in advance of the eye, which can cause coastal flooding and cut off exposed roadways and evacuation routes. Faster-moving storms can make preparations difficult; the 1938 hurricane raced from Cape Hatteras to the Connecticut coast in only eight hours. To reduce damage, disruption, and loss and limit the actions needed to prepare for these events, mitigation measures such as building code requirements for high winds and higher water levels; debris removal activities; safe storage of hazardous and toxic materials; and siting, designing, and retrofitting infrastructure and utilities to be resilient to high winds and floodwaters. Mitigation actions will limit the impacts of hurricanes on public health and safety, cultural and historic resources, the natural environment, and communities and businesses and make recovery faster and less costly.

5.9.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

As noted previously, the entire Commonwealth is vulnerable to hurricanes and tropical storms, and this is reflected in hazard mitigation plans from municipalities across Massachusetts. Even towns that have not historically been affected by a hurricane still note that a future event might cause significant damage. Flood risks from hurricanes are also identified as a concern by local municipalities in both coastal and inland areas. The Great New England Hurricane of 1938 is cited as a devastating example from both coastal and inland jurisdictions. Tropical Storm Irene is a more recent example of a hurricane that resulted in greater impacts to western Massachusetts than communities on the coast. Transportation, utility, and property damage are typically discussed as the primary risks from hurricanes in these plans. Table 5.9-2 below provides examples of how local plans have addressed hurricanes.

Table 5.9-2. Highlight of Local Plans and Municipal Vulnerability Preparedness Program Planning Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Multi-Hazard Mitigation Plan Update, town of Williamstown, June 2019	• Heavy rains, flooding, and high winds pose a risk to people and property throughout Williamstown. • In 2011, Tropical Storm Irene caused significant damage in Williamstown and throughout Berkshire County.	• Roads and bridges were vulnerable to damage from flooding of the Deerfield and Hoosic Rivers, disrupting transportation throughout the region. • Residents of The Spruces Mobile Home Park—mostly low-income and elderly people—lost their homes during Tropical Storm Irene.	• Hazus estimates $163,370 in building-related economic losses due to hurricane winds. Additional losses from hurricane flooding are not estimated.
Town of Erving Hazard Mitigation Plan (draft), October 2019	• No hurricane has ever tracked directly over Erving, but Franklin County has sustained damage in several prior events. • Overall, the entire town has high vulnerability to a tropical storm or hurricane, especially in areas prone to flooding.	• Populations near toxic storage facilities (e.g., Erving Paper Mill). • Wastewater treatment plants in the 100-year floodplain of the Millers River. • Elderly and disabled residents are particularly vulnerable. • The town's communication and energy infrastructure is at risk of wind damage.	• Not included

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Hazard Mitigation Plan 2022 Update, city of Somerville, January 2022	• Hurricanes historically are a medium-frequency event in Somerville. • A Category 4 hurricane has not been recorded in Massachusetts but could be possible with climate change.	• Key concerns: power outages, property damage, impacts to businesses, street closures, emergency access.	• Hazus estimates $52.5 million of property damage from a Category 2 hurricane and $246.6 million from a Category 4 hurricane.
Dukes County Multi-Jurisdiction Hazard Mitigation Plan Update: 2021, May 2022	• Hurricanes that reach Dukes County are often moving with high forward speed, which can increase intensity of the storm. • Storm surge creates the most damaging flood impacts in the area.	• Water-dependent critical infrastructure (e.g., ferry terminals) are most vulnerable. • The south shore of the island experiences the highest erosion rates, although greater development creates higher vulnerability to erosion on the north shore.	• $1.8 billion in National Flood Insurance Program claim payments since February 2020; 13 repetitive loss claims are responsible for 57% of the cost of all claims.
North Adams Hazard Mitigation and Climate Adaptation Plan, January 2021	• Several tropical depressions, tropical storms, and hurricanes have been recorded passing directly through Berkshire County. Tropical Storm Irene is a recent example.	• Low-income and elderly populations, who are limited by financial or physical ability to react, are especially vulnerable. • Loss of electricity due to downed power lines is a concern throughout North Adams; risk is reduced in the main commercial corridor, where power lines are buried underground.	• Not included

5.9.2.3 Secondary Hazards

Secondary hazards associated with hurricanes and tropical cyclones include coastal and riverine erosion, salinity intrusion, landslides, dam failure, mobilization of debris and contamination of water supplies, damage to wastewater treatment systems (including Title 5 subsurface systems), and tornadoes, all of which can increase the scale of damage, disruption, and loss.

5.9.2.4 Exposure and Vulnerability

The entire Commonwealth of Massachusetts may be exposed to wind and rainfall associated with hurricanes and tropical storms, depending on the path of a storm, while coastal areas have the additional risk of associated storm surge. Certain areas, types of buildings, and infrastructure are at greater risk than others, based on their proximity to the coast, shoreline characteristics, construction and materials, maintenance, age, and function. Storm surge from hurricanes or tropical storms poses one of the greatest risks to residents and property.

This analysis uses the framework defined by NOAA's Office for Coastal Management to discuss human populations located in coastal counties (NOAA, 2013). The framework identifies coastal counties as those "that are directly adjacent to the open ocean, major estuaries, and the Great Lakes, which due to their proximity to these waters, bear a great proportion of the full range of effects from coastal hazards and host the majority of economic production associated with coastal and ocean resources." Using NOAA's definition, eight out of the Commonwealth's 14 counties are coastal counties, and 74 percent of the total population (5.2 million out of 7.0 million) resides in a coastal county (Table 5.9-3 below). Following this approach, the Risk Assessment team conducted the analysis for hurricanes at the county level.

Table 5.9-3. Population Projections for Coastal Counties in Massachusetts

County	Population 2020	Projection 2030*	Projection 2040*	Population Change 2020–2040
Barnstable	213,505	199,466	176,007	-17.6%
Bristol	563,301	567,277	568,250	0.9%
Dukes	17,430	19,584	19,793	13.6%
Essex	787,038	816,022	827,531	5.1%
Middlesex	1,605,899	1,686,641	1,736,669	8.1%
Nantucket	11,212	11,804	12,212	8.9%
Norfolk	703,740	765,912	797,619	13.3%
Plymouth	518,597	534,464	539,424	4.0%
Suffolk	801,162	900,586	950,251	18.6%

Source: UMass Donahue Institute (2018).

* Projections are calculated from 2010 Census data.

In addition to changing climate conditions, future population distribution will affect hurricanes' impact on Massachusetts. All coastal counties, except for Barnstable, are projected to see some level of population growth in 2030 and 2040 compared to 2020 Census data. Suffolk County is projected to have nearly 150,000 new residents by 2040 (an 18.6 percent increase from 2020), and Middlesex County is expected to have over 130,000 new residents by 2040 (an 8.1 percent increase). Plymouth County, which includes some of the most vulnerable communities at the top of Buzzards Bay, is projected to have a smaller increase of around 20,000 residents (4 percent). Barnstable County, Cape Cod—another vulnerable geographical region—could see a significant decrease by 2040 (UMass Donahue Institute, 2018). The increasing population in most coastal counties makes hurricane mitigation measures an important consideration during siting and design of new construction, including climate-resilient building codes, and for programs to retrofit existing homes to meet new standards.

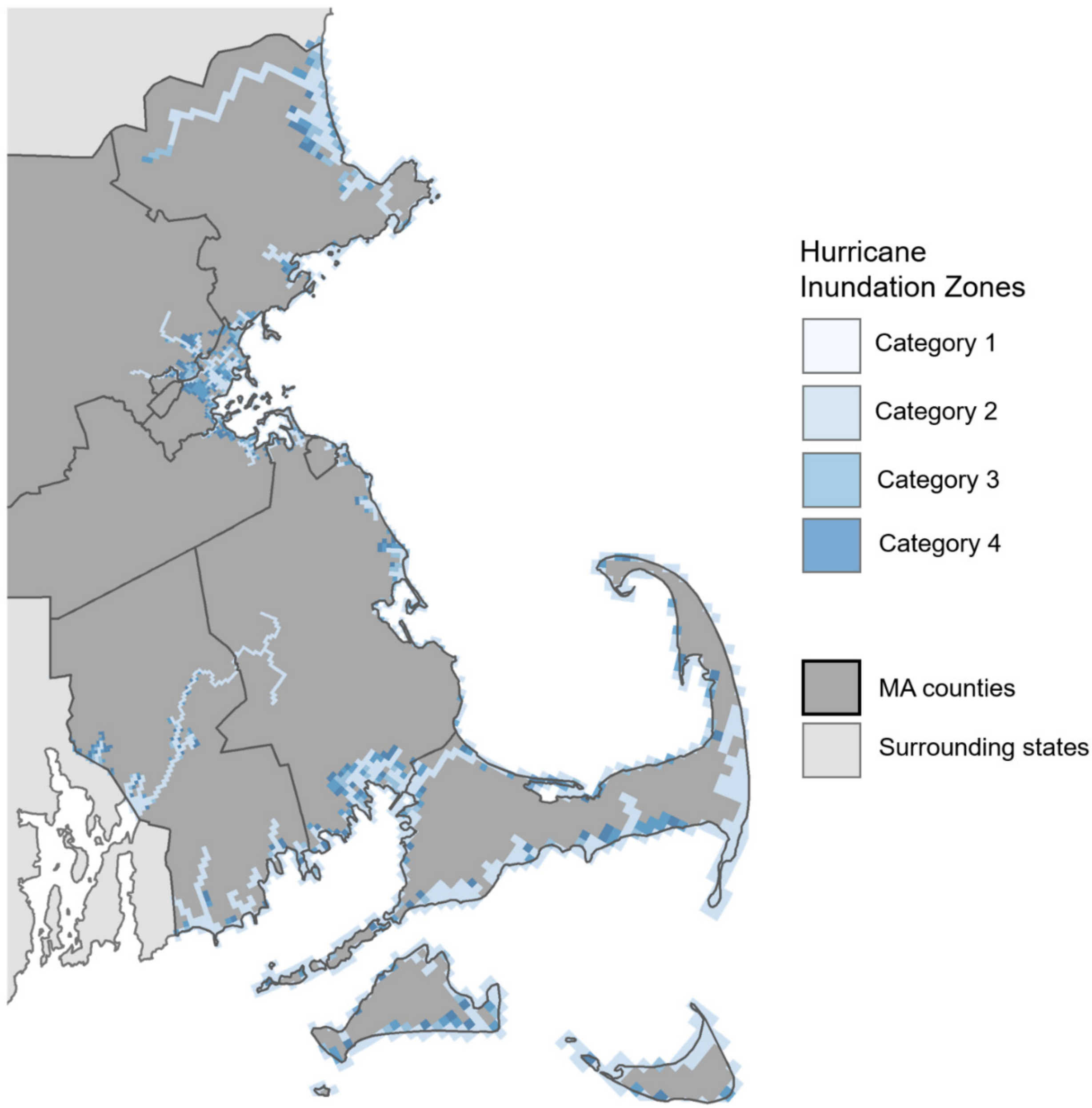
Table 5.9-4 below summarizes the priority impacts and high-consequence vulnerabilities related to the hurricane hazard, using themes identified in the 2023 MA SHMCAP Risk Assessment and the MA Climate Assessment.

Table 5.9-4. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Hurricanes and Tropical Storms

Sector	Priority Impacts and Vulnerabilities
Human	• Emergency service response delays and evacuation disruptions **(most urgent)** • Health effects from degraded air quality **(most urgent)** • Health effects of extreme storms and power outages • Increase in mental health stressors • Damage to cultural resources
Governance	• Reduction in state and municipal revenues **(most urgent)** • Increase in costs of responding to climate migration **(most urgent)** • Increase in demand for state and municipal government services **(most urgent)** • Damage to coastal state and municipal buildings and land
Infrastructure	• Damage to inland buildings **(most urgent)** • Damage to electric transmission and utility distribution infrastructure **(most urgent)** • Damage to rails and loss of rail/transit service **(most urgent)** • Damage to coastal buildings and ports • Damage to roads and loss of road service • Loss of energy production and resources

Sector	Priority Impacts and Vulnerabilities
Natural environment	• Freshwater ecosystem degradation **(most urgent)** • Coastal wetland degradation **(most urgent)** • Marine ecosystem degradation **(most urgent)** • Coastal erosion
Economy	• Reduced ability to work **(most urgent)** • Decrease in marine fisheries and aquaculture productivity **(most urgent)** • Reduction in the availability of affordably priced housing **(most urgent)** • Economic losses from commercial structure damage and business interruptions • Damage to tourist attractions and recreation amenities

The Risk Assessment team analyzed several storm surge inundation scenarios using the "maximum of maximums" outputs of the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model. These represent the worst-case storm surge scenarios for each hurricane category (Categories 1 through 4) and are shown in Figure 5.9-2. To assess the Commonwealth's exposure to storm surge from hurricanes and tropical storms, a spatial analysis was conducted using the SLOSH inundation layers intersected with updated population, facilities, and habitat datasets. It is important to note that the SLOSH model does not incorporate any future estimates of sea level rise and cannot be used to estimate exposure to inland flooding.



Map generated using NOAA SLOSH data.

Figure 5.9-2. SLOSH inundation zones, Category 1–4 hurricanes.

To supplement the SLOSH model, the Risk Assessment team conducted further hurricane analysis using FEMA's Hazus risk modeling software for some sectors. The Hazus Hurricane Model estimates damage from peak wind gusts under several probabilistic scenarios for all counties in the Commonwealth.[1] The team used this analysis to estimate displaced households and building-related economic losses.

5.9.2.4.1 Human

Population data are available at the Census block group level. This SLOSH analysis assumes that if any portion of the block group is inundated by storm surge, the entire population of the block group may be affected. Similarly, the Environmental Justice population data reported are the total number of people living in Environmental Justice–designated communities. As shown in Table 5.9-5, the population of Essex County has the highest population exposure to the hurricane-related storm surge hazard in Categories 1 and 2 hurricane scenarios. In stronger, Category 3 or 4 hurricane scenarios, Suffolk County becomes the most exposed in terms of population. In all hurricane categories, Suffolk County has the highest level of Environmental Justice population exposure to storm surge. It should be noted, however, that impacts from individual hurricane events vary widely; therefore, all coastal counties should evaluate the potential impacts of storm surge on residents with characteristics that make them more vulnerable to hurricanes.

Table 5.9-5. Populations Exposed to Hurricane-Related Storm Surge by County

County	Category 1		Category 2		Category 3		Category 4	
	Population	EJ	Population	EJ	Population	EJ	Population	EJ
Barnstable	116,178	17,899	123,212	19,297	134,403	24,451	142,611	26,847
Bristol	142,318	66,332	152,904	71,813	159,610	71,813	169,332	78,600
Dukes	17,312	4,361	17,312	4,361	17,312	4,361	17,312	4,361
Essex	215,677	60,484	251,119	90,553	281,011	115,687	285,597	116,531
Middlesex	116,127	77,542	151,318	108,031	175,204	126,308	235,851	182,348
Nantucket	5,631	871	6,769	871	6,769	871	8,287	871
Norfolk	61,978	30,860	65,427	30,860	75,354	36,884	89,649	51,179
Plymouth	142,565	13,926	143,635	13,926	150,589	13,926	157,878	13,926
Suffolk	166,889	107,684	217,569	147,527	331,733	246,912	395,831	297,857
Total	**984,675**	**379,959**	**1,129,265**	**487,239**	**1,331,985**	**641,213**	**1,502,348**	**772,520**

Table based on U.S. Census population data and NOAA SLOSH exposure data.

[1] Peak wind gusts can be higher than the sustained wind speeds used to categorize hurricanes; the World Meteorological Organization says that a conversion factor of 1.49 can be used to estimate peak three-second wind gusts from a given one-minute averaged wind speed estimate (Harper et al., 2010). The Hazus model estimates wind gusts for a 10-year storm scenario to be less than 50 mph, which could occur during a tropical storm or tropical depression. In the 500-year storm scenario, peak wind gusts range from 95 to 125 mph, which would likely occur during a Category 1 hurricane.

Residents may be displaced or need temporary shelter if a hurricane or tropical storm causes damage to their home. The number of people requiring temporary shelter is generally less than the number displaced, as some who are displaced use hotels or stay with family or friends following a disaster event. The Risk Assessment team estimated displacement and short-term shelter needs for each county with a Hazus probabilistic analysis for 10-, 50-, 100-, and 500-year hurricane events. In a 500-year event, nearly 25,000 households could be displaced and 16,000 could need short-term shelter. Most of these displaced households would be from Bristol and Plymouth counties, which border the west side of Buzzards Bay. In high-cost areas such as Massachusetts, it is even more critical to reduce the risk of damage, loss, and displacement from homes by ensuring that homes are built or retrofitted to reduce risks from likely hazards and impacts, such as the flooding and winds from hurricane events. Ensuring that new development is sited away from likely high-hazard zones or built to withstand current and projected hazards, and developing programs to retrofit existing homes, will reduce the need for temporary and long-term shelter.

Table 5.9-6 lists estimated shelter requirements for each Massachusetts county in the four Hazus-modeled hurricane scenarios.

Table 5.9-6. Estimated Shelter Requirements by County: Probabilistic Scenarios

County	10-Year Event		50-Year Event		100-Year Event		500-Year Event	
	Displaced House-holds	Short-Term Shelter Needs	Displaced House-holds	Short-Term Shelter Needs	Displaced House-holds	Short-Term Shelter Needs	Displaced House-holds	Short-Term Shelter Needs
Barnstable	0	0	71	32	19	9	2,157	953
Berkshire	0	0	0	0	0	0	444	220
Bristol	0	0	642	465	699	444	6,562	4,772
Dukes	8	5	15	8	6	4	299	173
Essex	0	0	103	64	615	448	1,337	888
Franklin	0	0	0	0	0	0	122	64
Hampden	0	0	0	0	15	11	1,557	1,237
Hampshire	0	0	0	0	3	2	402	210
Middlesex	0	0	152	66	1,635	958	2,563	1,501
Nantucket	42	24	0	0	0	0	40	23
Norfolk	0	0	183	79	712	337	2,478	1,211
Plymouth	0	0	353	214	315	243	3,852	2,387
Suffolk	0	0	204	150	950	711	2,885	2,194
Worcester	0	0	90	58	606	395	248	152
Total	**50**	**29**	**1,813**	**1,136**	**5,575**	**3,562**	**24,946**	**15,985**

Table based on Hazus analysis using U.S. Census population data.

Vulnerable and Priority Populations

Among populations exposed to hurricanes, Environmental Justice and other priority populations are the most vulnerable. They include low-income households, people over the age of 65 or under the age of five, people with underlying health conditions or disabilities, those with low English proficiency, renters, unhoused populations, single parents, transit dependent populations, and underrepresented race/ethnicities. For example, people from low-income households may have more difficulty preparing their homes in advance to reduce damage from storms, may struggle to evacuate due to a lack of resources, and may lack access to funds for necessary repairs after a storm. People with medical needs and disabilities may have more challenges when evacuating, may have more difficulty finding adequate accommodations, and may not be able to find needed medical care while displaced. Those with low English language proficiency may not receive or understand the warnings to evacuate or information about available storm shelters.

Many of the Environmental Justice and other priority populations described above may also be less likely to have adequate resources to recover from the loss of their homes and jobs or to relocate from a damaged neighborhood.

Mobile home residents, who often also meet other characteristics of social vulnerability, are at high risk as their houses are often not built to withstand hurricane-force wind and flooding (Atmos, 2021). As discussed in the Williamstown *Multi-Hazard Mitigation Plan Update*, Tropical Storm Irene caused structural damage to more than 225 homes in Williamstown's Spruce Mobile Home Park, which were ultimately deemed uninhabitable and led to the park's permanent closure. Many of the residents who lost their homes were elderly and low-income (Town of Williamstown, 2019).

During and after a storm event, rescue workers and utility workers are vulnerable to injury or death from exposure to high water, swift currents, damaged power lines, and submerged debris during their search and rescue or utility repair operations. Populations that live or work near facilities that use or store toxic substances are at greater risk of exposure to these substances during a flood event. The "Massachusetts Toxics Users and Climate Vulnerability Factors" map displays wastewater treatment plants; major facilities that treat, use, or store hazardous waste; and classified oil and/or hazardous material sites within the FEMA flood and storm surge zones (Massachusetts Office of Technical Assistance and Technology, n.d.). These areas may also expose adjacent communities and land uses to contaminated air, soil, and water.

High winds and flooding from rainfall and storm surge often lead to power outages affecting communities, businesses, and critical facilities, leading to a range of impacts including public health effects, injuries, and loss of life. Communities along the coastal zone, or in floodplains, low-lying areas, or areas built on historic wetlands are disproportionately exposed to this impact. People who use electricity-dependent medical devices and medications requiring refrigeration are at high risk of experiencing worse health outcomes during power outages.

As part of the Risk Assessment process, Massachusetts state agencies completed a survey in which they identified their primary concerns for populations their agencies serve and potential disproportionate impacts from hurricanes and tropical storms. Table 5.9-7 below summarizes their responses.

Table 5.9-7. State Agency Responses: Primary Concerns About Hurricane Impacts on Populations Served and Potential Disproportionate Impacts

Category	Primary Concerns
Populations served	• Elderly people • People with disabilities • Veterans and veteran family members • Commercial and recreational fishers, seafood-consuming public • Insurance consumers • Taxpayers
Potential disproportionate impacts	• Disproportionate impacts to Environmental Justice and other priority populations and those with less ability to evacuate and/or recover from a storm • Disproportionate transportation impacts to those reliant on public transit and required to work in-person jobs • Limited in-person services for people with disabilities • Disrupted access to financial benefits to veterans during power and internet outages

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Health Impacts

The health impacts from hurricanes and tropical storms can generally be separated into impacts from flooding and impacts from wind.

The potential health impacts of flooding are extensive and are discussed in detail in Section 5.8 (Flooding from Precipitation). In general, some of the most serious flooding-related health threats include floodwaters sweeping away people or cars; electrocution from downed power lines; and exposure to hazards in the water, including infectious organisms. Contact with contaminated floodwaters can cause gastrointestinal illness and elevated rates of emergency room visits. People who are housed in public shelters during or after hurricane events also have an increased risk of becoming infected with contagious diseases. This was a particular concern during the height of the COVID-19 pandemic (CDC, 2022).

Wind-related health threats associated with hurricanes are most often caused by debris mobilized during the storm that causes harm by direct impact, by blocking stormwater systems and increasing flood risk, or by severing utility or infrastructure networks and systems. Roadways, highways, transit, and rail networks that are blocked by debris can result in disruption that impairs evacuations and significantly delays emergency services as they respond to 9-1-1 calls. Such winds pose significant risks to emergency and public service providers responding to the storm and can result in injury and loss of life to these workers. An increased risk of injury to all residents during cleanup of debris and tree removal is also a concern.

The possibility of death due to hurricanes gives this hazard a very high magnitude of consequence in the human sector. There are several examples from historic events in Massachusetts. In the Great New England Hurricane of 1938, 564 lives were lost throughout southern New England (Massachusetts Office of Coastal Zone Management, n.d.). More recently, Tropical Storm Irene caused one death from electrocution in Massachusetts and 17 other deaths across the Northeast due to drowning, carbon monoxide poisoning, falling trees, and downed power lines (Associated Press, 2011).

Damage to residential structures from wind and water—for example, loss of power to homes for extended periods—can also increase the risk of health impacts by leaving residents more exposed to extreme temperatures, floodwaters, mold, and pollutants and debris carried by the hurricane. For more information regarding extreme temperatures, refer to Section 5.2 (Average/Extreme Temperatures).

After a hurricane or tropical storm subsides, substantial health risks remain. These risks include contaminated waters and soils, exposure to toxics, impaired water quality, mold, invasive species, pests, the need to recover from physical injuries, and mental health stressors. For example, the growth of mold inside buildings is often widespread after a flood. Investigations following Hurricane Katrina and Superstorm Sandy found mold in the walls of many water-damaged homes and buildings. Mold can cause allergic reactions and can exacerbate existing respiratory diseases, including asthma. Immunosuppressed individuals exposed to mold are at higher risk of invasive respiratory mold infections with high mortality rates (Chow et al., 2019). Additionally, flooded areas that do not drain properly can become breeding grounds for mosquitos, which can transmit vector-borne diseases.

Extended loss of electricity and heating systems increases the risk of carbon monoxide poisoning. Carbon monoxide is present in emissions from combustion appliances such as generators, cooking and heating devices (grills, stoves, etc.), and damaged chimneys. Improper location and operation of combustion appliances in indoor or poorly ventilated areas leads to increased health risks (Chen et al., 2015).

The MA Climate Assessment estimates that more than 400 additional annual storm-related medical incidents (including carbon monoxide poisoning and unintentional injury) could occur in Massachusetts by the end of the century because of climate change, a 52 percent increase from current estimates. The assessment finds that minority populations have 8 percent higher rates of health effects from extreme events, and language-isolated populations have a 14 percent higher rates of health effects, than the rest of the Commonwealth. It is also important to recognize that storm-related medical incidents are most likely an undercounting of the actual number, do not include mental health effects, and often fail to include those whose underlying health conditions were made worse by the storm event.

The storm surge, rain, and winds that occur as a result of hurricanes and tropical storms often cause significant damage and disruption to transportation networks, which prevents people from reaching health care and other critical services and resources for long periods during or after the storm has passed and impedes recovery and medical personnel's timely access to affected areas. Property damage and displacement of homes and businesses can lead to loss of livelihood and long-term mental stress for those facing relocation. People may develop post-traumatic stress disorder, anxiety, and depression following major flooding events.

5.9.2.4.2 Governance

Hurricanes will affect the governance sector through direct damage to government buildings and infrastructure from storm surge, flooding, and winds, and will increase the need for government services to prepare for, respond to, and recover from each event. Additionally, programs, additional research, education and outreach, preparation exercises, and assistance and support for residents and businesses will impose increased demands on governments as climate change increases the intensity and duration of these events. Increased resources will be needed for infrastructure and utility projects to increase resilience to storms. Increased government resources will also be needed for the conservation, management, and restoration of natural areas to reduce and reverse the impacts to these assets. Additionally, resources will be needed to create and implement strategies to limit development in high-hazard areas.

Vulnerability of State Assets

Any assets in coastal flood zones or low-lying inland areas are more vulnerable to flooding impacts from a hurricane, as are services that depend on reliable electricity and communications systems. The 2023 SHMCAP survey provided to state agencies included questions related to their primary concerns for services provided and updates that would be needed to address their concerns for hurricanes and tropical storms. Table 5.9-8 below summarizes agency responses.

Table 5.9-8. Example State Agency Responses: Primary Concerns About Hurricanes' Effects on Services, with Suggested Improvements

Category	Concerns/Improvements
Services provided	• Disruption to 911 services and call centers • Damage to roads, bridges, culverts, traffic lights, and signage; evacuation/emergency routes not available

Category	Concerns/Improvements
	• Delayed child protection services, such as emergency investigations of abuse allegations • Temporary loss of use of the recreational boating and fishing access facilities
Updates, improvements, or enhancements needed to address concerns	• Update state building code with higher standards in coastal zones • Bolster existing storm-preparedness activities to ensure employee readiness • Ensure communications infrastructure and budgets support increased frequency of events and service requests • Use the System-Wide Tunnel Flood Mitigation Program • Procure backup power generators for critical facilities • Implement outreach campaigns to promote safety during extreme events, including prevention of injuries and carbon monoxide poisoning

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Agency staff also identified specific locations vulnerable to the hurricane hazard. For example, the Registry of Vital Records storage building at 150 Mount Vernon Street, Dorchester, is in a flood zone and is vulnerable to sea level rise and storm surge associated with hurricanes. The Department of Public Health has already relocated staff from the Causeway Street location in Boston due to increasing disruptions from storm surge flooding in the area.

To assess the broader exposure of government facilities to the surge inundation from a hurricane event, the Risk Assessment team overlaid digital SLOSH zones on the state facility data. Table 5.9-9 summarizes the potential replacement values if all state-owned buildings were to be severely affected. While these numbers are likely to be overestimates of economic impacts, they do indicate that Suffolk County has by far the highest exposure of state-owned buildings to hurricane-related storm surge. Any state assets that serve as lifelines to the community will also have additional impacts that are not as easily quantified with a dollar value.

Table 5.9-9. State-Owned Building Exposure in SLOSH Zones

County	Category 1		Category 2		Category 3		Category 4	
	Count	Replacement Value	Count	Replacement Value	Count	Replacement Value	Count	Replacement Value
Barnstable	112	$393,228,673	112	$393,228,673	116	$465,163,673	119	$491,920,473
Bristol	65	$75,232,400	78	$117,121,600	78	$117,121,600	93	$234,135,300
Dukes	7	$240,000	7	$240,000	7	$240,000	13	$13,936,400

County	Category 1		Category 2		Category 3		Category 4	
	Count	Replacement Value	Count	Replacement Value	Count	Replacement Value	Count	Replacement Value
Essex	94	$61,949,950	139	$299,742,950	153	$309,157,700	157	$575,420,000
Middlesex	57	$104,023,399	69	$110,403,299	82	$128,553,299	89	$129,292,499
Nantucket	4	$2,925,000	4	$2,925,000	4	$2,925,000	4	$2,925,000
Norfolk	40	$9,095,000	53	$17,770,000	63	$17,854,000	68	$20,576,000
Plymouth	96	$156,486,250	118	$177,881,650	133	$178,531,450	145	$182,499,250
Suffolk	257	$1,553,039,037	378	$3,895,000,674	437	$6,028,858,299	505	$8,247,986,426
Total	**732**	**$2,356,219,708**	**958**	**$5,014,313,845**	**1073**	**$7,248,405,020**	**1193**	**$9,898,691,347**

Source: Massachusetts Division of Capital Asset Management and Maintenance (2022).

The Department of Conservation and Recreation (DCR) owns 528 sites throughout the state. In 2022, the DCR estimated its vulnerability to climate hazards and found that by 2030, 96 sites will have moderate to high vulnerability to coastal flooding, which can be caused by tropical storms and hurricanes. The DCR identifies some sites—Halibut Point State Park, Spectacle Island, and State Fish Pier—as the ones most vulnerable to multiple climate hazards, including sea level rise/storm surge and extreme precipitation flooding; this means these sites would also be highly vulnerable to the hurricane hazard (Massachusetts Department of Conservation and Recreation, 2022).

5.9.2.4.3 Infrastructure

Numerous impacts to infrastructure across the state may result from flooding or wind damage associated with tropical storms and hurricanes. This includes damage to electric transmission and utility distribution infrastructure, coastal buildings and ports, inland buildings, roads and rail services, and other critical facilities. Low-lying and linear infrastructure and utility networks are extremely vulnerable, especially buried sewer lines; wastewater treatment plants; power and communication infrastructure and services; and roads, bridges, and trails. In addition to location and elevation, the age, maintenance, and manner of construction of these networks can significantly affect vulnerability. Residential land uses are often overlooked in the consideration of critical assets, but are, in many cases, the most vulnerable and critical assets for social and economic resilience. Communities with significant losses of residential assets struggle the most to recover, including commercial areas, businesses, and public services. Residential uses are also some of the most difficult to make resilient due to diffuse and diverse ownership, the scale of the risk, and the lack of data at a parcel level.

Table 5.9-10 and Table 5.9-11 summarize critical facility exposure to the SLOSH zone inundation through four hurricane categories by facility type and county, respectively. Residential, maritime, water resources, transportation, and energy facilities are the critical facility categories with highest hurricane exposure in Massachusetts. The highest number of exposed critical facilities are in Suffolk County, followed by Plymouth and Barnstable Counties. The critical facilities listed in these tables, and some of the other infrastructure assets discussed in the sub-sections below, are considered community lifelines, and their exposure to hurricane damage could have many cascading consequences throughout Massachusetts.

Table 5.9-10. Number of Critical Facilities Exposed to SLOSH Hazard Zones by Facility Type

Type	Category 1	Category 2	Category 3	Category 4
Administration	5	9	9	13
Cold storage	—	—	1	1
Communications	2	2	3	4
Corrections	3	6	14	17
Education	4	6	7	9
Energy facilities	15	16	16	17
Fire facilities	3	3	3	4
Healthcare	—	—	4	4
Laboratories and research	4	5	5	5
Maritime	32	36	41	43
Military facilities	2	2	4	5
Parks and recreation	8	8	8	8
Police facilities	5	6	9	10
Residential	52	54	57	63
Social services	4	8	10	16
Stadium	1	2	2	2
Transportation	18	20	24	25
Waste management	9	15	16	17
Water resources	23	25	28	29
Total	**190**	**223**	**261**	**292**

Source: Massachusetts Division of Capital Asset Management and Maintenance (2022).

Table 5.9-11. Critical Facility Exposure to SLOSH Hazard Zones by County

County	Category 1		Category 2		Category 3		Category 4	
	Count	Replacement Value	Count	Replacement Value	Count	Replacement Value	Count	Replacement Value
Barnstable	33	$177,563,123	33	$177,563,123	36	$249,498,123	36	$249,498,123
Bristol	13	$67,243,300	13	$67,243,300	13	$67,243,300	16	$67,526,900
Dukes	1	$240,000	1	$240,000	1	$240,000	4	$7,762,800
Essex	19	$30,182,700	28	$114,405,200	31	$119,062,350	32	$128,817,550
Middlesex	13	$9,545,549	18	$9,905,549	19	$9,905,549	21	$10,644,749
Nantucket	4	$2,925,000	4	$2,925,000	4	$2,925,000	4	$2,925,000
Norfolk	3	$35,000	3	$35,000	4	$35,000	5	$2,757,000
Plymouth	42	$42,921,800	43	$46,550,600	50	$47,155,400	56	$48,808,400
Suffolk	62	$470,252,025	80	$1,510,107,813	103	$3,542,736,438	118	$4,086,559,751
Total	**190**	**$800,908,496**	**223**	**$1,928,975,584**	**261**	**$4,038,801,159**	**292**	**$4,605,300,272**

Source: Massachusetts Division of Capital Asset Management and Maintenance (2022).

Energy Assets and Services

Hurricanes and tropical storms often result in power outages caused by wind, storm surge, and rainfall, which lead to downed power lines, downed trees, mobilized debris, and water damage to water- and salt-sensitive components. These impacts result in a range of risks, including electrocution from damaged electrical infrastructure and disruption of transportation, communication, and power service. Transportation and transit disruptions make it difficult to evacuate and (for public service personnel) access damaged areas. The loss of power results in some of the broadest cascading consequences, including increased flood risk from a lack of power to pumps needed during storm events and other human health impacts discussed in Section 5.9.2.4.1 above. Contact with downed power lines during and after a storm may result in electrocution. In 2011, Tropical Storm Irene left 600,000 Massachusetts residents without power, many for several days (WBUR, 2011). The *Town of Erving Hazard Mitigation Plan* also identifies residents who depend on private well water as being high risk because they may lose access to drinking water and indoor plumbing for extended periods during a power outage (Erving Multi-Hazard Mitigation Plan Update Committee, 2020).

Telecommunications

Hurricane impacts to communication networks can result in less effective or widespread public information on evacuation and other instructions, as well as less effective coordination among public responders. Impacts to communications systems are similar to those discussed for energy assets; communication infrastructure such as telephone poles and wires can suffer damage from high winds and flooding. Any impacts to the electrical grid may also disrupt telecommunications, as electricity is necessary to support many communications systems.

Public Health

Combined sewer overflows associated with heavy rainfall can release contaminants, chemicals, and pathogens directly into the environment and into water systems, creating a public health risk. If a mass outbreak of waterborne illness were to occur, hospitals and medical providers might lack the capacity to treat patients. Hurricane impacts could also disrupt in-person services for clients, patients, and health care facility residents, including those with substance addictions, along with people with access and functional needs. Additional public health–related impacts are discussed in Section 5.9.2.4.1 above.

Public Safety

As discussed above, critical infrastructure, including local and state-owned police and fire stations, other public safety buildings, and facilities that serve as emergency operation centers, may experience direct loss or significant damage during a hurricane or tropical storm. Emergency responders may also be exposed to hazardous situations when responding to calls. Road blockages caused by downed trees and flooding may impair emergency response efforts. Multiple operational periods for first responders during and in the recovery phases of a storm, as well as personal/household concerns of these first responders, will stress the public safety system's resiliency.

Transportation Assets and Services

Some roads, bridges, and transportation infrastructure are considered critical infrastructure, particularly major routes that provide emergency access and lifeline connections across the Commonwealth, provide for cargo movement, and serve as evacuation routes. Hurricanes often cause costly damage and disruption to roads, bridges, and rail networks. People reliant on public transportation will be disproportionately affected by transit systems shut down during the storm or requiring repairs afterward.

Coastal transportation systems at risk of hurricane-induced flooding include Boston's Central Artery and Tunnel System (Massachusetts Department of Transportation, 2015), and Cape Cod's many low-lying road segments (Cape Cod Commission, 2021). Table 5.9-12 shows an analysis of roads in SLOSH inundation zones, using information on transportation assets from the Massachusetts Department of Transportation (2022). In total, nearly 3,000 miles of roads—including over 500 miles of highway or major roads—could be affected by flooding in a Category 3 hurricane. Barnstable County has the most road mileage exposed to the hurricane storm surge inundation.

Table 5.9-12. Road Exposure to SLOSH Hazard Zones by County

County	Category 1 (Miles of Road)	Category 2 (Miles of Road)	Category 3 (Miles of Road)	Category 4 (Miles of Road)
Barnstable	593	661	847	979
Bristol	218	252	271	333
Dukes	96	124	149	193
Essex	310	388	454	478
Middlesex	105	145	192	292
Nantucket	71	78	93	111
Norfolk	43	71	95	142
Plymouth	255	332	428	513
Suffolk	143	226	440	579
Total	**1832**	**2275**	**2967**	**3620**

Source: Massachusetts Department of Transportation (2022).

Inland roads may also be at risk of hurricane-induced flooding; Tropical Storm Irene, for example, caused severe transportation disruptions in western Massachusetts. Intense rainfall and riverine flooding closed several major travel routes in the region, including Interstate 91 in Deerfield, due to concern for the structural integrity of the highway bridge over the Deerfield River, and sections of Route 2 that were washed out by river flooding or blocked by landslide debris (Kinney, 2011; Town of Williamstown, 2019).

Bridges throughout the Commonwealth are at risk of damage from coastal storm surge or inland flooding. In 2022, a study found one in 12 of the Commonwealth's bridges (644 total) to be structurally deficient, putting them at higher risk of damage or loss from hurricanes (Elbeleidy & Baxandall, 2022). Damage to transportation structures such as bridges can also have cascading impacts on other sectors; for example, the town of *Adams Multi-Hazard Mitigation Plan 2019* identifies concerns about the structural integrity of the Quality Street Bridge, which carries the main water line into the town. If the bridge were damaged or destroyed by flooding, the entire municipality could be without drinking water (Town of Adams, 2019).

Water Infrastructure

Hurricanes and storm surge may put critical water and wastewater infrastructure at risk due to direct damage or contamination. Destruction or damage to wastewater treatment centers may cause elevated public health risks via the mobilization of contaminants and toxins. Heavy rains can lead to contamination of well water and can release contaminants from septic systems (Massachusetts Department of Public Health, 2014). Many inadequate or aging stormwater and sewer systems are unable to accommodate increased volume of flow from these storms which can cause contamination of water sources, and saltwater intrusion from storms may threaten coastal freshwater supplies. Quality of public drinking water supply may be compromised by increased sediment, nutrients, or other contaminants after a storm. Damage to dam infrastructure can exacerbate local flood impacts, as was evident in western Massachusetts during Tropical Storm Irene (WBUR, 2011).

5.9.2.4.4 Natural Environment

The impacts of hurricanes on the natural environment include coastal erosion, flooding of sensitive habitats, and saltwater intrusion, and are similar to those described for other hazards, including coastal flooding (Section 5.4), flooding from precipitation (Section 5.8), other severe weather (Section 5-12), and severe winter storms (Section 5-13). These impacts include flooding that disrupts normal ecosystem function and wind that damages trees and other vegetation. Mortality to animals can occur if they drown, are injured by debris, are transported by wind or floodwaters to a non-suitable habitat, are exposed to toxins or other hazardous substances, or (as dependent young) are separated from parents (Willis & Steinmetz, 2017). Hurricane Bob in 1991, which occurred in August when terns from throughout the Northeast U.S. were highly aggregated at coastal staging areas before migration, is linked to loss of almost the entire 1991 cohort of endangered roseate tern young, many adults, and a substantial drop in the population the following year (U.S. Fish and Wildlife Service, 2010). Severe impacts such as this can increase extinction risk for highly vulnerable native populations. Tidal estuaries are particularly susceptible to hurricanes and tropical storms, both because coastal storm surge physically damages them and because altering their salinity can cause widespread effects to their many inhabitant species. With rising sea levels and stronger tropical storms, saltwater encroachment is likely to pose a greater threat to estuarine species (UMass Amherst, 2017).

In the longer term, impacts to the natural environment as a result of hurricanes and tropical storms are generally related to changes in the physical structure of ecosystems. For example, flooding may cause scour in riverbeds, modifying the river ecosystem and depositing the scoured sediment in another location. Coastal ecosystems can similarly be altered by storm surge and high winds. Beaches, sand dunes, and salt marshes protect developed areas against storms in the North Shore, South Coast, and Islands, but erosion rates of these valuable natural resources are already high and are exacerbated by strong storms and sea level rise. Narrowing beaches can reduce the available habitat and nesting area for at-risk migrating shorebirds, and natural salt marsh migration will be limited in areas with high development (Trustees of Reservations, 2021). Currently, wetlands regulations do not allow alteration of salt marshes. Reduced elevations in coastal areas will increase tidal reach and frequency of flooding, which can render formerly suitable habitat unusable (Payandeh et al., 2022). See Section 5.4 (Coastal Erosion) for more on coastal erosion.

If the storm spreads pollutants into natural ecosystems, contamination can disrupt food and water supplies, causing widespread and long-term population impacts on species in the area.

Table 5.9-13 documents the exposure of core habitat and critical natural landscape areas—as defined by MassWildlife and The Nature Conservancy's BioMap3—to hurricane storm surge inundation based on GIS analysis. The percent total refers to the number of acres exposed to the SLOSH zone compared to the total acres of the habitat or landscape type within the coastal counties included in this analysis. Priority natural communities, coastal adaptation areas, and tern foraging habitats have some of the highest proportions of exposure to hurricane-related storm surge.

Table 5.9-13. BioMap Core Habitats and Critical Natural Landscape Exposure to SLOSH Zones

Habitat Type	Category 1		Category 2		Category 3		Category 4	
	Acres	% Total	Acres	% Total	Acres	% Total	Acres	% Total
Core Habitat								
Aquatic core	31528	9.95	35869	11.33	39743	12.55	42220	13.33
Forest core	24	0.01	92	0.02	301	0.07	306	0.07
Priority natural communities	23487	21.20	28822	26.02	33767	30.48	38340	34.61
Rare species core	70136	7.12	78547	7.98	89297	9.07	96960	9.84

Habitat Type	Category 1		Category 2		Category 3		Category 4	
	Acres	% Total	Acres	% Total	Acres	% Total	Acres	% Total
Vernal pool core	2322	0.96	3124	1.30	3882	1.61	4978	2.07
Wetland core	2047	1.28	2730	1.71	4228	2.65	4859	3.04
Critical Natural Landscape								
Aquatic buffer	10141	2.39	11614	2.73	13987	3.29	16112	3.79
Coastal adaptation areas	27518	34.46	36680	45.94	45793	57.35	52787	66.11
Landscape blocks	34836	2.32	42274	2.82	52192	3.48	59299	3.95
Tern foraging habitat	190814	76.09	204860	81.69	217119	86.58	224231	89.42
Wetland buffer	3431	1.61	4332	2.04	6159	2.90	7247	3.41

Source: MassWildlife and The Nature Conservancy (2022).

While cost estimates for restoration of natural areas or recovery of vulnerable species are not readily available in the same way as for structures and infrastructure, they are expected to rise with increasing storm frequency and severity. Additionally, the complex logistics of projects in coastal and, especially, offshore areas often result in significantly higher financial requirements as compared to restoration work in other areas across the Commonwealth.

5.9.2.4.5 Economy

Hurricanes are among the costliest natural disasters in terms of damage inflicted and recovery costs to restore assets and services to normal. Significant economic impacts from hurricanes are likely to be related to structure damage and business interruptions, especially in flood-prone areas; damage to tourist attractions and recreation amenities, such as beaches, coastal hotels, and rental homes; and a decrease in agricultural productivity in areas that experience significant flooding, wind damage, or secondary impacts such as landslides.

Although it is difficult to forecast the broad economic impact of a hurricane event, potential damage to buildings can serve as a valuable proxy because damage to buildings can affect a community's economy and tax base. The Hazus hurricane model estimates direct economic losses to buildings that could be expected from hurricane winds over a range of probabilistic scenarios. This includes capital stock losses (building damage, contents damage, inventory loss) as well as income losses (relocation loss, capital=related loss, wages loss, and rental income loss). Table 1-13 summarizes the annualized[2] building-

[2] Hazus defines *annualized loss* as the estimated long-term value of losses to the general building stock averaged on an annual basis for a specific hazard type. Annualized loss considers all future losses for a specific hazard type resulting from possible hazard events, with different magnitudes and return periods averaged on a "per year" basis. Like other loss estimates, annualized loss is an estimate based on available data and models. Therefore, the actual loss in any given year can be substantially higher or lower than the estimated annualized loss (FEMA, 2004).

related losses for each county in the Commonwealth. Statewide average building-related losses could be around $470 million annually, with significant year-to-year variability. The greatest annual losses are expected to be experienced in Middlesex, Plymouth, Bristol, and Norfolk Counties.

Table 5.9-14. Annualized Building-Related Economic Loss Estimates

County	Capital Stock Losses	Income Losses	Total Loss
Barnstable	$38,655,000	$4,147,000	$42,803,000
Berkshire	$2,169,000	$101,000	$2,270,000
Bristol	$57,392,000	$5,276,000	$62,666,000
Dukes	$4,667,000	$614,000	$5,281,000
Essex	$38,665,000	$2,757,000	$41,423,000
Franklin	$1,451,000	$69,000	$1,520,000
Hampden	$12,492,000	$959,000	$13,451,000
Hampshire	$4,366,000	$241,000	$4,607,000
Middlesex	$83,017,000	$5,503,000	$88,520,000
Nantucket	$5,425,000	$633,000	$6,058,000
Norfolk	$53,938,000	$3,214,000	$57,152,000
Plymouth	$62,581,000	$3,845,000	$66,426,000
Suffolk	$34,210,000	$4,800,000	$39,010,000
Worcester	$35,844,000	$2,482,000	$38,327,000
Total	**$434,872,000**	**$34,641,000**	**$469,514,000**

Table based on Hazus analysis. Totals may not add due to rounding.

Hurricane season overlaps with peak tourism in coastal regions of the Commonwealth, so storms may have a significant impact on this sector of the economy. For example, the forecast for Tropical Storm Henri in August 2021 prompted Governor Baker to issue a recommendation that vacationers consider leaving Cape Cod and the Islands prior to the storm or delay their trips to these locations until after the storm passed (Young, 2021). Damage to beaches and natural areas may require significant cleanup costs and may deter local tourism for longer periods after the storm.

The economic impacts of climate change are already being felt in localities across the Commonwealth. For example, the *2021 Hazard Mitigation Plan: Plymouth, Massachusetts* identifies seawall stabilization as a mitigation measure against coastal hazards such as hurricanes, but these structures are costly to maintain. In 2020, the Warrens Cove/Plymouth Beach seawall reconstruction project cost more than $8 million, but was considered necessary to protect nearby infrastructure from storm surges (Horsley Witten Group, 2021).

Overall, the MA Climate Assessment estimates that damages from coastal windstorms (including hurricanes and tropical storms) to structures and public infrastructure are currently about $500 million annually, but with large year-to-year variation. By the end of the century, this number could approach $2 billion per year with changing storm activity due to climate change. Projected flood damages to coastal properties, with damage from sea level rise and coastal storms taken into consideration, could be over $1 million by the end of the century.

Chapter 5. Risk Assessment and Hazard Analysis

Invasive Species

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5.10 Invasive Species

5.10.1 Invasive Species Problem Statement

Invasive species present a threat to ecosystems, public health, and infrastructure throughout the Commonwealth. Changing climatic conditions shift and shrink suitable habitat for native species (flora and fauna) while increasing the risk of new species introductions, competition from established invaders, and losses in native biodiversity and culturally important species. Invasive species are widely considered to be one of the costliest hazards in the U.S., due to the expense of controlling them and the damage they cause.

5.10.2 Invasive Species Risk Assessment

5.10.2.1 General Background

The Commonwealth has identified and profiled invasive species as a hazard for the 2023 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP). All of Massachusetts is susceptible to effects from invasive species. Invasive species threaten biodiversity and natural resources, as well as agriculture, and have significant economic impacts for the Commonwealth.

Invasive species are broadly defined as non-native species that cause or are likely to cause harm to ecosystems, economies, and/or public health (USDA, n.d.-b).The focus of this section is on invasive terrestrial plants, as this is the most studied and managed type of invasive; information for invasive aquatic flora and fauna (including marine species) is also provided when relevant.

Shifting climatic conditions shrink suitable habitat for native species, increase the risk of new species introductions, and increase competition from established invaders, potentially causing loss of native biodiversity and culturally important species. As noted above, invasive species are widely considered to be one of the costliest hazards in the U.S. due to the extensive and expensive efforts needed to control them, as well as the direct damage they cause (to crops, commercial forests, cultural resources, ecosystems, recreational amenities, conservation lands, dams, and water quality) and the increase in public health concerns and increased fire risk that come with them. For marine invasive species, management options are extremely limited or not feasible once an invasive species is established.

The Massachusetts Invasive Plant Advisory Group (MIPAG), a collaborative representing organizations and professionals concerned with the conservation of the Massachusetts landscape, is charged by the Executive Office of Energy and Environmental Affairs to provide recommendations to the Commonwealth to manage invasive species. MIPAG defines invasive plants as “non-native species that have spread into native or minimally managed plant systems in Massachusetts [causing] economic or environmental harm by developing self-sustaining populations and becoming dominant and/or disruptive to those systems” (MIPAG, 2022b). Table 5.10-1 below lists invasive, potentially invasive, and likely invasive plants in Massachusetts. The Massachusetts Natural Resources Collaboration’s Introduced Pests Outreach Project lists 15 invasive insects (Massachusetts Department of Agricultural Resources, n.d.-a). These invasive insects are listed in Table 5.10-1 below.

Invasive species have biological traits that give them competitive advantages over native species, particularly because they are not restricted by the biological controls of their native habitat. As a result, invasive species can outcompete natural communities, displacing many natives and causing widespread economic and environmental damage. A 2022 study of the economic costs of biological invasions in the U.S. found that, from 1960 to 2020, the reported cost of invasions totaled $4.52 trillion (Fantle-Lepczyk et al., 2022). The cost of invasive species identification, management, and monitoring has increased during this timeframe: between 1960 and 1969 costs totaled $2.00 billion annually and between 2010 and 2020 costs totaled $21.08 billion annually. The study reports that the primary costs associated with invasive species stem from resource damage (73 percent of costs were associated with damage, totaling $896.22 billion), with agriculture being the most affected sector ($509.55 billion in damage) (Fantle-Lepczyk et al., 2022). The U.S. Forest Service reports that invasive plants are found on over 133 million acres of land in the U.S., and that each year invasive plants advance on over 1.7 million acres each year. The Forest Service lists the following invasive species as the major non-native threats nationally: spongy moth, hemlock woolly adelgid, emerald ash borer, dogwood anthracnose, Asian longhorned beetle, white pine blister rust, sudden oak death, Port Orford cedar root, and beech bark diseases (U.S. Forest Service, 2006). Many of these species occur in Massachusetts.

As of December 2022, MIPAG listed 74 plant species as “invasive,” “likely invasive,” or “potentially invasive” (see Table 5.10-1 below for the full list). The criteria for an “invasive” species are listed below. MIPAG’s definition for “likely invasive” plants refers to non-native species that are “naturalized in Massachusetts but do not meet the full criteria that would trigger an ‘invasive plant’ designation” (MIPAG, 2022c). In order to be considered “invasive” by MIPAG, a plant species must meet the following criteria (MIPAG, 2022a):

1. Be non-native to Massachusetts.
2. Have the biologic potential for rapid dispersion and establishment in minimally managed habitats.
3. Have the biologic potential for dispersing over spatial gaps away from the site of introduction.
4. Have the biologic potential for existing in high numbers away from intensively managed artificial habitats.

5. Be naturalized in Massachusetts (persists without cultivation in Massachusetts).

If a species meets criteria 1–4 and criterion 5, it may be considered “invasive” or “likely invasive” in Massachusetts. If it does not meet criterion 5, it may be considered “potentially invasive” if it meets criteria 13–15.

6. The species is widespread in Massachusetts, or common in a region or habitat type(s) in the state.
7. The species has many occurrences in Massachusetts that have high numbers of individuals in minimally managed habitats.
8. The species is able to outcompete other species in the same natural plant community.
9. The species has the potential for rapid growth, for high seed or propagule production and dissemination, and for establishment in natural plant communities.

If a species meets the initial five criteria and criteria 6–9 at this time, it may be considered a “likely invasive” species in Massachusetts if it also meets at least one of the following three criteria:

10. The species has at least one occurrence in Massachusetts that has high numbers of individuals forming dense stands in minimally managed habitats.
11. The species has the potential, based on its biology, colonization history outside its native range, and likelihood of range expansion or change in biologic potential from climate change predictions, to become invasive in Massachusetts.
12. The species is acknowledged to be invasive in nearby states, but its status in Massachusetts is unknown or unclear. This may result from lack of field experience with the species or from difficulty in species determination or taxonomy.

If the species meets the basic criteria for invasiveness (criteria 1–4) but is not naturalized in Massachusetts (criterion 5), the species may be considered “potentially invasive” in Massachusetts if it meets the following three criteria (criteria 13–15):

13. The species, if it becomes naturalized in Massachusetts, based on its biology and biologic potential, would pose an imminent threat to the biodiversity of Massachusetts **and**
14. Its naturalization in Massachusetts is anticipated, **and**
15. The species has a documented history of invasiveness in other areas outside its native range including expansion of range and/or change in biological potential from climate change predictions.

The criteria for invasive animal species are less well-defined, but many of the same characteristics (including a non-Massachusetts origin and the ability to outcompete native species) are similar.

5.10.2.1.1 Regulations on Invasive Species

Massachusetts has a variety of laws and regulations to mitigate the impacts of invasive species. The Department of Agricultural Resources (DAR) maintains a list of prohibited plants for the state, which includes federally listed noxious weeds as well as invasive plants recommended by MIPAG and approved for listing by DAR. Species on the DAR list are regulated with prohibitions on importation, propagation, purchase, and sale in the Commonwealth.

Activities in the Wetlands Protection Act Buffer Zone, Agricultural Emergencies, and ecological restoration projects have additional requirements for all activities covered by the Act to account for, and take steps to prevent, the introduction or propagation of invasive species under the Massachusetts Wetlands Protection Act (Title 310 of the Code of Massachusetts Regulations [CMR] Chapter 10.00).

In 2002, Massachusetts passed an Aquatic Invasive Species Management Plan, making it eligible for federal funds to support and implement the plan through the federal Aquatic Nuisance Prevention and Control Act. The Massachusetts Department of Environmental Protection, the Department of Conservation and Recreation (DCR), the Massachusetts Institute of Technology Sea Grant College Program, and the Office of Coastal Zone Management are part of the Northeast Aquatic Nuisance Species Panel, which was established under the federal Aquatic Nuisance Species Task Force. This panel allows managers and researchers to exchange information and coordinate efforts on the management of aquatic invasive species. The Commonwealth also has several resources pertaining to terrestrial invasive species, such as the Massachusetts Introduced Pest Outreach Project. While a strategic management plan has not yet been prepared for terrestrial invasive species, in 2011 the DCR Division of Water Supply Protection, Office of Watershed Management, developed a management strategy for terrestrial invasive plants on their properties.

Massachusetts-specific regulations on invasive species include the following:

- 330 CMR 6.0(d) requires any seed mix containing restricted noxious weeds to specify the name and number per pound on the seed label. 339 CMR 9.0 restricts the transport of currant or gooseberry species to prevent the spread of white pine blister rust.
- Chapters 128, 130, and 132 of Part I of the General Laws of the state include language addressing water chestnuts, green crabs, Asian longhorned beetles, and many other species. These laws also include language allowing orchards and gardens to be surveyed for invasive species and for quarantines to be put into effect at any time.
- In 2005, MIPAG presented DAR with a list of designative invasive plants in Massachusetts. This list was combined with the Federal Noxious Weed List to create the Prohibited Plant List, which initially covered over 140 species. In 2006, DAR began a two-step ban on the importation and sale of species on the Prohibited Plant List. The two-step ban began with an importation ban that took effect in 2006, followed by a

propagation ban that took effect in 2009. As of January 2009, all species on the Prohibited Plant List are banned from importation, sale, trade, distribution, and related activities (Massachusetts Department of Agricultural Resources, n.d.-b).

Federal invasive species programs and mandates include:

- Executive Order 13112, signed in February 1999, prevents the introduction of invasive species and funds control programs to minimize the economic, ecological, and human health impacts caused by invasive species. The Executive Order assembled the National Invasive Species Council (NISC) to coordinative invasive species management within and across federal government agencies. NISC created the first National Invasive Species Management Plan (NISMP) in 2001; the plan has subsequently been updated with 2008–2012 and 2016–2018 versions. The NISMPs aim to prevent the introduction and spread of invasive species, minimize their impacts, restore native species and habitats, and encourage collaboration on invasive species issues (Masssachusetts Department of Conservation and Recreation, 2011).
- The Invasive Species Strategic Plan 2021–2025 provides a framework for the Department of the Interior's bureaus and offices to implement invasive species management plans. This strategic plan provides a comprehensive approach to invasive species management for the bureaus and focuses on five goals for management: collaboration, cost-effective prevention, cost-effective eradication, implementation of early detection and rapid response efforts, and improved invasive species data management for decision-making at all levels of government (U.S. Department of the Interior, 2021).

5.10.2.2 Hazard Description

The invasive species hazard described in this section includes non-native aquatic and terrestrial flora and fauna.

5.10.2.2.1 Location

The entire Commonwealth is vulnerable to invasive species and the damage done by invasive species is significant. The relevant types of species vary by location, elevation, ecosystem, and habitat type, as well as land and water uses. Due to the widespread nature of this hazard and the high number of invasive species in the Commonwealth (at least 140 invasive plant species alone), no maps showing the location of all invasive species present in Massachusetts exist as of March 2023. To develop this section of the Risk Assessment, the research team used the Early Detection and Distribution Mapping System (EDDMapS) to understand where some invasive species have been reported in the Commonwealth. Reports from EDDMapS show that invasive species are found in every county in the Commonwealth. The ability of invasive species to travel far distances (via either natural mechanisms once established or accidental human transport) allows them to propagate rapidly over a large area. Similarly, in open freshwater and marine ecosystems, invasive species can spread quickly, as there are generally no physical barriers (other than physiological tolerances) to prevent establishment and maritime cargo and port operations, as well as commercial and recreational water activities, provide ample opportunities for transport to new locations.

5.10.2.2.2 Previous Occurrences and Frequency

Previous Occurrences

The invasive, likely invasive, and potentially invasive plants identified by MIPAG (last updated in 2022) are listed in Table 5.10-1. The table also includes details on the nature of the ecologic and economic challenges presented by each species as well as information on when and where the species was first detected in Massachusetts as available. Due to the widespread and ongoing nature of this hazard, this is not an exhaustive list of all invasive species in the Commonwealth.

One example of the significant economic impacts from the invasive species hazard is the infestation of the Asian long-horned beetle. First detected in Massachusetts in 2008, the Asian long-horned beetle has infected thousands of trees in the Commonwealth; in 2008 27,000 trees had to be removed in Worcester alone. Since 2008, over 80,000 trees in Massachusetts have been infected by this beetle (Mass Audubon, n.d.-a).

Table 5.10-1. MIPAG List of Invasive, Likely Invasive, and Potentially Invasive Plants

Species	Common Name	Notes
Invasive		
Acer platanoides	Norway maple	A tree occurring in all regions of the state in upland and wetland habitats and especially common in woodlands with colluvial soils. Grows in full sun to full shade. Escapes from cultivation; can form dense stands; outcompetes native vegetation, including sugar maple; dispersed by water, wind, and vehicles.
Acer pseudoplatanus	Sycamore maple	A tree occurring mostly in southeastern counties of Massachusetts, primarily in woodlands and especially near the coast. It grows in full sun to partial shade. Escapes from cultivation inland as well as along the coast; salt-spray tolerant; dispersed by wind, water, and vehicles.
Aegopodium podagraria	Bishop’s goutweed; bishop’s weed; goutweed	A perennial herb occurring in all regions of the state in uplands and wetlands. Grows in full sun to full shade. Escapes from cultivation; spreads aggressively by roots; forms dense colonies in flood plains.
Ailanthus altissima	Tree of heaven	This tree occurs in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Spreads aggressively from root suckers, especially in disturbed areas.

Species	Common Name	Notes
Alliaria petiolata	Garlic mustard	A biennial herb occurring in all regions of the state in uplands. Grows in full sun to full shade. Spreads aggressively by seed, especially in wooded areas.
Berberis thunbergii	Japanese barberry	A shrub occurring in all regions of the state in open and wooded uplands and wetlands. Grows in full sun to full shade. Escaping from cultivation; spread by birds; forms dense stands.
Cabomba caroliniana	Carolina fanwort; fanwort	A perennial herb occurring in all regions of the state in aquatic habitats. Common in the aquarium trade; chokes waterways.
Celastrus orbiculatus	Oriental bittersweet; Asian or Asiatic bittersweet	A perennial vine occurring in all regions of the state in uplands. Grows in full sun to partial shade. Escaping from cultivation; berries spread by birds and humans; overwhelms and kills vegetation.
Cynanchum louiseae	Black swallowwort; Louise’s swallowwort	A perennial vine occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to partial shade. Forms dense stands, outcompeting native species: deadly to Monarch butterflies.
Elaeagnus umbellata	Autumn olive	A shrub occurring in uplands in all regions of the state. Grows in full sun. Escaping from cultivation; berries spread by birds; aggressive in open areas; can change soil.
Eragrostis curvula	Weeping lovegrass	A perennial warm season bunchgrass that occurs on road edges, agricultural grasslands, sandplain grassland, and coastal heathland areas, mainly in coastal and island counties. In globally rare early successional habitats, this grass has demonstrated the ability to expand rapidly
Euonymus alatus	Winged euonymus; burning bush	A shrub occurring in all regions of the state and capable of germinating prolifically in many different habitats. It grows in full sun to full shade. Escaping from cultivation and can form dense thickets and dominate the understory; seeds are dispersed by birds.
Euphorbia esula	Leafy spurge; wolf’s milk	A perennial herb occurring in all regions of the state in grasslands and coastal habitats. Grows in full sun. An aggressive herbaceous perennial and a notable problem in the western U.S.
Fallopia japonica	Japanese knotweed; Japanese or Mexican bamboo	A perennial herbaceous subshrub or shrub occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade, but hardier in full sun. Spreads vegetatively, by root fragments and by seed; forms dense thickets.

Species	Common Name	Notes
Ficaria verna	Lesser celandine; fig buttercup	A perennial herb occurring on stream banks, and in lowland and uplands woods in all regions of the state. Grows in full sun to full shade. Propagates vegetatively and by seed; forms dense stands especially in riparian woodlands; an ephemeral that outcompetes native spring wildflowers.
Frangula alnus	European buckthorn; glossy buckthorn	Shrub or tree occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Produces fruit throughout the growing season; grows in multiple habitats; forms thickets.
Glaucium flavum	Sea or horned poppy; yellow hornpoppy	A biennial and perennial herb occurring in southeastern Massachusetts in coastal habitats. Grows in full sun. Seeds float; spreads along rocky beaches; primarily Cape Cod and Islands.
Hesperis matronalis	Dame's rocket	A biennial and perennial herb occurring in all regions of the state in upland and wetland habitats. Grows in full sun to full shade. Spreads by seed; can form dense stands, particularly in flood plains.
Iris pseudacorus	Yellow iris	A perennial herb occurring in all regions of the state in wetland habitats, primarily in flood plains. Grows in full sun to partial shade. Outcompetes native plant communities.
Lepidium latifolium	Broad-leaved pepperweed; tall pepperweed	A perennial herb occurring in eastern and southeastern regions of the state in coastal habitats. Grows in full sun. Primarily coastal at upper edge of wetlands; also found in disturbed areas; salt tolerant.
Lonicera japonica	Japanese honeysuckle	A perennial vine occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Rapidly growing, dense stands climb and overwhelm native vegetation; produces many seeds that are bird dispersed; more common in southeastern Massachusetts.
Lonicera morrowii	Morrow's honeysuckle	A shrub occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Part of a confusing hybrid complex of non-native honeysuckles commonly planted and escaping from cultivation via bird dispersal.
Lonicera x bella	Bell's honeysuckle	This shrub occurs in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Part of a confusing hybrid complex of non-native honeysuckles commonly planted and escaping from cultivation via bird dispersal.

Species	Common Name	Notes
Lysimachia nummularia	Creeping jenny; moneywort	A perennial herb occurring in all regions of the state in upland and wetland habitats. Grows in full sun to full shade. Escaping from cultivation; problematic in flood plains, forests, and wetlands; forms dense mats.
Lythrum salicaria	Purple loosestrife	A perennial herb or subshrub occurring in all regions of the state in upland and wetland habitats. Grows in full sun to partial shade. Escaping from cultivation; overtakes wetlands; high seed production and longevity.
Myriophyllum heterophyllum	Variable watermilfoil; two-leaved watermilfoil	A perennial herb occurring in all regions of the state in aquatic habitats. Chokes waterways, spread by humans and possibly birds.
Myriophyllum spicatum	Eurasian watermilfoil	A perennial herb found in all regions of the state in aquatic habitats. Chokes waterways, spread by humans and possibly birds.
Phalaris arundinacea	Reed canary-grass	This perennial grass occurs in all regions of the state in wetlands and open uplands. Grows in full sun to partial shade. Can form huge colonies and overwhelm wetlands; flourishes in disturbed areas; native and introduced strains; common in agricultural settings and in forage crops.
Phragmites australis	Common reed	A perennial grass (listed by the U.S. Department of Agriculture as a subshrub/shrub) found in all regions of the state. Grows in upland and wetland habitats in full sun to full shade. Overwhelms wetlands forming huge, dense stands; flourishes in disturbed areas; native and introduced strains.
Polygonum perfoliatum; Syn: Persicaria perfoliata	Mile-a-minute vine or weed; Asiatic tearthumb	This annual herbaceous vine is currently known to exist in several counties in Massachusetts and has also been found in Rhode Island and Connecticut. Habitats include streamside, fields, and road edges in full sun to partial shade. Highly aggressive; bird and human dispersed.
Potamogeton crispus	Crisped pondweed; curlyleaf pondweed	A perennial herb occurring in all regions of the state in aquatic habitats. Forms dense mats in the spring and persists vegetatively.
Rhamnus cathartica	Common buckthorn	A shrub or tree occurring in all regions of the state in upland and wetland habitats. Grows in full sun to full shade. Produces fruit in fall; grows in multiple habitats; forms dense thickets.

Species	Common Name	Notes
Robinia pseudoacacia	Black locust	A tree that occurs in all regions of the state in upland habitats. Grows in full sun to full shade. While the species is native to central portions of eastern North America, it is not indigenous to Massachusetts. It has been planted throughout the state since the 1700s and is now widely naturalized. It behaves as an invasive species in areas with sandy soils.
Rosa multiflora	Multiflora rose	A perennial vine or shrub occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Forms impenetrable thorny thickets that can overwhelm other vegetation; bird dispersed.
Salix atrocinerea/ Salix cinerea	Large gray willow/rusty willow	A large shrub or small tree most commonly found in the eastern and southeastern areas of the state, with new occurrences being reported further west. Primarily found on pond shores but is also known from other wetland types and rarely uplands. *Salix atrocinerea* L./*Salix cinerea* L. are recognized either as closely related species or the conspecific subspecies *Salix cinerea* ssp. *oleifolia* and *S. cinerea* ssp. *cinerea*. Forms dense stands and can outcompete native species along the shores of coastal plain ponds
Trapa natans	Water chestnut	An annual herb occurring in the western, central, and eastern regions of the state in aquatic habitats. Forms dense floating mats on water.
Likely Invasive		
Actinidia arguta	Hardy kiwi; tara vine	A fast-growing woody vine that may climb to 30 feet or more on trees. Grows in sun or shade. Used in permaculture. Where it escapes it can aggressively climb trees and smother them, while also producing new seedlings.
Ampelopsis brevipedunculata	Porcelain-berry; Amur peppervine	A woody vine found primarily in southeastern counties of Massachusetts but known from some western counties as well. Occurs in upland woodland edges and thickets and grows in full sun to partial shade. Escapes from cultivation and is bird dispersed.
Anthriscus sylvestris	Wild chervil	A biennial or short-lived perennial herb with a few reported sites in minimally managed habitats scattered across the state. It occurs in old fields, wetlands, roadsides and proliferates in floodplain soils. Grows in full sun to partial shade. It has a very long taproot and is reported to be spreading in Vermont and Connecticut.

Species	Common Name	Notes
Berberis vulgaris	Common barberry; European barberry	A shrub occurring in all regions of the state, primarily in uplands. It grows in full sun to full shade. The potential of this plant to spread is high; once common but widely eradicated because it is an alternate host for wheat rust; it hybridizes with Japanese barberry.
Butomus umbellatus	Flowering rush	An herbaceous perennial. Can occur on inundated shorelines and in shallow water, river and lakeshores, mudflats, and floodplain forests.
Cardamine impatiens	Bushy rock-cress; narrowleaf bittercress	A winter annual or biennial herb found in western Massachusetts occurring in rich woods, rocky ledges, roadsides, and stream banks. It grows in full sun to full shade. Disperses seeds easily and is spreading rapidly in other parts of New England.
Centaurea stoebe	Spotted knapweed	A biennial or perennial herb occurring in all regions of the state in upland and coastal habitats. Grows in full sun. Aggressively grows in well-drained, disturbed soils; serious problem in western states where it outcompetes native grassland species, literature reports are currently lacking for this in the northeast.
Cynanchum rossicum	European swallowwort; pale swallowwort	A perennial herb occurring in the western region of the state in upland habitats. Grows in full sun to partial shade. Forms dense stands; found primarily in the lower Connecticut River Valley.
Cytisus scoparius	Scotch broom	A shrub that occurs along roadsides, coastal sites, disturbed sites, pastures, and dry scrubland. Its nitrogen fixing ability allows it to compete successfully on nutrient-poor, dry, sandy soils. It is seen as an ecological threat to native grasslands of Massachusetts as well as the globally rare sandplain grasslands of the coast and islands.
Egeria densa	Brazilian waterweed; Brazilian elodea	A perennial herb occurring in the eastern and southeastern regions of the state in aquatic habitats. Common in the aquarium trade; chokes waterways; currently only found in a few Massachusetts ponds.
Epilobium hirsutum	Hairy willow-herb; codlins and cream	A perennial herb occurring in all regions of the state in wetlands. Grows in full sun. Seeds dispersed by wind and water; evidence currently lacking that this species outcompetes other vegetation in minimally managed habitats.
Euphorbia cyparissias	Cypress spurge	A perennial herb occurring in all regions of the state in upland habitats. Grows in full sun. Persists in open areas; evidence currently lacking that this species outcompetes other vegetation in minimally managed habitats.

Species	Common Name	Notes
Festuca filiformis	Hair fescue; fineleaf sheep fescue	A perennial grass occurring in all regions of the state, in grasslands and open woodlands. Grows in full sun to partial shade. Common in minimally managed grassland habitats; more data needed on its ability to outcompete native species.
Glyceria maxima	Tall mannagrass; reed mannagrass	A perennial grass currently known from one marsh in Essex County. Grows in full sun to partial shade. Spreads vegetatively and produces viable seeds; forms dense stands.
Heracleum mantegazzianum	Giant hogweed	A perennial herb occurring in scattered sites across all regions of the state; thrives in multiple habitats. Grows in full sun to full shade. Escapes from cultivation; seeds can be dispersed by water; can cause severe skin reactions.
Humulus japonicus	Japanese hops	An annual herbaceous vine with current records in western Massachusetts, but historical records from all regions of the state. Grows in floodplain forests and riverbanks in full sun to partial shade. Escapes from cultivation; capable of prolific growth.
Hydrilla verticillata	Hydrilla; water-thyme; Florida elodea	A perennial aquatic herb occurring in the eastern region of the state. Easily dispersed by birds and humans; chokes entire water bodies.
Ligustrum obtusifolium	Border privet	A shrub occurring in all regions of the state in woodlands and woodland edges. Grows in full sun to full shade. Widespread and shade tolerant, bird dispersed; more data needed on density and distribution; flowers are needed to identify species.
Lonicera tatarica	Tatarian honeysuckle	A shrub found from Boston westward in thickets, woods, and edges of woods. Can grow in full sun to full shade. Commonly confused with other non-native honeysuckles; crosses with Morrow's honeysuckle *(L. morrowii)* to produce the invasive hybrid Belle's honeysuckle.
Microstegium vimineum	Japanese stilt grass; Nepalese browntop	An annual grass occurring in the western region of the state in upland and wetland habitats. Grows in full sun to full shade. Forms dense stands; currently localized in the lower Connecticut River Valley; spreads in flood plains.
Miscanthus sacchariflorus	Plume grass; Amur silvergrass	This perennial grass is currently known to occur in central Massachusetts in wetland margins and roadsides. Grows in full sun. Spreads by rhizomes and develops dense stands along roadsides and adjacent native habitats.

Species	Common Name	Notes
Myosotis scorpioides	Forget-me-not	A perennial herb occurring in all regions of the state in wetlands. Grows in full sun to full shade. Escaping from cultivation; prolific in open wooded streams, stream-banks and wet meadows; evidence about its persistence is needed.
Myriophyllum aquaticum	Parrot-feather; water-feather; Brazilian watermilfoil	A perennial herbaceous aquatic occurring in southeastern Massachusetts along a shallow pond edge. Grows in full sun to partial shade. Reproduces from fragments; commonly used in the water garden trade.
Najas minor	Brittle water-nymph; lesser naiad	An annual herb occurring in the western region of the state in aquatic habitats. Chokes waterways; spread by humans and possibly birds.
Nymphoides peltata	Yellow floating heart	This aquatic perennial occurs in ponds in central Massachusetts. Grows in full sun to partial shade. Can create a dense floating mat on ponds and can reproduce from fragments.
Phellodendron amurense	Amur cork-tree	This tree occurs in uplands of eastern to central Massachusetts. Grows in full sun to full shade. A bird-dispersed species that has escaped cultivation.
Pinus thunbergii	Japanese black pine	A small evergreen tree that can reach heights of about 6–9 meters tall and about 6–11 meters wide in cultivation. It occurs in coastal sites, disturbed sites, sand dunes, and dry scrubland. It is seen as an ecological threat to native grasslands and dune systems, including the globally rare sandplain grasslands of coastal Massachusetts and the islands.
Pueraria montana	Kudzu; Japanese arrowroot	A perennial herbaceous vine found in southeastern Massachusetts. Occurs at Arnold Arboretum, uplands. Grows in full sun to partial shade. Present in Massachusetts and subject to control; marginally hardy in Massachusetts but has the potential to invade minimally managed areas based on its performance elsewhere.
Ranunculus repens	Creeping buttercup	A perennial herb occurring in all regions of the state in wetlands. Grows in full sun to full shade. Common around springs and wetlands; evidence currently lacking that this species outcompetes other vegetation in minimally managed habitats.
Rorippa amphibia	Water yellowcress; great yellowcress	A perennial herb occurring in central Massachusetts. Grows in wetlands in full sun to partial shade. Common and increasing in central Massachusetts river drainages; a major threat to riparian habitats forming dense stands at some locations.

Species	Common Name	Notes
Rubus phoenicolasius	Wineberry; Japanese wineberry; wine raspberry	A shrub found in uplands of southern Massachusetts. Can grow in full sun to partial shade. Animal and human dispersed; forms thickets.
Senecio jacobaea	Tansy ragwort; stinking Willie; stinking Billy	A biennial herb occurring in a few sites east of the Connecticut River; habitat is open uplands. Grows in sun or partial shade. This species is highly invasive in the Canadian Maritimes; may also spread from disturbed areas.
Tussilago farfara	Coltsfoot	A perennial herb occurring in all regions of the state in upland and wetland habitats. Grows in full sun to full shade. Particularly problematic in lime seeps and disturbed sites; evidence currently lacking that this species outcompetes other vegetation in minimally managed habitats.
Potentially Invasive		
Arthraxon hispidus	Hairy joint grass; jointhead; small carpetgrass	An annual grass historically known from Franklin County but not currently known from the state. Habitats elsewhere include roadsides, shores, ditches, and low woods and fields. Grows in full to partial shade. It is problematic in Connecticut and southward.
Carex kobomugi	Japanese sedge; Asiatic sand sedge	A perennial sedge established mainly in sand dunes and growing in full sun. There is only one current New England location—Rhode Island; it can spread rapidly in dune systems.
Lonicera maackii	Amur honeysuckle	A shrub having specimens and reports from a number of Massachusetts counties, but verification of naturalization at these locations is needed. The likely habitats are woods and woodland edges. Can grow in full sun or shade. Escapes from cultivation, but documentation needed regarding naturalized populations in Massachusetts; recognized as invasive in the Midwest and portions of the southeastern U.S.

Sources: MIPAG (2022b, 2022c, 2022d).

Invasive fauna offer one of the best examples of the significance of the invasive species hazard: the infestation of the Asian longhorned beetle. First detected in Massachusetts in 2008, this beetle has infected thousands of trees in the Commonwealth; in 2008, 27,000 trees had to be removed in Worcester alone. Since 2008, this beetle has infected over 80,000 trees in Massachusetts (Mass Audubon, n.d.-b).

In marine systems, meanwhile, management of invasives is extremely difficult once a species has become established; therefore, the focus is on monitoring established populations, preventing new populations from forming, and surveying marine habitats for early detection and rapid response.

Although the Commonwealth lacks the same type of criteria for invasive fauna that have been established for flora, a number of pests have disrupted natural systems and inflicted economic damage on the Commonwealth, as summarized in Table 5.10-2 below. Because of the rapidly evolving nature of the invasive species hazard, this list is not considered exhaustive.

Table 5.10-2. Massachusetts Introduced Pests Outreach Project List of Invasive Insects

Species	Common Name	Notes
Acrolepiopsis assectella	Leek moth	Larvae feed inside hollow leaves or stems of onion or garlic. Larvae can bore into onion or garlic bulbs, predisposing them to secondary bacterial or fungal infection.
Adoxophyes orana	Summer fruit totrix moth	The summer fruit totrix moth feeds on a wide variety of plants with a preference for rosaceous plants, especially apple and pear. The moth is reported to feed and develop on more than 50 plant species in multiple families including fruits, forest trees, and ornamentals.
Agrilus planipennis	Emerald ash borer	Emerald ash borer is a small, invasive beetle that is devastating to all ash tree species in Massachusetts.
Anoplophora glabripennis	Asian longhorned beetle	Asian longhorned beetle larvae damage trees by eating the outer sapwood, beneath the bark layer, hollowing out the wood.
Callidiellum rufipenne	Japanese cedar longhorned beetle	The Japanese cedar longhorned beetle larvae create puckering incisions along the bark. Adults leave small oval exit holes when exiting the wood in the spring.
Contarinia nasturii	Swede midge	Swede midge larvae feed on the growing tips of brassicas, causing malformed plants. Because swede midge can be blown on winds, early spring infestations may occur in fields downwind of fall infestations.
Epiphyas postvittana	Light brown apple moth	The light brown apple moth is reported to feed and develop on more than 200 plant species in 120 plant genera in 50 families. Hosts include fruits (apples, blueberry, peach), broadleaved weeds (plantain), vegetables (cabbage, corn, pepper, tomatoes), trees (oak, willow, poplar, walnut) and ornamentals (roses, chrysanthemums, dahlia).
Halyomorpha halys	Brown marmorated stink bug	The brown marmorated stink bug feeds on a variety of shade and fruit trees, vegetables, and legumes. Reported hosts include apple, peach, pear, citrus, figs, mulberries, soybean, butterfly bush, and some weeds such as burdock.
Lycorma delicatula	Spotted lanternfly	Spotted lanternfly is an invasive sap-feeding insect from Asia that was first found in the U.S. in 2014, in Pennsylvania.

Species	Common Name	Notes
		While the main host plant of this pest is tree of heaven, it attacks a variety of trees, shrubs, and vines, and has the potential to affect a broad range of agricultural commodities, including grapes and wine, apples, peaches, and maple syrup.
Operophtera brumata	Winter moth	The winter moth is an invasive insect that can wreak havoc on trees. Introduced into the U.S. from Europe via Canada, it is most commonly observed in late fall, early winter as a whitish adult moth and in spring as a tiny green caterpillar.
Phyrrhalta viburni	Viburnum leaf beetle	Viburnum leaf beetle larvae chew holes in viburnum leaves in the spring, creating a lace-like pattern. The larvae feed individually or in small groups and can cause significant damage to viburnum shrubs.
Sirex noctilio	European woodwasp	The European woodwasp bore galleries deep into and through the wood, unlike bark beetles, which typically confine themselves to just under the bark. All pine species are believed to be at risk, particularly stressed Scots (or Scotch) pine and red pine, as well as eastern pine.
Tomicus piniperda	Pine shoot beetle	In North America, all pine tree species are susceptible to this beetle, including jack pine, red pine, eastern white pine, and the Scots pine. When the beetle is abundant, it can also threaten the balsam fir, Norway spruce, and larch. Heavy pine shoot beetle infestations can cause severe damage to pine shoots, as a single adult beetle can destroy up to six branches during its maturation period.
Urocerus gigas	Giant woodwasp	Giant woodwasp larvae live in the wood of pine trees where they spend up to five years developing. The wasps attack the trunks of damaged or weakened trees.
Vespa mandarinia	Northern giant hornet, formerly known as Asian giant hornet	The Northern giant hornet is potential pest of honeybees, as well as yellow jacket wasps, paper wasps, and other wasps. Bee/wasp colonies are targeted as a food source late in the growing season, when colonies of this pest grow large, and occur in close proximity to the home nest.

Source: DAR (n.d.-a). Accessed 2022.

Frequency

Because the presence of invasive species is ongoing rather than a series of discrete events, it is difficult to quantify the frequency of these occurrences. However, increased rates of global trade and travel have created many new pathways for the dispersion of species outside their natural ranges. As a result, the frequency with which these threats have been introduced has increased significantly with globalization. Increased international trade in ornamental plants is particularly concerning because many of the invasive plant species in the U.S. were originally imported as ornamentals or for medicinal purposes.

In addition to the effects of expanded global and commercial trade and travel on the distribution of invasive species to date, climate change is predicted to increase the abundance of invasive species globally. Non-native species are expected to enter new regions due to climate change, with species that prefer warmer climates increasing their range northward. The species hierarchies in ecosystems will also change, and ecosystems that are already experiencing land use, climate, and other stressors (habitat loss and land conversion, drought, increased temperatures, wildfires, flooding, etc.) will be more susceptible to invasive species. Additionally, increased carbon dioxide in the atmosphere will drive an increase in photosynthesis, making plants grow faster (Cho, 2022). Research shows that, when looking at native and invasive species under the same conditions, invasive plants can use carbon dioxide more effectively than native plants. This is thought to be due to higher productivity and more efficient resource use than native plants, therefore helping them outcompete native species (North American Invasive Species Management Association, 2022). As the climate warms and temperatures shift, species—both native and invasive—are moving further north into habitats that were previously inhospitable. Research indicates that the Northeast and the Midwest are likely to be key locations for new species to become established (North American Invasive Species Management Association, 2022).

Warmer weather and shorter winters are also a direct result of climate change. Research shows that some invasive plants are better suited to take advantage of these changes by emerging and leafing out earlier in the spring before the native species do, which helps them outcompete the native species by monopolizing the soil space, nutrients, and sunlight before native species are active (North American Invasive Species Management Association, 2022).

Extreme climate events are expected to increase with climate change. While many invasive species are able to disproportionately take advantage of these extreme events, there may be instances where native species may benefit—for example, floods benefitting some fish species, or some native plants being able to survive prolonged droughts (Diez et al., 2012). While a considerable amount of research exists on the interaction between climate change and invasive species, at this time it remains difficult to make accurate predictions and draw direct conclusions about the interactions between extreme events, invasive species invasions, and their interaction with native species (Diez et al., 2012).

5.10.2.2.3 Severity/Intensity

The geographic extent, severity, and intensity of invasive species varies greatly depending on the species in question and other factors, including the availability of hospitable natural or artificial habitats, as well as availability of disturbed habitats and ecosystems, and the range that the invasive species can inhabit. In marine environments, for example, most invasive species are found on artificial substrates such as docks, oceanic platforms, boats, and ships (Mineur et al., 2012). Invasive species are measured through monitoring and recording observations into existing databases (e.g., EDDMapS, iNaturalist, DAR pest reporting). However, monitoring and reporting activities are time-consuming and costly and must be factored into the costs of this hazard.

Due to the widespread and rapidly evolving nature of the invasive species hazard, it is difficult to accurately quantify the actual extent of invasive species, and equally difficult to quantify costs associated with monitoring, management, damage (to landscapes, humans, animals, etc.), and restoration activities in Massachusetts. Additionally, there is no way to directly evaluate or quantify impacts from invasive species on aesthetics or the perceived value of natural areas (Marsh et al., 2021).

MIPAG has developed a list of "Early Detection" plant species: species classified (by MIPAG) as invasive, likely invasive, or potentially invasive that have limited prevalence in Massachusetts, have partial containment potential, or pose a public health threat. The Early Detection list (Table 5.10-3 below) includes the documented distribution of a species by county. All plants listed are classified as Category 1—that is, they should be eradicated and reported if found anywhere in Massachusetts (MIPAG, 2011). This list was last updated in 2011.

Table 5.10-3. MIPAG Early Detection Plant Species

Species	Common Name	Current Distribution (as of November 2010)	Notes
Arthraxon hispidus	Hairy joint grass; jointhead; small carpetgrass	Franklin County (historically)	This species is not currently known in Massachusetts; it was last collected in Deerfield in 1973. This is an annual grass that co-occurs with Japanese stilt grass further south.
Butomus umbellatus	Flowering rush	Essex County Middlesex County	*Butomus umbellatus* is an aquatic perennial herb which reproduces by seed dispersal or vegetatively by bulbils.
Carex kobomugi	Japanese sedge; Asiatic sand sedge	Barnstable County (historically)	Native to northeastern Asia, *Carex kobomugi* is an invasive plant that invades coastal sand dunes and can outcompete native dune-binding grasses. This species was last collected in 1973.

Species	Common Name	Current Distribution (as of November 2010)	Notes
Egeria densa	Brazilian waterweed; Brazilian elodea	Essex County Middlesex County Norfolk County Plymouth County Worcester County	This species is often confused with Hydrilla and native *Elodea* spp. but has larger, nickel-sized flowers. This is a submerged aquatic species whose rapid growth often leads to dense mats on the water surface, which crowds out native plants and damages fish and aquatic habitat. The mats can also impede boat traffic.
Glyceria maxima	Tall mannagrass; reed mannagrass	Essex County	This perennial grass invades low shrub-swamps and other wetlands.
Heracleum mantegazzi-anum	Giant hogweed	Berkshire County Franklin County Hampden County Hampshire County Middlesex County Norfolk County Suffolk County Worcester County	Giant hogweed is a federal noxious weed that is currently being eradicated under the U.S. Department of Agriculture's authority. This is a perennial herb that can cause painful burns and permanent scarring to humans if they touch the plant.
Hydrilla verticillata	Hydrilla; water-thyme; Florida elodea	Barnstable County Plymouth County Worcester County	Hydrilla is an invasive non-native submerged plant. This plant grows and reproduces rapidly, displacing native species, hampering recreational uses, and slowing water flow. Hydrilla, once established, can replace native vegetation and affect fish populations.
Myriophyllum aquaticum	Parrot-feather; water-feather; Brazilian watermilfoil	Norfolk County	Parrot-feather is a perennial aquatic plant native to South America. This plant typically grows in freshwater, with a preference for areas with high nutrient contents. Parrot-feather has been introduced worldwide for use in indoor and outdoor aquaria.

Species	Common Name	Current Distribution (as of November 2010)	Notes
Nymphoides peltata	Yellow floating heart	Hampden County Middlesex County Worcester County	Yellow floating heart is native to Asia and now is found in over 15 states in the U.S. This plant forms dense mats on the water surface, restricting light penetration into the water and decreasing air exchange between the water's surface and the atmosphere. Algae can be shaded out by this plant, resulting in food chain disruptions for an entire lake.
Persicaria perfoliata syn.: Polygonum perfoliatum	Mile-a-minute vine or weed; Asiatic tearthumb	Barnstable County Essex County Franklin County Norfolk County Plymouth County Suffolk County	Mile-a-minute vine is a barbed vine that can grow up to 6 inches a day. This vine smothers other herbaceous plants, shrubs, and even trees by growing over them and blocking their access to sunlight.
Peuraria montana ssp. lobata	Kudzu; Japanese arrowroot	Barnstable County Bristol County Essex County Middlesex County Plymouth County Suffolk County	Kudzu is native to Japan and southeast China and was introduced to the U.S. during the Philadelphia Centennial Exposition in 1876. Once established, kudzu can grow at a rate of a foot per day, with mature vines as long as 100 feet.
Senecio jacobaea	Tansy ragwort; stinking Willie; stinking Billy	Essex County Suffolk County Worcester County	This biennial herb is a weedy plant that infests woodlands, pastures, and hayfields. This plant is toxic to all classes of livestock but most toxic to cattle and horses. The plant can cause chronic liver disease, and affected animals usually die within a few weeks after ingesting it.
Trapa natans	Water chestnut	Berkshire County Bristol County Essex County Franklin County Hamden County Hampshire County Middlesex County Suffolk County Worcester County	Water chestnut is an annual aquatic species with both floating and submerged leaves.

Sources: MIPAG (2011); Plant Conservation Alliance (2009); The Nature Conservancy (n.d.); USDA (2018).

Potential Effects of Climate Change on Invasive Species

Temperature, concentration of carbon dioxide in the atmosphere and oceans, frequency and intensity of coastal storm events, habitat disturbances (from storms, flooding, and other weather-related events), changes in seasons due to climate change (e.g., shorter winters, drier summers) and available nutrients are key factors in determining the ability of invasive species to survive and propagate. Climate change is already altering these variables, increasing the temperature of the oceans, the frequency and intensity of storms, and the concentration of carbon dioxide in the atmosphere and the oceans. Additionally, increased risks to ecosystems from flooding, fire, drought, heat, and salinity intrusion are already creating stress to native flora and fauna, making it easier for invasive species to outcompete them. Some research suggests that extreme weather events, which are increasing due to climate change, may lead to increased establishment of invasive species. Extreme events, such as hurricanes, high wind events, and others, can cause damage or mortality for native species and allow invasive species to take over as they are often able to establish more rapidly following a disturbance (North American Invasive Species Management Association, 2022). Other climate change impacts that could increase the severity of the invasive species hazard include the following (Casey, 2021; Finch et al., 2021; North American Invasive Species Management Association, 2022; Sorte, 2014):

- Elevated atmospheric carbon dioxide levels could increase some organisms' photosynthetic rates, improving the competitive advantage of those species.
- Changes in atmospheric conditions, such as changes in temperature and humidity, could decrease the transpiration rates of some plants, increasing the amount of moisture in the underlying soil. Species that could most effectively capitalize on this increase in available water would become more competitive.
- Fossil fuel combustion can result in widespread nitrogen deposition, which tends to favor fast-growing plant species. In some regions, these species are primarily invasive, so continued use of fossil fuels could make conditions more favorable for these species.
- As the growing season shifts to earlier in the year, several invasive species (including garlic mustard, Japanese barberry, glossy and common buckthorn, and Asian bush honeysuckle) have proven more able to capitalize on this by beginning to flower earlier, which allows them to outcompete later-blooming plants for available resources. Species whose flowering times do not respond to elevated temperatures have decreased in abundance.
- Some research has found that forest pests (which tend to be ectotherms, drawing their body heat from environmental sources) will flourish under warming temperatures. As a result, the populations of defoliating insects and bark beetles are likely to increase.
- Warmer winter temperatures also mean that fewer pests will be killed over the winter season, not only allowing populations to grow beyond previous limits, but also

allowing southern pests previously limited by winter temperatures to spread north into Massachusetts.

- There are many environmental changes possible in the marine environment that can affect the introduction, spread, and establishment of marine species, including increased water temperature, decreased oxygen concentration, decreased ocean pH (ocean acidification), and longer shipping seasons and new travel routes from reduced ice. For example, increases in winter water temperatures could facilitate year-round establishment of species that currently cannot overwinter in New England (Sorte, 2014).

5.10.2.2.4 Warning Time

Once introduced, invasive species often go undetected for years or decades. Species that were introduced many decades ago are only now being recognized as invasives. Additionally, changing climatic conditions are predicted to enable the growth of “sleeper species,” allowing them to become invasive. Sleeper species are non-native species that are established but are not yet invasive because they are limited by biotic or abiotic conditions such as temperature. With increasing temperatures, and lack of preemptive management actions, sleeper species are predicted to become invasive. For example, the growth and full establishment of the kudzu vine is currently temperature-limited in New England, and current temperatures are not conducive to its growth. However, kudzu is a well-established invasive species in the southeastern U.S. If temperatures continue to increase in the Northeast, it is possible that kudzu could become an established invasive species in the region (O’Uhuru et al., 2022).

Because these species can occur anywhere (on public or private property), new invasive species often escape notice until they are widespread and eradication is difficult, costly, and (in some cases) environmentally and sometimes culturally or socially damaging. As a result, early and coordinated action between public and private landholders is critical to prevent widespread damage from invasive species. As of 2022, the Massachusetts DCR Division of Water Supply Protection has rapid response plans for the following aquatic invasive species:

- Curlyleaf pondweed (*Potamogeton crispus*)
- Eurasian watermilfoil (*Myriophyllum spicatum*)
- Fanwort (Cabomba caroliniana)
- Hydrilla (Hydrilla verticillata)
- Common reed (Phragmites australis)
- Northern snakehead (*Channa argus*)
- Variable watermilfoil (Myriophyllum heterophyllum)
- Zebra mussel (Dreissena polymorpha)

5.10.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

Municipalities expressed concern for the impacts of invasive species on local budgets, operations, cultural and economic assets, and the amplifying effect that invasive species could have on hazards the municipalities were already experiencing. Several municipalities did not mention invasive species or mentioned invasive species tangentially as a secondary effect of rising temperatures. In municipalities that are heavily wooded—like Erving, which has 83 percent tree cover—invasive species can reduce forest health, leading to increases in fallen branches and debris that amplify the risk of utility outages (communications, electricity, water supplies) and injuries. Municipalities are concerned when trees and stream vegetation are damaged and tree mortality near water systems increases, resulting in higher rates of erosion and increased stormwater flooding. Economic implications highlighted by most municipalities relate to ecosystems that support local livelihoods, enabling uses such as sugar bushes for maple syrup, stands for cordwood, and lumber used for heating. Invasive animals such as mosquitoes are also of concern in areas with high recreational activity due to the transmission of communicable diseases. Table 5.10-4 below provides a highlight of local plans, summarizing hazard, vulnerability, and dollar values of local assets associated with invasive species.

Table 5.10-4. Highlight of Local Plans and Municipal Vulnerability (MVP) Preparedness Program Planning Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Town of Erving Hazard Mitigation Plan (draft), October 2019 Invasive species was not considered in the town Municipal Vulnerability Planning.	• Cold-water streams shaded by dense hemlock stands are particularly vulnerable due to the hemlock woolly adelgid. • Erving is especially concerned for the health of its forest, which makes up 83% of the town. • When Japanese knotweed damages streambank vegetation, it exacerbates stormwater flooding and erosion issues.	• Concern for humans susceptible to allergies from invasive species. • Risk to people who rely on natural systems for livelihood, mental, and emotional wellbeing. • Stress and mental health impacts from ecosystem damage.	• Costs associated with managing pests placing a toll on local budgets.
2021 Hazard Mitigation Plan: Plymouth, Massachusetts, 2021	• The most significant challenges with invasives have been in Plymouth's many freshwater and saltwater wetlands, disturbed upland areas of fields and exposed soils, and brackish marsh habitats.	• Considered a nuisance hazard not associated with primary impacts like loss of life, property damage, or inhibiting evacuation.	• Strain on municipal finances, no estimate shared. • Invasive species are considered to have small/local-level damage.
Town of Shutesbury Hazard Mitigation Plan, January 2022	• Shutesbury is 88% forested and vulnerable to species that affect forest health. • The tree of heaven produces powerful allelochemicals that trigger immune responses and limited reproduction of other species. • The zebra mussel is also a species of concern.	• Asian tiger mosquito detected in 2019 by local surveillance is of concern for human health as a transmitter of communicable diseases. • Loss of urban canopy, exacerbating heat island effects.	• Cost to control invasive species on public and private land.

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
	• Facilities that rely on biodiversity or the health of surrounding ecosystems.		
Auburn Hazard Mitigation Plan Update, September 2018	• Concern with the Asian longhorned beetle. • Part of Auburn, the City of Worcester, and several other towns have been affected by the infestation.	• Trees weakened by the infestation could be further damaged, resulting in risk from branches especially during rain and wind events.	• Not provided.

5.10.2.3 Secondary Hazards

Invasive species can cause cascading harm that results in significant damage and loss to ecosystem services. They reduce the resilience of ecosystems to other stresses and hazards by placing a constant stress on the system and alter ecosystem function. Some invasive species can harm native pollinators, crowd out native vegetation, and alter the physical structure of a habitat (Plant Conservation Alliance, 2020). For example, black swallowwort (*Cynanchum louiseae*), a perennial vine listed as invasive by MIPAG, can outcompete common milkweed, which is the preferred habitat of monarch butterflies; this reduces habitat for monarch butterflies and contributes to the death of monarch caterpillars (Maine Department of Agriculture, Conservation, and Forestry, 2019). Invasive species can contribute to increased wildfire risk, tree damage and die-offs, and erosion.

5.10.2.4 Exposure and Vulnerability

Table 5.10-5 below summarizes the priority impacts of invasive species in the Commonwealth using themes identified in the Risk Assessment based on information from analysis and research, the *2022 Massachusetts Climate Change Assessment* (MA Climate Assessment) and information related to past and current events in the Commonwealth and the U.S.

Table 5.10-5. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Invasive Species

Sector	Priority Impacts and Vulnerabilities
Human	• Reduction in food safety and security **(urgent)** • Increase in vector-borne disease incidence and bacterial infections **(urgent)**
Governance	• Increase in demand for state and municipal government services **(most urgent)** • Damage to coastal state and municipal buildings and land **(urgent)** • Increase in need for state and municipal policy review and adaptation coordination **(urgent)** • Damage to inland state and municipal buildings and land
Infrastructure	• Loss of urban tree cover **(most urgent)** • Damage to water resource infrastructure
Natural environment	• Coastal wetland degradation **(most urgent)** • Marine ecosystem degradation **(most urgent)** • Forest health degradation **(most urgent)** • Shifting distribution of native and invasive species **(most urgent)**

Sector	Priority Impacts and Vulnerabilities
Economy	• Decrease in marine fisheries and aquaculture productivity **(most urgent)** • Damage to tourist attractions and recreation amenities **(urgent)** • Decrease in agricultural productivity **(urgent)**

Invasive species are virtually certain (99–100 percent likely) to exist and present challenges to the Commonwealth. This likelihood is based on historical occurrence; current trends; and projections for invasive species and factors that influence their spread and establishment, such as cargo movement, tourism, land conversion, use of ornamental species, and climate change impacts including higher temperatures and shifting seasons, drought, wildfire, and flooding. This likelihood is also influenced by the presence of invasive species throughout the Commonwealth that is expected to continue. While the entire Commonwealth is exposed to invasive species, the types of species vary by location, elevation, ecosystem, and habitat type, as well as land and water uses. Areas with high amounts of plant or animal life may be at higher risk of exposure to invasive species than less vegetated urban areas; however, invasive species can disrupt ecosystems of all kinds. Areas that have been disturbed by fires, floods, landslides, construction, or extreme storm events are often at greater risk from invasive species, and care should be taken before and after disturbances to ensure that they do not result in the increase in density or expansion of invasive species.

5.10.2.4.1 Human

Because this hazard is present throughout the Commonwealth, the entire population is considered exposed. Most invasive species do not have direct impacts on human wellbeing; however, as described in the following subsections, there are some health impacts associated with invasive species.

Population Projections

By 2030, the population of Massachusetts is expected to increase by 20,000 to 70,000, with the largest population growth occurring in Middlesex County (a projected increase of 70,000 people by 2030). The population of Barnstable County is expected to decrease by 5,000 in 2030. Humans are the primary mechanism for introduction of non-native species into the environment, so the connection between population increases and invasive species increase is strong. One study found that the density of humans residing around environmentally protected areas was the top determinant for the number of introduced species found inside the protected area (Miller, 2013). Human population growth is also a threat to the success of native species: current global population growth trends indicate that the number of threatened species will increase by 14 percent by 2050. This number does not account for impacts from global warming (Center for Biological Diversity, n.d.).

Vulnerable Populations

Invasive species can affect all populations within the Commonwealth, but some characteristics can make people more vulnerable to specific invasive species that are present in Massachusetts. Populations that are more vulnerable include Environmental Justice populations, defined according to the Commonwealth's definition and criteria, and priority populations. Priority populations are people or communities who are disproportionately affected by climate change due to life circumstances that systematically increase their exposure to climate hazards or make it harder to respond. In addition to factors that contribute to Environmental Justice status (such as income, race, and language), other factors such as physical ability, access to transportation, health, and age can indicate whether someone or their community will be disproportionately affected by climate change. This is driven by underlying contributors such as racial discrimination, economic disparities, or accessibility barriers that create vulnerability. Invasive species can bring new diseases or aggravate existing health issues. Invasive insects can increase arbovirus risk for humans. As noted in the secondary hazard sections, some invasive species (such as zebra mussels) can increase the growth of dangerous algae in aquatic environments, which can negatively impact recreation opportunities as well as human health. Microcystin, a toxin that is released by some species of blue-green algae, can be poisonous to humans if they come in contact with it. Symptoms of microcystin poisoning range from skin rashes to nausea and vomiting to liver damage (Iowa Department of Health and Human Services, n.d.). Invasive species can also increase wildfire risk, which can broadly affect populations directly.

Those who rely on natural systems for their livelihood or mental and emotional wellbeing or have cultural or historical relationships to native species are more likely to experience negative repercussions from the expansion of invasive species. For example, agricultural workers might be affected by loss of crops due to invasive species and either be out of a job or have added responsibilities (such as invasive species management). Agricultural workers, parks and recreation workers, and other outdoor workers tasked with controlling invasive species might need to use herbicides or other chemical control methods that could expose them and others to toxic chemicals.

Health Impacts

Health impacts from invasive species include the spread of infectious diseases, dermatitis, respiratory allergies, wounds and bites, and loss of native species (Marsh et al., 2021). Invasive species could lead to a reduction in food security if they threaten native crops and agriculture (Paini et al., 2016). Some research suggests that "unnatural" green space that appears to fall outside the expected appearance of a natural area can cause psychological stress in visitors to that area (Fuller et al., 2007). When an invasive species causes an area to appear overrun and unmanaged, the area is also more likely to be perceived as unsafe, reducing the likelihood that residents and visitors will use degraded lands and get the health benefits associated with outdoor recreation.

The *Town of Shutesbury Hazard Mitigation Plan* makes specific reference to concerns about the Asian tiger mosquito (*Aedes albopictus*) and its potential impact on human health in Shutesbury. This mosquito is known as a competent vector for tropical flaviviruses including Zika virus, dengue, yellow fever, and chikungunya, in addition to other diseases such as West Nile virus and eastern equine encephalitis. The Asian tiger mosquito was detected in a city near Shutesbury and was also found north of Shutesbury in Brattleboro, Vermont, in 2019 (Shutesbury Hazard Mitigation Planning Team & Franklin Regional Council of Governments, 2021).

Other examples of invasive species in Massachusetts that have been found to have negative impacts on human health include the following:

- The tree of heaven (*Ailanthus altissima*) produces powerful allelochemicals that prevent the reproduction of other species and can cause allergic reactions in humans (Bardsley & Edwards-Jones, 2007).The tree of heaven also has very strong roots, which can damage sewer systems and foundations up to 90 feet away from the parent tree. (It is also the primary host of the spotted lanternfly. After it attracts them, they will infest other nearby trees, such as fruit trees.)
- *Alexandrium catenella* is an invasive dinoflagellate that produces toxins. *A. catenella* causes harmful algal blooms and paralytic shellfish poisoning (PSP). Humans develop PSP after consuming shellfish that have been contaminated with the saxitoxins (neurotoxins) from *A. catenella.* Symptoms from PSP are purely neurological and usually resolve in a few days but can be lethal in some cases. New England states, including Massachusetts, have well-established monitoring programs for PSP and enact shellfishing closures whenever PSP is detected; this means cases of PSP are fairly rare. Still, *A. catenella* continues to pose a public health risk.
- Invasive shrubs, such has Japanese barberry (*Berberis thunbergii* de Candolle; Rananculales; Berberidaceae), have been linked to an increase in Lyme disease in the Northeast. Lyme disease hosts include a range of birds, mammals, and reptiles. In the Northeast, its main vector is blacklegged ticks. One of the most abundant hosts of Lyme disease is white-footed mice, which prefer woodland habitats across Mexico and the eastern U.S., except for parts of the Southeast. The diversity of forests in New England has declined in the past century; the prevalence of closed-canopy tree stands has hindered the development of a diverse understory of shrubs and ground cover plants, which would support diverse wildlife species. An overabundance of white-tailed deer and aggressive invasive species such as the Japanese barberry has further changed the forest habitats. Japanese barberry is of particular concern due to its ability to maintain high densities of ticks infected with pathogens. Linske et al. (2018) draw the connections between these factors to determine the relationship between these invasive species and disease; in intact Japanese barberry stands, they observed increased tick attachment to mice. Therefore, they concluded that invasive Japanese barberry has a strong influence on increased presence and spread of Lyme disease in the Northeast (Linske et al., 2018).

Cultural Impacts

As previously discussed, invasive species often outcompete native species and can lead to biodiversity loss. Indigenous peoples can be affected by invasive species due to loss of traditional food and medicine sources, loss of ceremonial materials, and loss of species with cultural value (Marsh et al., 2021).

5.10.2.4.2 Governance

All state assets are considered exposed to this hazard, with some assets such as parks and open spaces, marine environments, forests, and other natural environments experiencing more impacts. State facilities that rely on or cultivate specific species (e.g., a greenhouse that is propagating endangered plant species, state-owned or supported farmland) are more vulnerable to this hazard than other state facilities. Invasive species in the Commonwealth pose a significant cost and management burden to government agencies responsible for monitoring, preventing, or controlling the spread of invasive plants, animals, and fungi. The cost of ecological restoration due to damage from invasive species can be significant (see Section 5.10.2.4.5 below for further discussion on economic impacts to government as a result of invasive species).

Trees that are damaged or lost due to invasive insects—such as the emerald ash borer, which is common in Massachusetts—can become hazardous in urban environments. Diseased trees are more likely to fall and damage utilities and transmission lines, structures, vehicles, or people in urban areas, or to block transportation routes and stormwater and drainage networks. Dead trees or invasive grasses can increase wildfire risk, particularly during extreme drought conditions.

Invasive species affect all state-owned lands and resources including wetlands, forests, and water bodies or water sources. Health impacts to state workers responsible for maintaining these resources are also considered under invasive species' impacts to state assets. DCR manages and oversees over 450,000 acres of land across the Commonwealth (Massachusetts Department of Conservation and Recreation, n.d.). The DCR Division of Water Supply Protection manages and protects drinking water supply for Massachusetts. The Division's aquatic invasive species plan, last updated in October 2020, focuses on protecting reservoir systems from aquatic invasive species through three primary techniques: "public education and outreach; exclusion and decontamination measures at boat ramps and other potential entry points; and an expanded monitoring program."

Lifelines

The Federal Emergency Management Agency (FEMA) defines community lifelines as "the most fundamental services in the community that, when stabilized, enable all other aspects of society to function" (FEMA, 2023). Community lifelines include safety and security; food, water, and shelter; health and medical services; energy; communications; transportation; and hazardous material. The impacts of invasive species on these community lifelines in Massachusetts are not explicitly called out in local hazard mitigation plans for municipalities in Massachusetts or in other hazard mitigation planning documents for the Commonwealth. However, potential impacts of invasive species on community lifelines may include water pollution and subsequent impacts to water treatment plants and infrastructure. For example, if a water treatment plant is infested by invasive species (such as an algal bloom), the system could become clogged and the water treatment plant's ability to operate may be impaired. Additionally, erosion caused by decaying vegetation can have an impact on critical facilities that are built on or around affected soils (Tetra Tech, 2021) Other impacts to lifelines include damage to utility and transportation infrastructure, maritime industries, and cargo and port assets.

5.10.2.4.3 Infrastructure

The built environment often has high instances of invasive species since native species are less likely to be able to survive in these areas. Invasive species in urban environments create a number of "ecosystem disservices," such as acting as vectors of human and animal diseases or increasing the risks of fire in the wildland-urban interface (Gaertner et al., 2017). Land use, the amount of impervious surface (e.g., concrete and pavement), and human population size and density are also associated with the success of invasive species in urban areas (Gaertner et al., 2017).

State-owned recreation areas or facilities that rely on healthy ecosystems for services such as space for outdoor recreation or gatherings are exposed to invasive species. Loss of ash trees (primarily due to damage from emerald ash borers) has affected trails and campgrounds, particularly in the western part of Massachusetts where there are high concentrations of ash trees. Affected trees are at risk of falling on visitors, roads, and other infrastructure in these areas. Aquatic recreation areas that provide recreational fishing opportunities are affected by invasive plant and animal species (Marsh et al., 2021). Invasive species management and control can also affect recreation areas, as land managers might use techniques such as insecticides, herbicides, or prescribed burning; these techniques might temporarily prohibit people from using a recreation space (Dolesh, 2012).

Invasives can reduce the function and capacity of vegetated stormwater drainage infrastructure such as detention basins, particularly when there is a failure to inspect and maintain the infrastructure. Stormwater basins along municipal and state-owned roads and highways are particularly susceptible, due to road salt, which invasives such as *Phragmites* can tolerate.

Agriculture

The agriculture sector is vulnerable to increased invasive species due to changing temperatures, drought, and growing seasons. More pest pressure from insects, diseases, and weeds may harm crops and cause farms to increase pesticide use. In addition, floodwaters may spread invasive plants that are detrimental to crop yield and health. Invasive species could also reduce forage for grazing animals, contribute to disease transmission among livestock, and even potentially poison livestock—as is the case with tansy ragwort, which causes liver failure in livestock (Marsh et al., 2021).. Spotted lanternflies, first detected in Massachusetts in 2014, are known to feed on over 103 species of plants including beech and linden trees, fruit trees, sugar maples, and grape vines. They reduce fruit production in fruit trees and can eventually kill the tree by creating open wounds that become infected. The spotted lanternfly was first detected in Pennsylvania in 2014; a Penn State study estimated that the overall annual agricultural losses in Pennsylvania due to the lanternfly would be $99.1 million statewide (Duke, 2020). Estimates of the economic impact to agriculture from invasive species in Massachusetts have not been published.

Public Safety

An increase in species not typically found in Massachusetts could expose populations to vector-borne disease. A 2019 article points to the spread of pathogens via invasive species as one of the most direct effects of invasive species on human health. For example, West Nile virus and eastern equine encephalitis are viruses spread by infected mosquitoes which cause severe health impacts to humans and can sometimes result in death. Humans can also be affected if they ingest food that has been contaminated with pathogens (Neill & Arim, 2019). Increases in incidence of West Nile virus, Lyme disease, other diseases, and associated fatal and nonfatal outcomes are already occurring as a result of changes in temperature and extended seasons for vectors (e.g., mosquitoes and ticks) due to climate change (Commonwealth of Massachusetts, 2022).

Transportation

Invasive species can disrupt and damage maritime transportation and assets, and the maritime commercial and industrial uses and functions must also increase monitoring, maintenance, and removal of these species. Species such as zebra mussels can damage aquatic infrastructure and vessels. *Reynoutria japonica* Houtt. (Japanese knotweed) grows aggressively along waterways and roads in Massachusetts and in other areas of the Northeast. This vine can grow large enough to block sightlines and grow over guardrails, contributing to challenges with road maintenance and issues with safety (Gover et al., 2020).

Water Infrastructure

Water storage facilities may be affected by zebra mussels and other invasive aquatic species. Aquatic invasive species may lead to reduced water quality, which has implications for the drinking water supplies and the cost of treatment. A U.S. Department of the Interior report on the impact of invasive species on Bureau of Reclamation facilities and water resources focuses heavily on the impact of zebra mussels on Reclamation water infrastructure. The report explains that zebra mussels have infested Reclamation reservoirs, water intakes, and power plants in the West. Zebra mussels can clog hydroelectric facilities and irrigation systems and disturb aquatic ecosystems. Their larvae are microscopic and float freely in the water column and are therefore extremely hard to control and detect before they are mature (City of Pittsfield, n.d.).

The fiscal year 2021 budget for Reclamation included $7.8 million for combating invasive species throughout Reclamation facilities and structures, including $5.6 million for prevention, early detection and monitoring, and control of zebra and quagga mussels at Reclamation facilities (U.S. Department of the Interior, 2020). While zebra mussels are not currently widespread in Massachusetts, they are widely dispersed throughout much of the Mississippi River, all the Great Lakes, and the Chesapeake Bay watershed; they have been recorded in New York, Connecticut, and Vermont. Zebra mussels have been reported in densities of over 700,000 individuals per square meter in some facilities in the Great Lakes area (City of Pittsfield, n.d.)

Zebra mussels were confirmed in Laurel Lake (located in Lenox and Lee, Massachusetts) in 2009. The extent of the infestation in Laurel Lake indicates that there is an established population in this area. Three programs, the State Aquatic Invasive Species Planning Efforts, the DCR Boat Ramp Monitor Program, and the DCR Zebra and Quagga Mussel Monitoring Program, are in place in Massachusetts to monitor and curb the spread of zebra mussels in the Commonwealth (Massachusetts Department of Conservation and Recreation & Massachusetts Department of Fish and Game, 2009). Invasive species such as zebra mussels and invasive aquatic plants in Massachusetts have the same effects to water infrastructure as described in the Reclamation case.

Invasive species such as *Phragmites* can block drainage channels and increase the potential for flooding during a rainstorm. Japanese knotweed contributes to streambank erosion by killing existing ground cover, increasing runoff. Additionally, Japanese knotweed contributes to under-bank erosion by inhibiting the regeneration of native species that support the physical structure of streambanks (Colleran et al., 2020).

5.10.2.4.4 Natural Environment

An analysis of threats to endangered and threatened species in the U.S. indicates that invasives are implicated in the decline of 42 percent of the endangered and threatened species. In 18 percent of the cases, invasive species were listed as the primary cause of the species being threatened (USDA, n.d.-a). A 2019 paper reports that invasive species are one of the most significant disturbances that threaten native biodiversity, in addition to direct habitat loss. Experiments have shown that biodiverse ecosystems have higher ecosystem function than less diverse ones, so biodiversity loss caused by invasive species has significant consequences for ecosystem function (Linders et al., 2019). Invasive species present a significant threat to the environment and natural resources in the Commonwealth. In addition to threatening native species, they can degrade water quality and wildlife habitat. Some impacts of invasive species include (Massachusetts Office of Coastal Zone Management, 2002):

- Reduced diversity of native plants and animals
- Impairment of uses of recreational water bodies, such as swimming, boating, and fishing

- Damage to or total loss of forested areas
- Degradation of water quality
- Degradation or loss of wildlife habitat
- Increased threats to public health and safety
- Diminished property values
- Declines in fin- and shellfish populations
- Loss of coastal infrastructure due to the habits of fouling and boring organisms
- Local and complete extinction of rare and endangered species

Some hazard mitigation plans for municipalities in Massachusetts discuss the impacts of invasive species and potential actions to mitigate these impacts. For example, the *Town of Erving Hazard Mitigation Plan* notes that Erving is highly vulnerable to invasive species, partially due to the high amount of forested area (83 percent) in the town. The plan notes that invasive species have the potential to reduce canopy cover in town forests, worsening the risk of extreme temperatures and wildfire risk (Erving Multi-Hazard Mitigation Plan Update Committee, 2020). Existing plans and programs in the Commonwealth to attempt to control or prevent the spread of invasive species are mentioned in Section 5.10.2.1.1. Specific actions that municipalities in Massachusetts can take to mitigate the effects of invasive species include identification and monitoring, properly cleaning and washing boats or other vessels to help stop the spread of aquatic invasive species, abiding by Massachusetts laws and regulations to stop the spread of invasive species, and developing invasive species management plans (Erving Multi-Hazard Mitigation Plan Update Committee, 2020).

5.10.2.4.5 Economy

Invasive species are one of the costliest hazards in the U.S. Globally, it is estimated that invasive species have contributed to economic costs (e.g., expenditures to prevent, reduce, or mitigate impact or losses caused by invasive species) of over $1.288 trillion over the past 50 years (1971–2021) (Zenni et al., 2021). A new study found that invasive species cause over $21 billion in damage per year in the U.S., with the agriculture sector experiencing the most damage (Sheridan, 2022). Decreased agricultural productivity as a result of invasive species would have a severe economic impact on farmers (due to lost revenue) and farm workers (due to lost work and wages), as well as on local food supplies. The agriculture sector also faces economic impacts due to the cost of controlling invasive species and pests. As of 2022, spending for the DAR-managed Massachusetts Integrated Pest Management program was $66,718 (Commonwealth of Massachusetts, 2022).

Because most costs associated with invasive species relate to resource damage and loss, some economic losses could be prevented or lessened with investment in monitoring, management, and prevention. The fiscal year 2022 budget for Massachusetts allocated

$100,000 for aquatic invasive species control for the Charles and Mystic Rivers; $75,000 was allocated to the Friends of the Fells to support conservation efforts (including invasive species management and monitoring) on the Middlesex Fells Reservation. DCR also received a grant for $82,838 from the U.S. Fish and Wildlife Service for aquatic invasive species management (192nd General Court of the Commonwealth of Massachusetts, 2021). In 2023, the Massachusetts Division of Fisheries and Wildlife awarded $483,930 in Habitat Management Grants to municipalities, land trusts, and local nonprofits, $154,244 of which was dedicated to invasive species control.

All Massachusetts residents depend on the Commonwealth’s ecosystems and therefore will be impacted by the loss of existing ecosystems. People who are particularly vulnerable to the economic impacts of this hazard, and who may be affected sooner and more directly, include people working in agriculture-related, forestry-related, and fisheries or aquaculture fields, as well as those whose livelihoods depend on outdoor recreation activities such as hunting, fishing, hiking, or aquatic sports. The tourism and recreation industry are affected by invasive species when invasive species damage or disrupt recreation amenities and tourist attractions.

Decreases in marine fisheries and aquaculture productivity would cause economic damage to people who rely on this industry for their livelihoods, as well as the Commonwealth as a whole; in 2019, Massachusetts was second only to Alaska in “ex-vessel value of landings” totaling $679.3 million (Massachusetts Division of Marine Fisheries, 2021). Also in 2019, the Port of New Bedford was the highest-valued port in the U.S. for the 20th year in a row, with “ex-vessel landings” totaling $451 million, primarily due to sea scallop landings (Massachusetts Division of Marine Fisheries, 2021). Additionally, homeowners whose properties are adjacent to vegetated areas could experience property damage in a number of ways. For example, the roots of the invasive tree of heaven (*Ailanthus altissima*) plant are aggressive enough that they can damage both sewer systems and foundations up to 50 to 90 feet from the parent tree.

Additional economic impacts from invasive species include health care expenditures in response to an increase in vector-borne disease incidence or bacterial infections. Health care expenditures for asthma medical care, vibriosis, and Lyme disease could be $40 million, $54 million, and $45 million, respectively by 2050 (Commonwealth of Massachusetts, 2022). MassHealth spending of $19.2 billion is roughly one third of the total Massachusetts health care spending of $61 billion; therefore, MassHealth could incur roughly $50 million of these cost increases in 2050 (Commonwealth of Massachusetts, 2022).

Chapter 5. Risk Assessment and Hazard Analysis

Landslides/Mudflows

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5.11 Landslides/Mudflows

5.11.1 Landslides/Mudflows Problem Statement

Areas in the Commonwealth with geologic conditions such as steep slopes, persistent wet conditions, and/or excessive subsurface water or saturated soils are the most at risk from landslide and mudflow disturbances. Portions of Mount Greylock and the adjacent Deerfield River, the U.S. Highway 20 corridor near Chester, and the main branches of the Westfield River are the areas in Massachusetts that are currently most vulnerable to landslides and mudflows. Due to climate change and the associated increases in precipitation and extreme weather and wildfires—as well as rising temperatures and drought that will reduce the vegetation cover—the risk of landslides and mudflows will increase. New development and infrastructure in remote locations may increase the risks and impacts from landslides and mudflows. Landslides and mudflows can damage communities, infrastructure, utilities, and pipelines; mobilize toxic and hazardous wastes; result in loss of life; degrade habitats; and require long and costly cleanup and rebuilding of lost and damaged assets.

5.11.2 Landslides/Mudflows Risk Assessment

5.11.2.1 General Background

A landslide or mudflow is the movement of rocks, earth, or debris down a slope (USGS, n.d.-b). The most common types of landslides in Massachusetts include translational debris slides, rotational slides, and debris flows (Mabee & Duncan, 2013). Most of these events are caused by a combination of unfavorable geologic conditions (silty clay or clay layers contained in glaciomarine, glaciolacustrine, or thick till deposits), steep slopes, and/or excessive water or saturated soils leading to excess pore pressures in the subsurface. In 2013, the Massachusetts Geological Survey and the University of Massachusetts Amherst published a Slope Stability Map of Massachusetts. This project, which was funded by the Federal Emergency Management Agency's Hazard Mitigation Grant Program, was designed to provide statewide mapping and identification of landslide hazards that can provide the public, local governments, and emergency management agencies with the locations of areas where slope movements have occurred or may possibly occur in the future under conditions of prolonged moisture and high-intensity rainfall (see Section 5.11.2.2 for more detail). Historical landslide data for the Commonwealth suggest that most landslides are preceded by two or more months of higher-than-normal precipitation, followed by a single, high-intensity rainfall of several inches or more that can cause slopes to become saturated and fail (Mabee & Duncan, 2013).

Landslides associated with slope saturation occur in areas with steep slopes underlain by glacial till or bedrock. Bedrock is impermeable relative to the unconsolidated material that overlies it. Similarly, glacial till is less permeable than the soil that forms above it. Thus, there is a permeability contrast between the overlying soil and the underlying, less permeable, un-weathered till and/or bedrock. Water accumulates on this less permeable layer and cannot filter through it, resulting in pore pressure at the interface of the hard and impermeable layer and the soils and unconsolidated material that forms the surface. This interface becomes a plane of weakness and materials above it are at high risk for landslides.

Geologic conditions also contribute to landslide risk. Adverse geologic conditions exist wherever there are lacustrine or marine clays, as clays have relatively low strength. These clays often formed in the deepest parts of the glacial lakes that existed in Massachusetts following the last glaciation. These lakes include Bascom, Hitchcock, Nashua, Sudbury, Concord, and Merrimack, among many other smaller glacial lakes in more remote areas of the Commonwealth. The greater Boston area is underlain by the Boston Blue Clay, a glaciomarine clay. The northeastern coast of Massachusetts is underlain by marine clays. When over steepened or exposed in excavations, these vulnerable areas often produce classic rotational landslides.

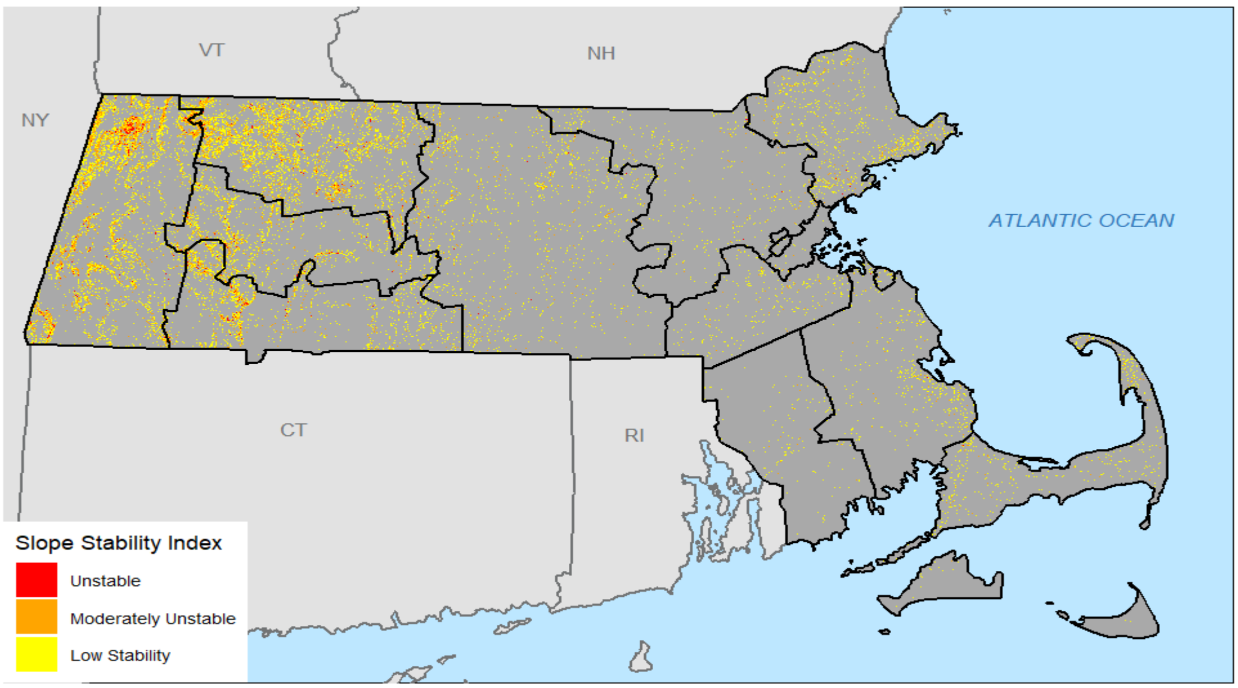
External forces such as undercutting due to flooding or wave action can initiate landslides. Undercutting of slopes during flooding or coastal storm events is a major cause of property damage. Streams and waves erode the base of the slopes, causing them to over-steepen and eventually collapse. This is particularly problematic in unconsolidated glacial deposits, which cover most of the Commonwealth. This type of failure occurs often along the coasts and rivers in the Commonwealth, for example in Cape Cod, Nantucket, Martha's Vineyard, Scituate, Newbury, the Connecticut River Valley, the Cold River in Savoy, and the Deerfield River.

Another external force can be construction. Construction-related failures occur predominantly in road cuts through glacial till where topsoil has been placed on top of the till. Examples of these failures can be found along the Massachusetts Turnpike. Other construction-related failures occur in utility trenches constructed in areas with very low cohesive strength and an associated a high water table (usually within a few feet of the surface). This situation occurs in sandy deposits with very few fine sediments and can occur in any part of the Commonwealth.

In Massachusetts, landslides tend to be more isolated in size and pose threats to linear systems and networks such as highways, roadways, rail, and utilities. Additionally, due to their location in more remote and less populated areas, structures that support fisheries, tourism, outdoor recreation, rural communities, and interstate transportation infrastructure are often exposed to landslides.

5.11.2.2 Hazard Description

The 2013 Slope Stability Map of Massachusetts offers the most up-to-date data and information for the Commonwealth—data and information that are referenced throughout this section (see Figure 5.11-1). The maps produced from this project should be viewed as a first-order approximation of potential landslide hazards across the state at a scale of 1:125,000. They are not intended for site-specific engineering design, construction, or decision-making. The maps are provided only as a guide to areas that may be prone to slope instability when subjected to prolonged periods of antecedent wetness followed by high-intensity rainfall; they likely do not identify all areas with a risk of landslides and mudflows.



Map created by ERG using data from Mabee & Duncan (2013).

Figure 5.11-1. Slope stability map of Massachusetts.

5.11.2.2.1 Location

The 2013 slope stability map (see Figure 5.11-1) categorizes areas of Massachusetts into stability zones, and the categorization is correlated to the probability of instability in each zone. The probability of instability metric indicates how likely each area is to be unstable, based on the parameters used in the analysis (e.g., slope angle, angle of internal friction and cohesion, flow direction, transmissivity/recharge) (Mabee & Duncan, 2013). Thus, although specific landslide events cannot be predicted, this map shows where slope movements are most likely to occur after periods of high-intensity rainfall or other external events. According to the map, these unstable areas are located throughout the Commonwealth. However, the highest prevalence of unstable slopes is found in the western portion of the Commonwealth, including the area around Mount Greylock and the nearby portion of the Deerfield River, the U.S. Highway 20 corridor near Chester, and the main branches of the Westfield River.

5.11.2.2.2 Previous Occurrences and Frequency

Previous Occurrences

According to the U.S. Landslide Inventory, there have been at least 14 landslide incidents in Massachusetts between 2008 and 2017 (Jones et al., 2019). During this timeframe the Massachusetts Geological Survey reported three landslides or mudflows in 2011, with damage to roadways, homes, utilities, and stormwater infrastructure. There is a slow-moving rotational landslide on Route 2 in Charlemont by Trout Brook; this landslide has been moving since the 1930s and causes damage and disruption to the roadway after major storm events. The most recent event was a mudflow event at Buzzards Bay, in which a torrential downpour triggered a mudslide at a construction site (Jones et al., 2019). Often only large and damaging landslides and mudslides are reported at a statewide level, while remote or localized events go unreported or are reported only in local newspapers, making it difficult to understand the frequency of these events across the Commonwealth.

Available datasets do not identify all ground failure events that have affected the Commonwealth and these data are not frequently updated. Changes in the intensity and use of land at risk from landslides for housing, utilities, and infrastructure contributes to an increase in the damage, disruption, and loss caused by landslides.

Frequency

Landslides commonly occur shortly after other major natural disasters, such as extreme precipitation events, wildfire, earthquakes, and floods, which can slow response and recovery efforts, including emergency response, evacuations, debris removal, restoration of services, and stabilization efforts. Many landslide events occur in remote areas and are unobserved or reported, making it difficult to account for the frequency of landslides, the scale of such events, and the geographic range. In general, landslides are most likely during periods of higher-than-average rainfall, with the intensity of the rainfall being an important factor, as well as the health of the soil. Areas that have experienced disturbance due to wildfire, drought, invasive species, recent development, or vegetation or tree removal are more likely to experience landslides.

Potential Effects of Climate Change on Landslides and Mudflows

It is difficult to determine the probability of future occurrences due to a lack of recent data on landslides in the Commonwealth (The 2013 data for landslides in Massachusetts—the most data recent available—are a decade old). Impacts of climate change on the duration and intensity of rainfall events, wildfire, drought, and invasive species will result in an increase in the frequency of landslides and may result in an increase in the areas at risk from landslides. Another factor is the changes in the intensity and type of land uses in areas with high risk for landslides.

5.11.2.2.3 Severity/Intensity

Variables that contribute to the extent of potential landslide activity include soil properties, topographic position and slope, and historical incidence. Predicting a landslide is difficult and data are limited and hard to collect due to limited monitoring instruments and lack of eyewitness accounts. As a result, estimations of the severity of landslides are informed by previous occurrences as well as an examination of landslide susceptibility. Information about previous landslides, such as the information and images from 2011 landslides (after Hurricane Irene)[1] shown in Table 5.11-1 and Figure 5.11-2, can provide insight on where landslides may occur and what types of damage may result. It is important to note, however, that susceptibility only identifies areas potentially affected and does not imply a timeframe when a landslide might occur. Nor does this process account for how climate change is altering the intensity and frequency of the hazards that increase the risks of landslides. Therefore, it is important not to rely solely on past events, but to also consider the variables and conditions that increase landslide risk and evaluate areas for those factors. The distribution of susceptibility across the Commonwealth is shown on Figure 5.11-1’s slope stability map, with areas of higher slope instability considered to be more susceptible to landslides and mudflows.

As shown in Table 5.11-1 below, a range of parameters is used to measure and characterize landslides after an event.

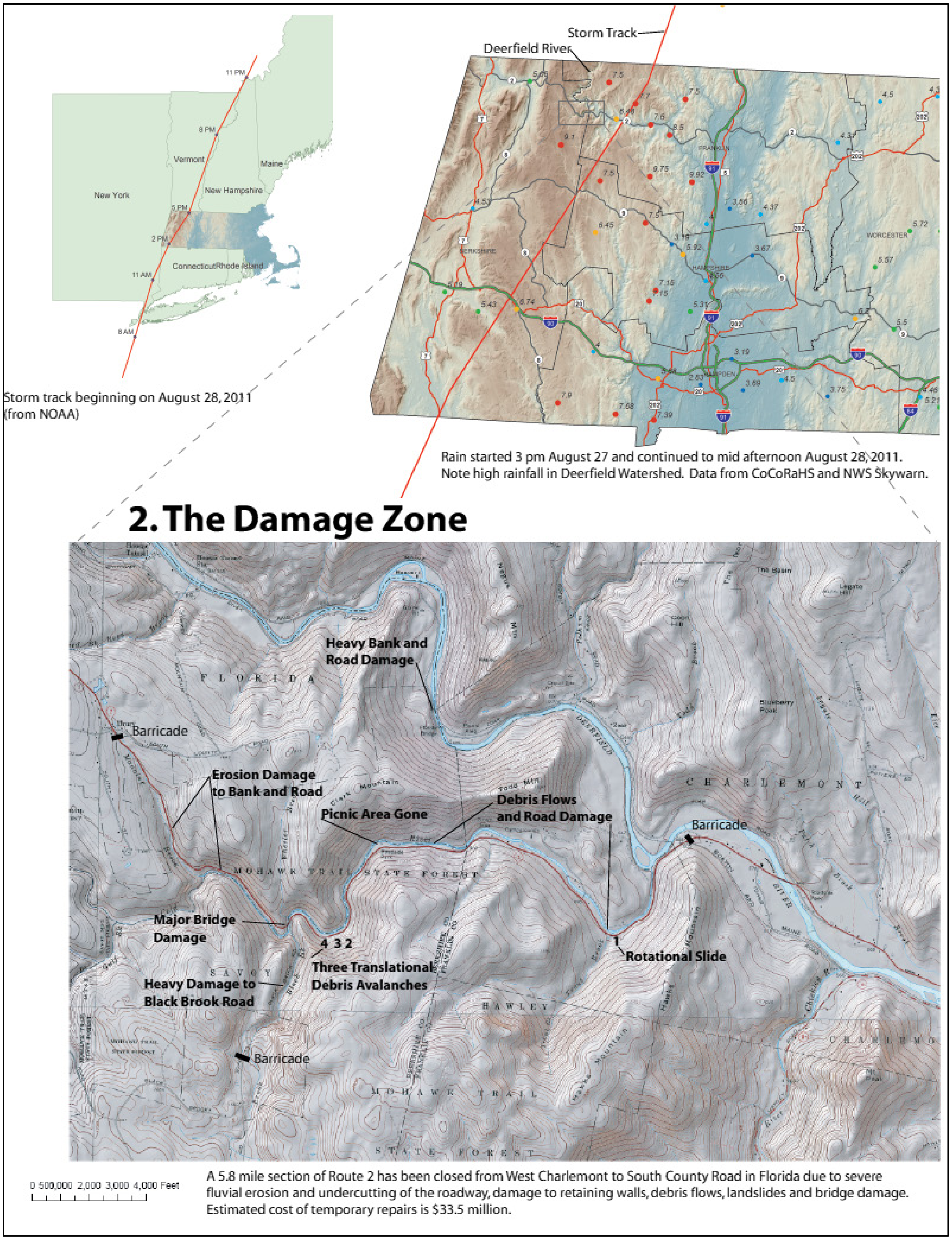
Table 5.11-1. Statistics on the August 2011 Landslides

Statistics on all the slides: Nearly 2,500 feet in combined length, 3 acres of coverage, and about 9,800 cubic yards of material moved.

Parameter	Slide 2	Slide 3	Slide 4
Bottom width (ft)	120	58	48
Top width (ft)	45	42	38
Avg. slope angle (°)	28	33	33
Horizontal length (ft)	868	813	520
Slope length (ft)	902	969	620
Elevation difference (ft)	460	522	337
Area (sq. ft)	66,881	39,854	25,149
Area (Ac)	1.54	0.91	0.58
Thickness range (ft)	1.5–2.5	1.5–2.5	1.5–2.5
Min. volume (CY)	3,716	2,214	1,397
Max. volume (CY)	6,193	3,690	2,329
Ave. volume (CY)	4,954	2,952	1,863

Source: Mabee (2012).

[1] Notably, there have not been any recent events that have caused widespread landslides or mudflows since Hurricane Irene in 2011.



Source: Mabee (2012).

Figure 5.11-2. 2011 landslide location overview.

5.11.2.2.4 Warning Time

Mass movements that result in landslides and mudflows can occur suddenly or slowly. The velocity of movement may range from a slow creep of inches per year to many feet per second, depending on slope angle, material, and water content. There are currently no early warning systems for local landslide incidents in Massachusetts. The U.S. Geological Survey lists the following warning signs for landslide activity (USGS, n.d.-a):

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements, or sidewalks
- Soil moving away from foundations
- Ancillary structures, such as decks and patios, tilting and/or moving relative to the main building
- Tilting or cracking of concrete floors and foundations
- Broken waterlines and other underground utilities
- Leaning telephone poles, trees, retaining walls, or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels even though rain is still falling or has just recently stopped
- Sticking doors and windows and visible open spaces, indicating jambs and frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together

5.11.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

All 15 local hazard mitigation plans reviewed as part of the 2023 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP) assessed the vulnerability of their municipalities to landslides or mudflows. All but one of the plans reported that there have been no recorded incidences of landslides in their jurisdictions, and therefore conclude that landslide risk is relatively low. Most plans used slope stability maps to identify locations where people and property could be at risk if a landslide were to occur in the future.

Areas with unstable slopes are more common in western Massachusetts, and some of these towns have taken measures to reduce vulnerability to landslides. The town of West Stockbridge voted to invoke the Berkshire Scenic Mountain Act, a provision that a town or city in Berkshire County can adopt to impose additional regulations to protect watershed resources and preserve their natural scenic qualities of mountain regions (Town of

Stockbridge, 1996). Using the Act enables West Stockbridge to adopt rules and regulations to reduce erosion across steep-sloped areas in the town, and the town plans to manage land change activities (such as timber harvesting) on slopes vulnerable to erosion to reduce landslide and mudslide risks (Foresight Land Services, 2021). The town of Adams Public Works Department identified areas with steeply sloped ravines at greater risk from landslides and continuously monitors roadways for potential soil stabilization needs; it is also considering adopting the Berkshire Scenic Mountain Act (Town of Adams, 2019) as a way to further reduce its risks. Table 5.11-2 provides more information of how landslides and mudflows are addressed in local hazard mitigation plans.

Table 5.11-2. Highlight of Local Hazard Mitigation Plans

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Multi-Hazard Mitigation Plan, town of Adams, April 2019	• Development in and downslope of higher-risk landslide areas is vulnerable to damage.	• The most unstable lands are part of Mount Greylock State Reservation and are not developed. • 111 buildings throughout the town are located on unstable or moderately unstable land. • East Mountain Road, East Road, Upper East Hoosac Street, and Meadow Street have notable sections running through unstable land.	Not provided
Town of Hull Hazard Mitigation Plan: 2018 Update, April 2018	• No record of historical landslide damage exists in Hull. • Hazard classified as low frequency and minor severity.	• Potential vulnerabilities include localized damage to structures and roads. • Injuries and casualties are unlikely from a landslide in Hull.	Not provided
City of Somerville Hazard Mitigation Plan: 2022 Update, January 2022	• There have been no recorded landslides in Somerville. • The city is classified as having low susceptibility to landslides. • Changing precipitation patterns could increase landslides.	• Potential vulnerabilities include localized damage to structures and roads. • Injuries and casualties are unlikely from a landslide in Somerville.	Not provided

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
2021 Hazard Mitigation Plan: Plymouth, Massachusetts, 2021	• Overall, Plymouth has a very low risk of landslides, although they have occurred along Nameloc Drive in southern Plymouth.	• Houses along Nameloc Drive in southern Plymouth are vulnerable to landslides due to continuing coastal erosion and slope instability.	N/A

5.11.2.3 Secondary Hazards

Landslides can result in a number of secondary hazards. These hazards include flooding, downed trees, invasive species, and wildfire. Landslides also result in exposure and vulnerability to a range of assets and services, including roads, railways, highways, homes, recreation facilities; as well, they can damage and disrupt utilities, resulting in a loss of access and service to communities, recreation areas, and critical assets. These impacts can isolate residents and businesses and delay commercial, public, and private transportation; emergency response and evacuation; and the restoration of service and repair of these critical assets. Such disruption results in economic losses for communities, businesses, and the government, as well as risks to public health and safety and environmental damage to natural areas and open spaces. Power outages can result in unsafe use of combustion heaters, cooking appliances, and generators in indoor or poorly ventilated areas, leading to increased risks of carbon monoxide poisoning. Landslides also destabilize the foundation of structures, resulting in significant damage or loss of homes and injury or mortality for residents. Landslides often result in major damage to vegetation on steep slopes, weakening soils and contributing to increased runoff. Increased runoff results in additional soils and debris being discharged to waterways, potentially impairing water quality of downstream water bodies and contaminating reservoirs or waterways with sediment-laden runoff.

With the changing climate, the Commonwealth is expected to experience an increased frequency and severity of storms; this will increase soil saturation conditions, likely resulting in an increased frequency of landslides. In addition, an overall warming trend is likely to increase the frequency and duration of droughts and wildfire, both of which could reduce the extent of vegetation throughout the Commonwealth (Commonwealth of Massachusetts, 2022). The loss of the soil stability provided by vegetation will increase the probability of landslides throughout the Commonwealth and should be considered when updating the data and information on the risk, likelihood, and locations most susceptible to these events.

5.11.2.4 Exposure and Vulnerability

The likelihood of experiencing landslides and mudflows in Massachusetts—in areas with steep slopes, saturated soils, and a mix of permeable and impermeable geologic conditions, or in areas exposed to extreme precipitation, wildfires, drought, flooding, or earthquakes—is **extremely high**. See Section 5.11.2.2.2 for detailed information on previous occurrences. Table 5.11-3 summarizes the potential impacts of landslide/mudflow events in the Commonwealth using themes identified in the *2022 Massachusetts Climate Change Assessment*, as well as information related to past events in the Commonwealth and across the U.S. Notably, potential impacts related to loss of human life, delays in emergency service response, loss of rail/transit service, damage to buildings, and business interruptions can be the most immediate priorities to be addressed.

Table 5.11-3. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Landslides and Mudflows

Sector	Priority Impacts and Vulnerabilities
Human	• Loss of human life • Emergency service response delays and evacuation disruptions **(urgent)** • Increase in mental health stressors • Health effects of extreme storms and power outages
Governance	• Increase in demand for state and municipal government services **(urgent)** • Increase in need for state and municipal policy review and adaptation coordination
Infrastructure	• Loss of urban tree cover • Damage to electric transmission and distribution infrastructure **(urgent)** • Damage to inland buildings **(urgent)** • Damage to rails and loss of rail/transit service **(urgent)** • Damage to roads and loss of road service
Natural Environment	• Forest health degradation • Freshwater ecosystem degradation **(urgent)** • Soil erosion • Shifting distribution of native and invasive species
Economy	• Reduced ability to work **(urgent)** • Damage to tourist attractions and recreation amenities • Economic losses from commercial structure damage and business interruptions

5.11.2.4.1 Human

As part of the 2023 MA SHMCAP process, Massachusetts state agencies completed a survey to identify their primary concerns about populations served and potential disproportionate impacts from landslides and mudflows. Table 5.11-4 lists some of the primary concerns.

Table 5.11-4. State Agency Responses: Primary Concerns About Landslide and Mudflow Impacts on Populations Served and Potential Disproportionate Impacts

Category	Primary Concerns
Populations served	• All residents, businesses, and municipalities
Potential disproportionate impacts	• Loss of in-person services • Extended response times • Effects on public transportation services • Damage to communication towers and infrastructure

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Vulnerable and Priority Populations

People and communities in high-risk areas are vulnerable to direct damage or loss to infrastructure, utilities, and critical assets that they rely on from landslides. People are also more vulnerable if have characteristics that make them less able to prepare, respond, or recover. For example, vulnerability is higher for:

- Housing cost–burdened or low-income households
- Single-parent households
- People aged over 65 or under five
- People with low English proficiency or linguistic isolation
- People with underlying health conditions
- People with disabilities and mobility limitations
- Renters
- Residents in rural areas with limited access to redundant services and who may lose roadway, communications, and utility services
- Hourly and outdoor workers
- Other underserved/under-resourced communities

Health Impacts

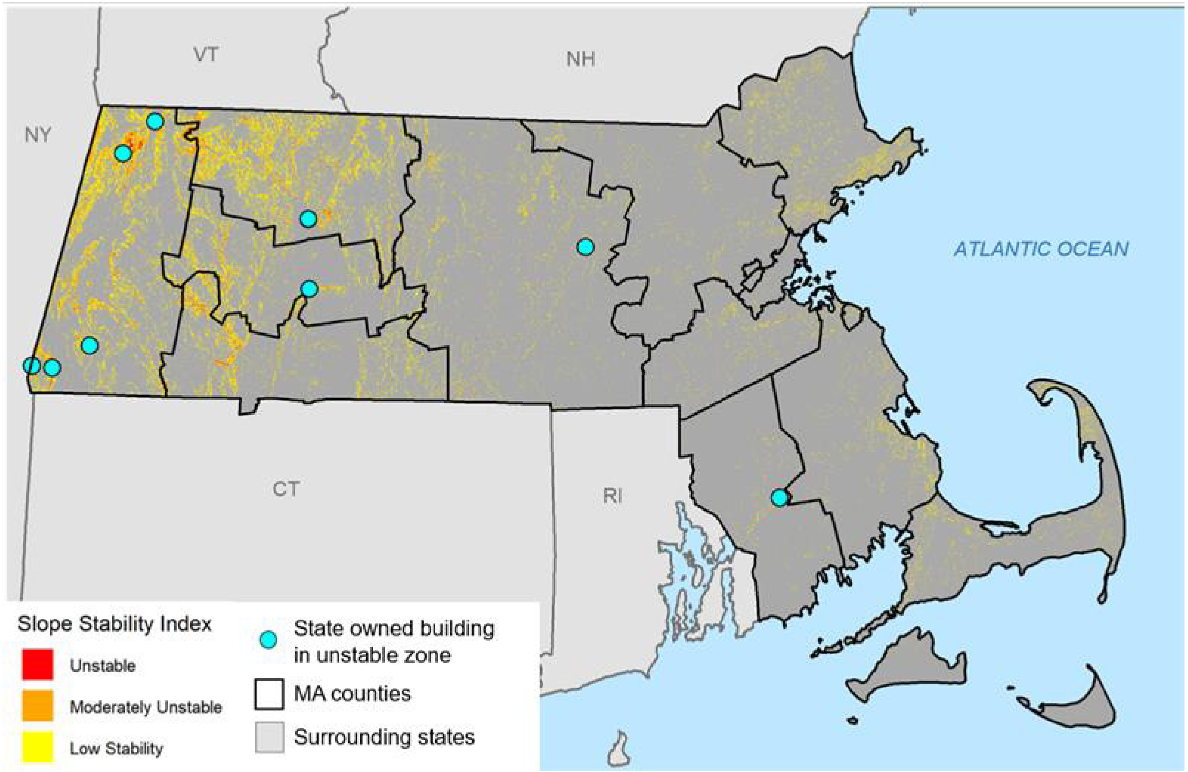
Damage to infrastructure that impedes emergency access, evacuations, or access to health care is the largest health impact associated with landfill hazards. Mass movement events could deposit many tons of sediment and debris on top of infrastructure and utilities. Restoring service is often a lengthy and expensive process.

People living in, working in, or travelling through landslide hazard zones and mudflow hazard areas are also exposed to the risk of death or injury during a landslide. By 2040, the projected population growth in areas characterized as having low stability, moderately unstable, and unstable slope (see Figure 5.11-1) will stabilize—that is, either **decline or grow slightly** by 10,000 people (see Section 5.1, Risk Assessment Introduction) for population projections for 2025, 2030, 2035, and 2040 based on UMass Donahue Institute data). Based on the projections of future population growth, communities will continue to be exposed to landslide and mudflow hazards; areas where housing, utility, and infrastructure development is growing will increase the exposure and risk from these events.

5.11.2.4.2 Governance

Vulnerable government assets include **hospitals, safety and security services, communication infrastructure, transportation infrastructure, hazardous material facilities, and utilities** in areas with conditions that increase the risk for landslides. Towns surrounding Mount Greylock, as well as bridges, tunnels, culverts, and some coastal roads across the Commonwealth, are also vulnerable to landslides and mudflows. Culverts and roadways are particularly vulnerable to these events: debris often covers and blocks these types of assets, creating access issues and increased flood risks. The Massachusetts Department of Transportation (MassDOT) is responsible for 9,578 lane miles of roadway, including interstate and limited-access freeways, and is responsible for maintaining these roads if they are damaged or disrupted due to a landslide or mudflow (Massachusetts Department of Transportation, 2022). MassDOT is also responsible for more than 5,000 bridges (Massachusetts Department of Transportation, 2023). Some bridges are in areas at risk of landslides. If landslides occur, they can cause significant damage or loss to these structures and require costly and time-consuming projects to restore service and access.

To assess the exposure of the state-owned facilities identified by the Massachusetts Division of Capital Asset Management and Maintenance and the Office of Leasing, the Risk Assessment team conducted an analysis with the approximate landslide hazard areas. Using ArcMap GIS software, the team overlaid Figure 5.11-1’s slope stability map with state-owned facilities data, as shown in Figure 5.11-3.



Map created by ERG using data from Mabee & Duncan (2013) and the Massachusetts Division of Capital Asset Management and Maintenance (2022).

Figure 5.11-3. Overview of state-owned buildings in unstable zones.

Fourteen state-owned facilities were found to be located within four unstable slope areas identified by the 2013 Slope Stability Index. These are listed in Table 5.11-5. In addition to these highly exposed facilities, 47 facilities were found to be located on “moderately” unstable slopes and 190 were found to be located on areas of “low” instability. Note that state facilities next to these areas of instability may also be exposed to the landslide hazard, as falling debris may extend beyond the area identified by the modeling or damage or disrupt the utilities and infrastructure that these facilities rely on for services such as water, power, communications, and access.

Table 5.11-5. Replacement Values of State-Owned Buildings in Unstable Zones

Site	Building/Asset and Replacement Value
Bash Bish Falls State Park	• Falls view area (replacement value: unknown) • Lower viewing area walks/stairs (replacement value: unknown)
East Mountain State Forest	• Tom Leonard privy (replacement value: $1,800)
Freetown–Fall River State Forest and Wading Pool/Spray Deck	• Profile Rock (replacement value: unknown)
Mount Everett State Reservation	• Glen Brook shelter (replacement value: $22,400) • Glen Brook privy (replacement value: $4,800)

Site	Building/Asset and Replacement Value
Mount Greylock Reservation	• Deer Hill lean-to (camping shelter) (replacement value: unknown)
Mount Sugarloaf Reservation	• Observation tower (replacement value: unknown) • Main summit parking lot (replacement value: unknown) • Summit overflow parking lot (replacement value: unknown)
Natural Bridge State Park	• Lower contact station (replacement value: $63,000)
Skinner State Park	• Old well shed (replacement value: $36,000) • Pavilion (replacement value: unknown)
Wachusett Watershed	• Lower gatehouse (inactive power supply facility) (replacement value: unknown)

Table 5.11-6 lists agency responses to the 2023 MA SHMCAP survey regarding primary concerns and the activities taken or planned to address landslides and mudslides.

Table 5.11-6. State Agency Responses: Primary Concerns About Landslide and Mudflow Effects on Services, with Suggested Improvements

Category	Concerns/Improvements
Services provided	• Coordination of emergency services at the federal, state, and local levels • Communication infrastructure, including 911 services • Transportation infrastructure
Updates, improvements, or enhancements to address concerns	• Conduct studies on ways to mitigate landslides and mudflows • Identify vulnerable infrastructure that services the 911 and communication network • Collaborate with partner agencies to prioritize mitigation strategies for landslides • Move network infrastructure to more resilient locations and implement redundant infrastructure (e.g., through third-party facilities and cloud solutions)

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

5.11.2.4.3 Infrastructure

Landslides can have direct and indirect impacts. Infrastructure in unstable areas identified in Figure 5.11-1’s slope stability map, in areas with similar characteristics to those of the areas marked as unstable on the map, and in areas with steep slopes exposed to extreme precipitation, wildfire, drought, flood, or invasive species—should be considered at risk from landslides or mudslides. Mountain roads, coastal roads, and transportation infrastructure and utilities are highly vulnerable, both because their linear nature and locations expose them to this hazard and because of the lack of redundancy that exists for much of these assets in the rural and remote locations where the risks are often greater.

Agriculture

Landslides that affect farmland can result in significant loss of livelihood and long-term loss of productivity: they can damage crops, soils, critical equipment, and utilities; disrupt access and services from roadways and utilities; and cut farms off from access to markets and agricultural services, as well as from critical deliveries. Landslides and mudslides can significantly damage forestry and timber, causing loss of trees, soil damage, disruption or loss of roadway access, disruption or loss of utilities, introduction of invasive species, and difficulty reestablishing trees.

Energy

The energy sector is vulnerable to infrastructure damage associated with landslides. Transmission lines, towers, and stations and substations are all subject to damage or disruption from landslides. A landslide may cause a tower to collapse, bringing down the lines and causing a transmission fault that breaks a connection; this in turn can cause extended and broad outages, as well as leading to fires. Downed transmission lines, downed towers, and damaged stations and substations can cause significant economic and social impacts, and disruptions in service can extend for many days in rural locations with fewer redundant power sources.

Public Safety

Access to transportation infrastructure and utility services is crucial to safety and public health, particularly during a disaster but also during normal days when people need to call 911 for medical emergencies or drive to school or the hospital. Emergency responders need access to communication services and clear roadways to reach people and property affected by landslides—access that landslide damage to roads and utilities can disrupt for extended periods. With landslides often being a secondary hazard, these roadway and utility disruptions can result in a lack of access to communities experiencing flooding and needing assistance to evacuate. The instability of areas where landslides have occurred can also limit emergency responders’ ability to reach survivors.

Transportation

Landslides pose a significant risk to roads, rail, and bridges. As noted above, some of the most significant damage and disruption from landslides is to transportation infrastructure, due to its linear nature and its location—often at the bottom of steep slopes and along waterways. Landslides block roads, isolating neighborhoods and disrupting public and private transportation. These impacts can result in economic losses for businesses and community members and the social and public health impacts mentioned above. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous to use and costly and time-consuming to repair.

Landslide impacts to highways represents a significant economic and social vulnerability for the Commonwealth. In the last several years, MassDOT District 2 responded to two landslide incidents in the Bernardston and Brimfield-Warren areas and one landslide by the I-91 southbound exit 15 on-ramp in Holyoke that disrupted access and services to nearby communities. MassDOT District 1, in the far western part of the Commonwealth, reports that it spends on average $104,000 per year in labor to clean up nuisance landslide debris and has spent upwards of $350,000 with contractors for the same service. MassDOT District 2 (west central) reports an average of $100,000 per year spent on rock slope and landslide debris cleanup. An example of the upper part of the range of damage costs is the damage caused by Tropical Storm Irene in 2011 to a 6-mile stretch of Route 2. This damage included debris flows, four landslides, and fluvial erosion and undercutting of infrastructure. It cost $23 million for initial repairs, as well as resulting in disruption and delays to access and service for the surrounding areas.

Water Infrastructure

Surface water bodies may be directly or indirectly contaminated by landslides. Landslides may mobilize legacy sediments that are contaminated. In addition, contaminants that are often found in our environment, such as oils, fuels, and concrete, may also be mobilized. Landslides often reduce the flow of streams and rivers, which can result in upstream flooding and reduced downstream flow. In addition, vegetation and banks may be damaged, enabling the introduction of invasive species or necessitating intervention to restore areas to health. Landslides can disrupt the availability of drinking water by directly damaging the source water or damaging the utility infrastructure that supplies the water. Water, wastewater, and stormwater infrastructure can be physically damaged by landslides and mudflows. The influx of sediment can clog intake filtration systems and reduce available storage capacity in water bodies, resulting in water supply shortages and costs to repair and restore services.

5.11.2.4.4 Natural Environment

Landslides directly and indirectly cause damage to the natural environment, including soil damage, vegetation loss, scouring, increased sediment in rivers and streams, blocked flows or damaged banks, habitat loss, damage to aquatic ecosystems and habitats, and damage and loss of forest cover and health. Landslides can cause long-lasting changes to natural environments by rerouting streams and rivers and changing soil conditions. Flora in the area may struggle to re-establish following a significant landslide because of a lack of topsoil. Landslides and mudflows can lead to an increased susceptibility to invasive species due to disturbed surfaces (Gomes et al., 2020). Following a disturbance, revegetation needs to take place and the disturbed surfaces open opportunities for invasive species to colonize before local species can regenerate (Mungi et al., 2018). While small-scale landslides can have positive effects on the natural environment, such as sediment supply and vegetation distribution, large-scale landslides are generally quite disruptive to the natural environment and upland and aquatic ecosystems.

5.11.2.4.5 Economy

Landslides are one of the costliest natural hazards in the world, costing local and state jurisdictions hundreds of thousands to millions of dollars to repair direct damage and services, as well as additional costs due to disruptions and delays of service and productivity. MassDOT spends upwards of $100,000 or more in the western part of Massachusetts to clean up landslide debris. Damage, disruption, and loss to roadways, bridges, utilities, structures, agricultural and timber resources, recreational resources, and water supply and water utilities cost local jurisdictions, businesses, communities, and state agencies significant resources in dollars, staff time, preparation, response, and recovery, and can necessitate costly and time-consuming repairs and replacements.

Chapter 5. Risk Assessment and Hazard Analysis

Other Severe Weather

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5.12 Other Severe Weather

5.12.1 Severe Weather Problem Statement

The Commonwealth is exposed to strong winds and extreme precipitation events (including thunderstorms), and it is highly likely that the Commonwealth will continue to experience these events several times a year. Some areas of Massachusetts experience these events with more frequency and intensity. The coastal zone is the most frequently impacted by high-wind events. High wind gusts can cause scattered power outages from downed trees and wires, particularly if they occur after prolonged drought or excessive rain, which destabilize soils. Damage from high winds can delay or prevent access from emergency services. High winds also pose a hazard for boating, shipping, water transportation, and aviation industries and their workers.

High-intensity rainfall events (including thunderstorms) are highly likely to continue and increase across the Commonwealth, along with lightning strikes. While most thunderstorms produce minimal disruption and damage, they have the potential to cause widespread flooding, and lightning may cause injury, death, or fires even when accompanied by heavy rain. Severe weather can cause direct and indirect impacts to public health and safety, the environment, and the economy. Populations and workers located outside are at higher risk during severe weather and storms. People who are not connected to warning systems via smartphones or other technologies, or with limited English proficiency, are also exposed.

5.12.2 Other Severe Weather Risk Assessment

5.12.2.1 General Background

Several frequent natural hazards in Massachusetts—particularly strong winds and extreme precipitation events—occur outside of notable storm events (e.g., hurricanes, nor’easters, snowstorms). This section discusses the nature and impacts of these severe weather events, as well as the effects that climate change is projected to have on these events.

5.12.2.2 Hazard Description

In the Commonwealth, other severe weather includes high winds, thunderstorms, lightning, thunder, hail, tropical storms, and extreme precipitation events.

High Winds

Wind advisory events are defined by the National Weather Service (NWS) as sustained winds of 31 to 39 miles per hour for at least one hour or any gusts of 46 to 57 miles per hour over land. Wind advisories pose a moderate threat to life and property and the NWS recommends securing objects that are outdoors and taking caution when driving in wind advisories. High winds are sustained winds of over 40 miles per hour or any gusts of over 58 miles per hour and pose a high threat to life and property. The NWS recommends reducing driving speeds and seeking shelter during high winds. Over water, the NWS issues a small craft advisory for sustained winds of 25 to 33 knots, a gale warning for sustained winds of 34 to 47 knots, a storm warning for sustained winds of 48 to 63 knots, or a hurricane-force wind warning for sustained winds of 64 knots or more.

For tropical systems, the NWS issues a tropical storm warning for any inland or coastal areas expecting sustained winds of 39 to 73 miles per hour. NWS issues a hurricane warning for any coastal or inland areas expecting sustained winds of 74 miles per hour. High winds can cause downed trees and/or power lines; damage to communication infrastructure; and damage or loss to buildings, particularly roofs, windows, outbuildings, and structures and utilities on roofs or outside of buildings. High winds can also damage unanchored structures such as mobile homes, carports, awnings, trampolines, and debris that is not properly stored, including hazardous waste and toxic materials. High wind events can disrupt transportation services, resulting in air travel delays, cancellation of ferry service, closed roadways due to debris and downed power lines, and transit service delays. High winds also pose unique risks to outdoor workers and often result in power outages, transportation delays, and communication disruptions due to downed trees and power lines. High winds are also a hazard for the maritime, shipping, and aviation industry sectors. Tornadoes are analyzed separately in Section 5.14 (Tornadoes) and are not discussed in detail in this section.

Thunderstorms

Thunderstorms include heavy rains, strong winds, lightning, thunder, and sometimes hail and tornadoes. A thunderstorm is classified as “severe” when it produces damaging wind gusts in excess of 58 miles per hour (50 knots), hail that is 1 inch in diameter or larger (quarter size), or a tornado (NWS, n.d.). Three basic components are required for a thunderstorm to form: moisture, rising unstable air, and a lifting mechanism. As warm surface air rises, it transfers heat from the surface of the Earth to the upper levels of the atmosphere (i.e., the process of convection). The water vapor it contains begins to cool, releasing the heat, and the vapor condenses into a cloud. The cloud eventually grows upward into areas where the temperature is below freezing. Some of the water vapor turns to ice and some of it turns into water droplets; both have electrical charges. When a sufficient charge builds up, the energy is discharged in a bolt of lightning, which causes the sound waves we hear as thunder. An average thunderstorm is 15 miles across and lasts 30 minutes; severe thunderstorms can be much larger and longer. Southern New England typically experiences 10 to 15 days per year with severe thunderstorms.

Every thunderstorm has an updraft (rising air) and a downdraft (sinking air). Sometimes strong downdrafts known as downbursts can cause tremendous wind damage similar to that of a tornado. A small (less than 2.5-mile path) downburst is known as a “microburst” and a larger downburst is called a “macroburst.” An organized, fast-moving line of microbursts traveling across large areas is known as a “derecho;” these occasionally occur in Massachusetts. Winds exceeding 100 miles per hour have been measured from downbursts in Massachusetts.

Extreme Precipitation

Extreme precipitation generally refers to events of rainfall or snowfall that substantially exceeds what is normal in an area. In Massachusetts, extreme precipitation is often defined or measured as an accumulation of rain or snow of 2 or more inches within 24 hours (Commonwealth of Massachusetts, 2018; Runkle et al., 2022). Heavy precipitation events occur when an air mass holding significant amounts of moisture moves over land or converges into a storm system. Extreme precipitation events do not mean that total precipitation in an area has increased—it only refers to more intense events occurring over a shorter duration. Climate change is expected to increase the intensity and frequency of extreme precipitation. The impacts of these events include crop damage, soil erosion, and increased flood risk. For more discussion on flooding, please see Section 5.5 (Coastal Flooding) and Section 5.8 (Flooding from Precipitation).

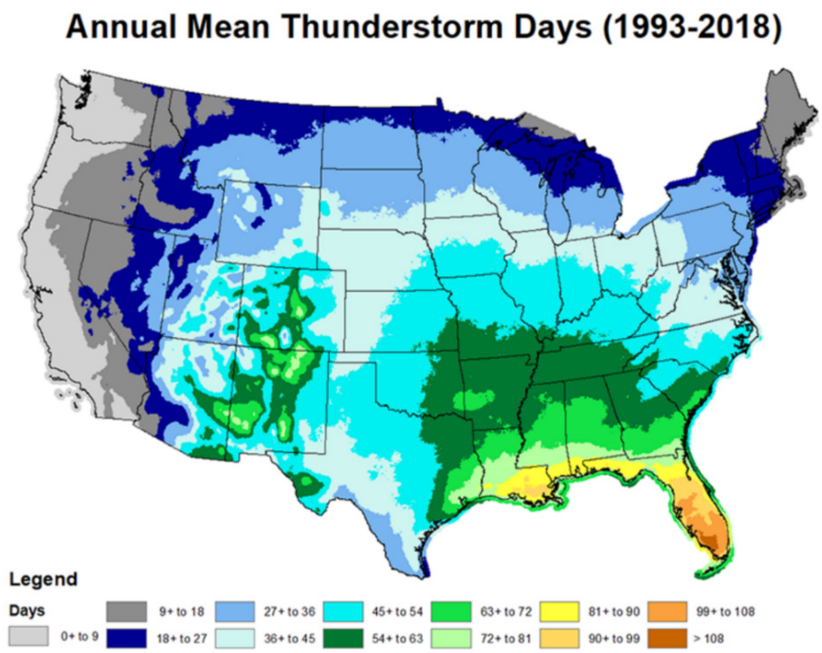
5.12.2.2.1 Location

High Winds

The entire Commonwealth is vulnerable to damaging winds. However, the coast is most frequently impacted by damage from high-wind events. The Federal Emergency Management Agency (FEMA) has divided the U.S. into four wind zones. States located in Wind Zone IV have experienced the greatest number of tornadoes and the strongest tornadoes. The Commonwealth is located within Wind Zone II, which includes wind speeds up to 180 miles per hour. The entire Commonwealth is also located within a Hurricane Susceptible Region. The Commonwealth is located within the special wind zone classified as moderate risk, in which wind-speed anomalies are present and additional consideration of the wind hazard is warranted (FEMA, 2021). According to the FEMA National Risk Index, Most of Massachusetts experiences “relatively low” risk of Strong Wind with exception of Worcester County, which has a “relatively moderate” risk (FEMA, n.d.). Counties experiencing very low risk of Strong Wind include Norfolk, Suffolk, Dukes, and Nantucket (FEMA, n.d.).

Thunderstorms

Unlike nor’easters and hurricanes, which affect large regions, thunderstorms affect relatively small areas, although in some cases the entire Commonwealth can experience the effects and impacts of thunderstorms. Figure 5.12-1 indicates that historically, Massachusetts experiences between nine and 27 thunderstorm days each year, with western and central Massachusetts experiencing more thunderstorms on average compared to the coast.



Source: Koehler (2020). Published 2020 by the American Meteorological Society.

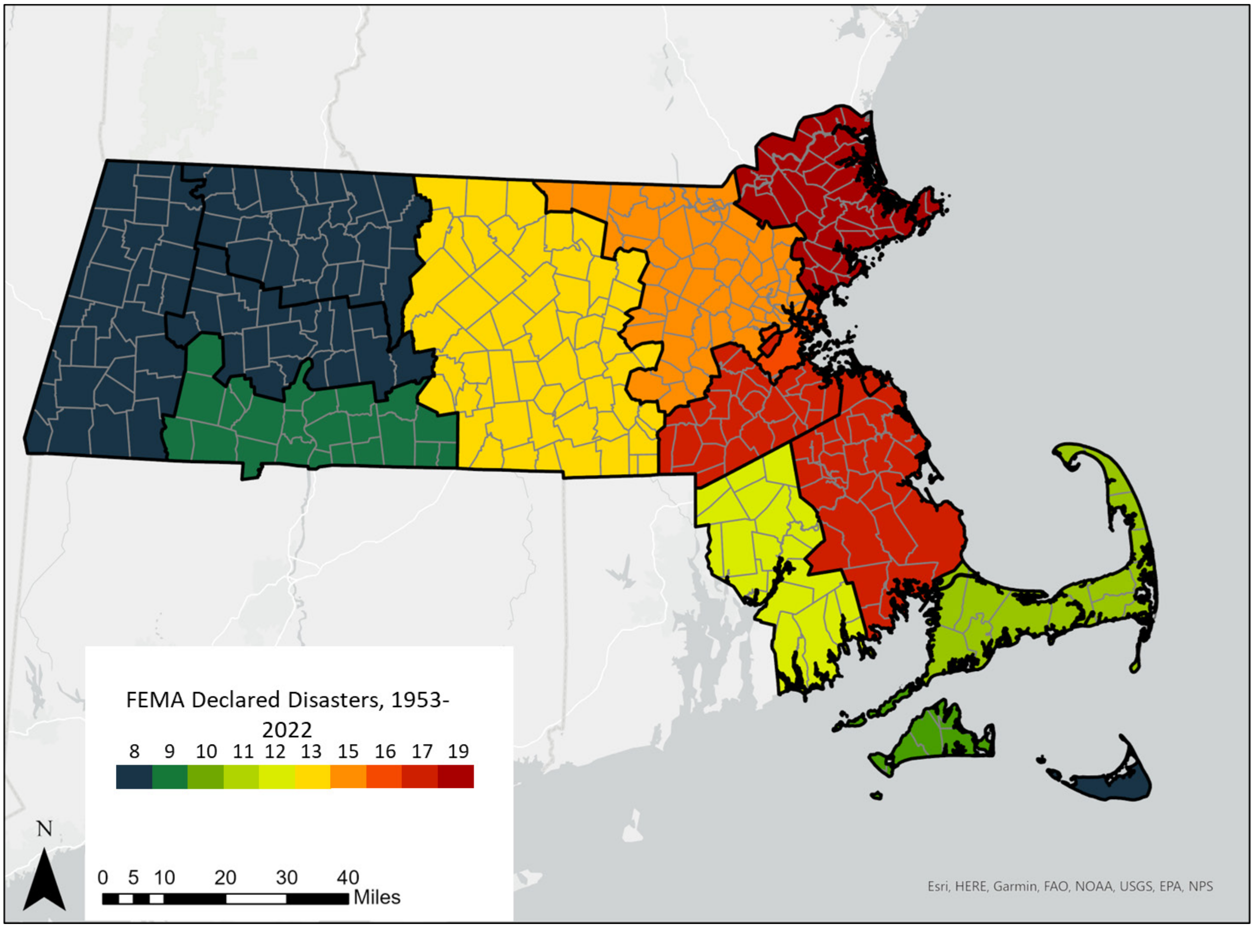
Figure 5.12-1. Annual average number of thunderstorm days in the U.S.

Extreme Precipitation Events

The entire Commonwealth has experienced extreme precipitation events. From 2005 to 2014, Massachusetts had the largest number of extreme precipitation events on record for the Commonwealth, which was about 30 percent higher than the long-term average (Runkle et al., 2022).

5.12.2.2.2Previous Occurrences and Frequency

Known severe weather events that have affected Massachusetts and received FEMA disaster declarations are identified in Appendix 5.A. Figure 5.12-2 illustrates the number of storm-related disasters per county. It should be noted that this count of severe weather events encompasses several natural hazards, including hurricanes, snowstorms, severe storms, severe ice storms, coastal storms, and tornadoes. FEMA disaster declarations are made at the county level. Disasters that impacted multiple counties will have a separate declaration per each affected county. Although this means storm events may also be accounted for in other sections of the SHMCAP Risk Assessment, the overall number of occurrences per county provides valuable insight into each county’s exposure.



Map created by ERG using data from FEMA (2023).

Figure 5.12-2. FEMA declared disasters by county, 1953–2022.

High Winds

Over the last 15 years (between January 1, 2008, and December 31, 2022), a total of 911 high-wind events occurred in Massachusetts over 198 days, with an average of 13 high-wind days per year and an average of 61 wind events per year (NOAA, 2022). The Storm Event Database estimates that these events caused around $21 million worth of building damage. However, many of the high-wind events logged in the Storm Event database may have occurred as a result of the same weather system, so this count may overestimate the frequency of the high-wind hazard as a standalone event.

Potential Effects of Climate Change on High Winds

Climate models and projections do not always model changes in winds, and some climate scientists have found uncertainties in long-term wind trends (Schauffler, 2021). However, global wind speeds on average have increased since 2010 and buoy data off the Gulf of Maine has tracked an increase in monthly average wind speeds (Zeng et al., 2019). Massachusetts is highly likely to continue experiencing high wind events based on previous occurrences. Though the effect of climate change on high winds is not certain, based on recent data, it appears likely that high wind events will increase because of more frequent severe weather events in the future.

Potentential Effects of Climate Change on Thunderstorms

As shown in Figure 5.12-1, Massachusetts experiences between nine and 27 thunderstorm days each year. Based on previous occurrences, Massachusetts is highly likely to continue experiencing thunderstorms. Data for Massachusetts from the Localized Constructed Analogs' downscaled global climate models supports the trend of slightly increased frequency. Based on these projections the probability of future thunderstorm events is anticipated to increase. Two key factors lead to the formation of thunderstorms: convective available potential energy (CAPE) and strong wind shear. Climate change is expected to increase CAPE while decreasing wind shear in mid-latitudes. Modeling suggests that CAPE will increase enough to overwhelm the small decrease in wind shear, leading to more favorable conditions for thunderstorms in the eastern United States (NASA Earth Observatory, 2013).

CAPE and thunderstorm precipitation rates can be used to predict lightning strikes. Climate change is very likely to increase lightning strikes over the contiguous United states by about 50 percent over the next century. Modeling using a 1990–2020 baseline predicts lightning strikes to increase in every Massachusetts county by at least 40 percent by 2030 and by over 100 percent in 2070 (Romps et al., 2014).[1]

Potential Effects of Climate Change on Extreme Precipitation

Scientists expect that there will be more rain overall in Massachusetts. The amount of annual precipitation and intensity of precipitation is likely to increase, and this increase is expected to occur in most years. The patterns emerge as higher temperatures are anticipated to increase the moisture-holding capacity of the atmosphere. The days of rainfall, however, are likely to be more variable and reduce overall, implying that on days when it does rain, there will be more moisture. The Massachusetts Climate and Hydrologic Risk Project supports the trend of a slightly increased frequency of high-intensity rainfall events, defined here as a day with more than 2 inches of precipitation. Table 5.12-1 shows modeling results for the planning horizons identified in this plan (2030, 2050, 2070, and 2090) for the increase in days with more than 1 inch of rain and more than 2 inches of rain. Extreme precipitation projections by U.S. Geological Survey subbasins indicate that the coast will experience the greatest number of high-intensity rainfall days, but increased precipitation will occur in every region of the Commonwealth.

Figure 5.12-3 shows the change in frequency of the historical 10 percent annual probability rainstorm (a one in 10-year return period) from the [2022 Massachusetts Climate Change Assessment] (hereafter MA Climate Assessment). The historical baseline data is from 1985 to 2005. Circles on the graphs represent the mean amount of precipitation projected by available climate models for the 10 percent annual storm, while

[1] The study did not provide any data for Nantucket County.

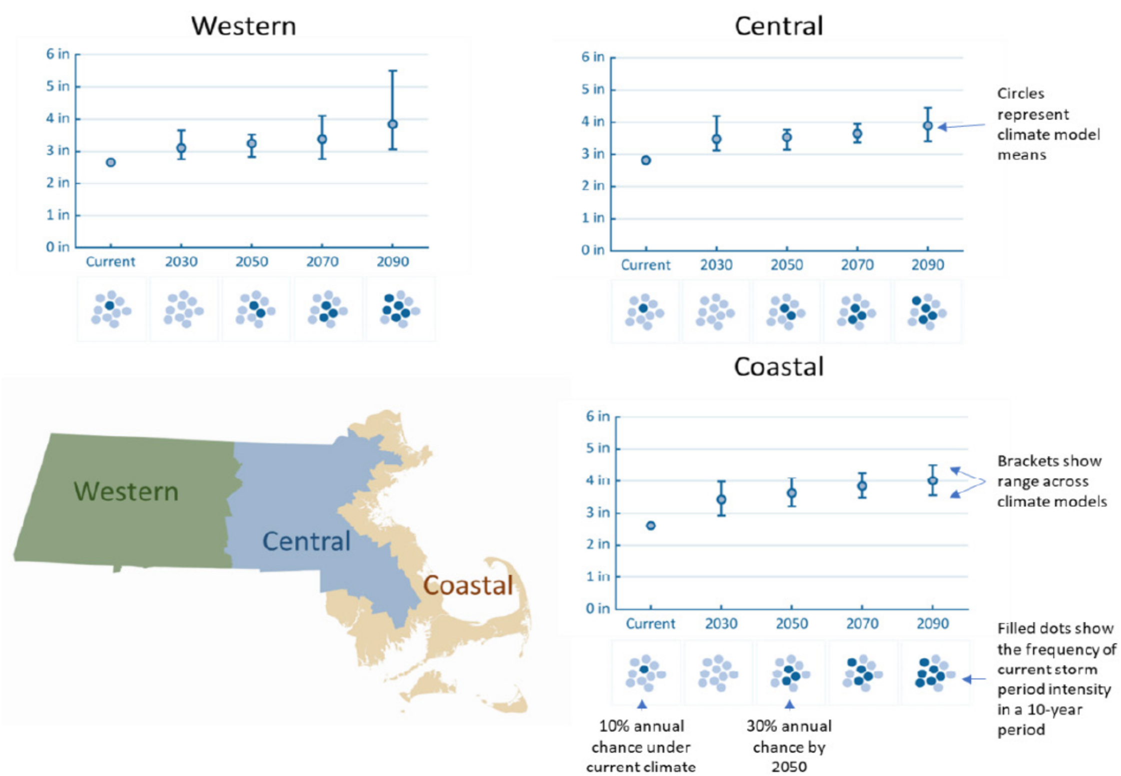
the brackets show the range of climate models. The dots below the graphs show the change in frequency of the historical (baseline) 10-year, 24-hour rainstorm. All regions are projected to see an increased intensity of the 10-year storm from under 3 inches in 24 hours to around 4 inches in 24 hours. The coastal region is expected to see the biggest increase in frequency of the historical 10-year storm.

Table 5.12-1. Projected Frequency of Future Annual Extreme Precipitation Events in Massachusetts

	2030	2050	2070	2090
Number of days >1” precipitation	2.7–7.3	3.1–8.0	3.7–8.7	4.0–9.2
Number of days >2” precipitation	0.2–1.0	0.2–1.2	0.3–1.4	0.4–1.5

Note: This table was developed with information in the Massachusetts Climate and Hydrologic Risk Project (Phase 1) Stochastic Weather Generator Climate Projections

Source: Massachusetts Executive Office of Energy and Environmental Affairs (2023).



Source: MA Climate Assessment (Commonwealth of Massachusetts, 2022).

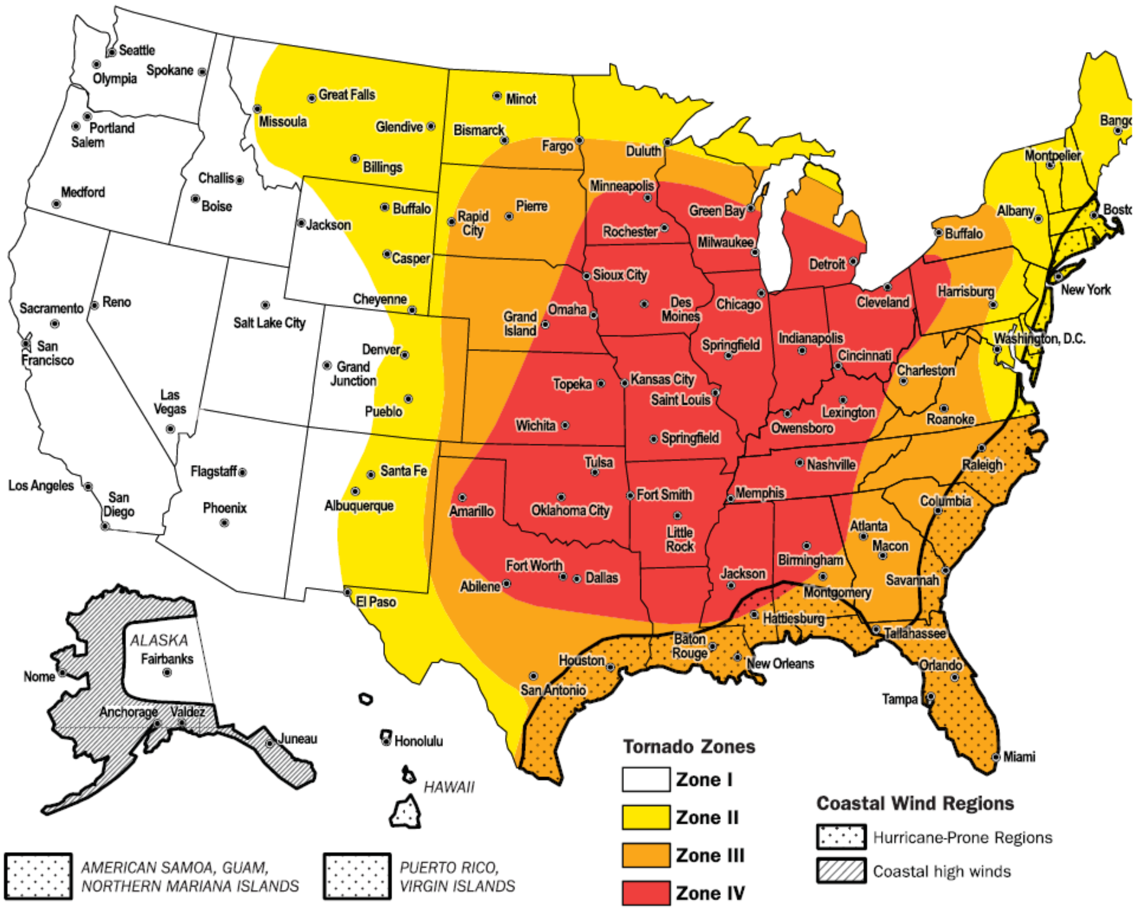
Figure 5.12-3. Change in intensity and frequency of extreme precipitation events: impact of climate change on the 10 percent annual probability historical rainstorm.

5.12.2.2.3Severity/Intensity

High Winds

Massachusetts is susceptible to high winds from several types of weather events: straight-line winds, before and after frontal systems, hurricanes and tropical storms, severe thunderstorms and tornadoes, and nor'easters. Straight-line winds are often the result of a thunderstorm downdraft but can be caused by several other meteorological processes. Straight-line winds are defined as winds exceeding 50 to 60 miles per hour and can reach up to 100 miles per hour and cover hundreds of miles (FEMA, 2021). Sometimes, wind gusts of only 40 to 45 miles per hour can cause scattered power outages from downed trees and wires. This is especially true after periods of prolonged drought or excessive rainfall since both can weaken root systems and make trees more susceptible to the wind's effects. Winds measuring less than 30 miles per hour are not considered to be hazardous under most circumstances. High winds are of particular concern to coastal areas, where wind speeds can reach 110 miles per hour or higher.

Figure 5.11-4 presents a map of wind hazards in the United States. Massachusetts is in tornado Zone II, which corresponds with a moderate risk of high winds but low risk of tornadoes. The eastern and southern portions of Massachusetts are also located in the hurricane-prone regions, which represent high risk for hurricanes and other coastal high-wind events. High-wind events that are not associated with nor'easters or hurricanes tend to have localized impacts. However, if winds damage critical assets such as power generation or distribution infrastructure, the impacts may be felt at a larger scale.



Source: FEMA (2021).

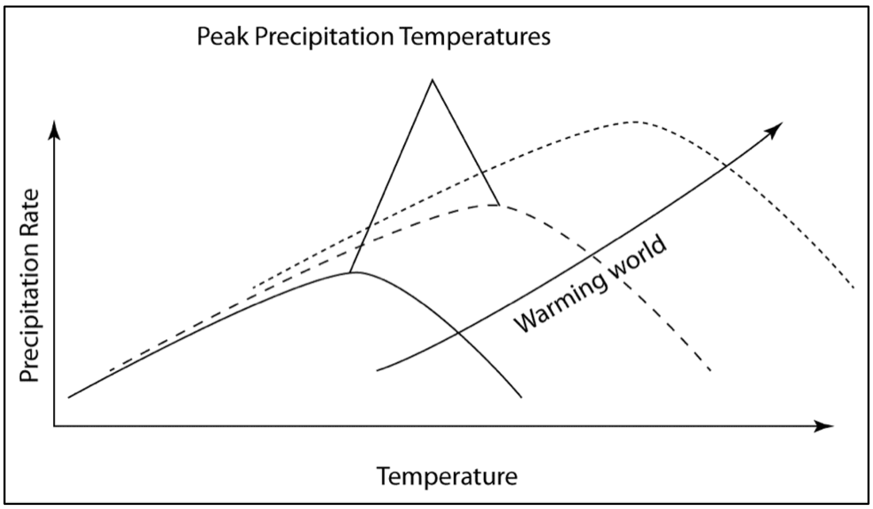
Figure 5.11-4. Wind hazards in the United States.

Thunderstorms

The severity of thunderstorms can vary widely, from short-term, localized events to large-scale storms that result in major consequences, including flooding and direct damage to people, buildings, and ecosystems throughout a region. For example, severe storms in eastern Massachusetts in late August 2022 brought torrential rain, wind, and hail; the storm caused flooding in roadways in parts of Boston, as well as power outages for nearly 20,000 customers across the Commonwealth (WCVB, 2022). Widespread flooding is the most common characteristic that leads to a storm being declared a disaster in Massachusetts. The severity of flooding varies widely based on characteristics of the storm and the region in which it occurs. Lightning can also present a high magnitude of consequence to humans. According to the National Oceanic and Atmospheric Administration (NOAA) Storm Events Database, between 1990 and 2022, there have been eight fatalities and 148 injuries as a result of lightning events in the Commonwealth (NOAA, 2022).

Extreme Precipitation

As shown in Figure 5.12-5, there are several factors that make it increasingly likely that extreme precipitation events will increase in the next decades. Additional information on flooding from extreme precipitation is included in Section 5.8 (Flooding from Precipitation). The relationship between climate change and rainfall is complex, and scientific consensus does not yet exist on the likely changes to precipitation. As the climate warms, the capacity of the atmosphere to hold water vapor will increase, potentially resulting in more extreme precipitation events. However, observational studies have shown that the relationship between temperature and precipitation likely depends on several variables. An additional complication is that some evidence suggests the temperature at which peak precipitation occurs is likely to increase in a warming world (as shown in Figure 5.12-5). As temperatures increase due to climate change, warming temperatures will likely influence the distribution, intensity, and annual variation of precipitation rates globally.



Source: Abraham (2017). Reproduced with permission from author.

Figure 5.12-5. Peak precipitation temperatures in a warming climate.

Based on an analysis of global climate models downscaled using the Localized Constructed Analog approach, the intensity of extreme precipitation events is also expected to increase across the Commonwealth. Under current climate conditions, a 10-year return period event is roughly 3 inches of rainfall in 24 hours for all regions (Commonwealth of Massachusetts, 2022). In the future, the intensity of that event could increase by one third, to 4 inches of rainfall in 24 hours. The frequency of the 3 inches in 24 hours historical event is projected to reduce in all regions in 2030, but by 2050, the frequency will double compared to the current climate, and by 2090, the frequency will increase five-fold for the western and coastal regions of the Commonwealth, and by a factor of four in the central region (Commonwealth of Massachusetts, 2022). These changes in the frequency and intensity of extreme precipitation events are connected to higher temperatures and the increased capacity of the atmosphere to hold water. Impacts from extreme precipitation events tend to be localized but may impact larger regions depending on the size of the storm and the effects on infrastructure and utilities. Changes in precipitation patterns would affect the frequency, intensity, and duration of inland flooding; cause stormwater volumes to potentially exceed drainage capacities which have been "sized" for historic events; and increase the possibility of inland dams being overtopped or breached.

5.12.2.2.4 Warning Time

Meteorologists can often predict the likelihood of severe storms, including thunderstorm outbreaks, with several days of lead time. However, meteorologists cannot predict the exact time of onset or the severity of individual events. Some events, such as "pulse" type and "popcorn" afternoon thunderstorms, may develop quickly and offer only a few minutes of advance warning. Other storms, such as a well-organized squall line, can have lead times of up to an hour (from the time a Severe Thunderstorm Warning is issued to the time that severe criteria are observed). High wind warning times vary depending on their source but are typically issued between 12 to 48 hours before onset.

5.12.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

All local hazard mitigation plans reviewed identified other severe weather as a municipality-wide hazard that occurs frequently (defined as more than once every five years). These plans characterized thunderstorms, high winds, and hailstorms as less severe than other hazards since these storms tend to have more localized impacts. Most of the plans reviewed for this assessment relied on the exposure and vulnerabilities identified in the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP). In general, local municipalities' biggest concerns regarding severe storms were damage to utility, telecommunications, and transportation infrastructure and localized flooding from heavy precipitation. Table 5.12-2 highlights some of the key risks and vulnerabilities municipalities identified regarding other severe weather events.

Table 5.12-2. Highlight of Local Plans and Municipal Vulnerability Preparedness (MVP) Program Planning Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Town of Adams Multi-Hazard Mitigation Plan, August 2019	The entire town is exposed to thunderstorms and high winds.	Damage to utility infrastructure and prolonged power outages pose the greatest concern to human health.	Total structure replacement cost value for residential buildings is $353 million. Severe thunderstorms and hail in 2011 caused nearly $100,000 of property damage.
City of Salem Hazard Mitigation Plan 2020 Update, February 2020	The whole city is exposed to other severe weather events. Severe events can cause localized riverine- and urban drainage-related flooding.	Recent microburst events resulted in losses of utility poles, downed trees, and loss of power for over 24 hours.	Between 2000 and 2019, thunderstorms caused $2.57 million in property damage in Essex County.
Town of Shutesbury Hazard Mitigation Plan, January 2022	The whole town is exposed to severe thunderstorms, lightning, and high winds.	Flooding from severe storms may impact residents who live on gravel roads. Residents who rely on private wells for drinking water may be impacted by prolonged power outages.	If 10% of buildings are damaged, total estimated damage is $22,599,040.
City of Somerville Hazard Mitigation Plan 2022 Update, January 2022, and *Somerville Climate Forward*, November 2018	The whole city is exposed, with vulnerability to nor'easters.	Stormwater from extreme precipitation is a major concern. The city's stormwater infrastructure is already under capacity for extreme precipitation events.	Between 2015 and 2020, thunderstorms caused $1.6 million in property damage in Middlesex County.

5.12.2.3 Secondary Hazards

The most significant secondary hazards associated with severe thunderstorms include flooding, lightning strikes, and high winds. Heavy rain can overwhelm both natural drainage and stormwater systems, causing overflows. Heavy rain can also damage or destroy buildings, infrastructure, utilities, and the environment. Thunderstorms can also cause floods and landslides. Lightning can cause severe damage, injury, and death, and severe lightning can cause fires, even when accompanied by heavy rains. High winds can down power lines, uproot trees, and damage buildings and transportation assets and services. High winds can also blow around debris, increasing the risk of injury or death.

5.12.2.4 Exposure and Vulnerability

The likelihood of Massachusetts experiencing severe weather is extremely likely or certain based on historical occurrences; current trends; and projections for near-, mid-, and long-range risks. Communities in Massachusetts can experience severe precipitation, high winds, and thunderstorms several times a year (see Previous Occurrences and Frequency section above). While not every event results in significant impacts on communities and the natural environment, severe weather can disrupt human and natural systems depending on the intensity and frequency of the event. Table 5.12-3 summarizes the potential impacts of severe weather events in the Commonwealth as identified in the MA Climate Assessment, as well as information related to past events in the Commonwealth and across the U.S.

Table 5.12-3. Priority Impacts and High-Consequence Vulnerabilities

Sector	Priority Impacts and Vulnerabilities
Human	• Emergency service response delays and evacuation disruptions **(most urgent)** • Increase in mental health stressors • Health effects from extreme storms and power outages • Health and financial impacts from increased flooding from precipitation
Infrastructure	• Damage to electric transmission and distribution infrastructure **(most urgent)** • Loss of urban tree cover • Damage to roads and loss of road service
Natural environment	• Forest health degradation **(most urgent)** • Increased incidence of harmful algal blooms • Water quality disturbances from uprooted forests
Governance	• Increase in demand for state and municipal government services **(most urgent)** • Increase in need for state and municipal policy review and adaptation coordination • Damage to inland state-owned buildings and land • Damage to coastal state and municipal buildings and land
Economy	• Reduced ability to work **(most urgent)** • Economic losses from commercial structure damage and business interruptions • Decreased agricultural productivity

5.12.2.4.1 Human

The entire population of the Commonwealth is considered exposed to high-wind and thunderstorm events. While most thunderstorm and high-wind events in Massachusetts do not significantly impact human life, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. In addition, disruption to power and communications service can have impacts on people who need access to emergency services or use medical equipment. Unhoused people are more vulnerable to other severe weather, with high winds, lightning, and extreme rains posing great risks to their health and safety. Outdoor workers are considered at risk and more vulnerable to many storm impacts, particularly lightning strikes, compared to those who are located inside. Utility and rescue workers are vulnerable to lightning strikes and debris from high winds and thunderstorms. High winds can down trees and powerlines as well as damage other critical infrastructure. This can result in air travel delays, cancellation or delay of water transit, closed roadways, and transit service delays. Communications disruptions, power outages, and transportation delays can prevent or delay access to emergency services. Workers who rely on public transportation and work outdoors may also experience reduced ability to work due to transit delays and extreme weather conditions. High winds are also a hazard for the maritime, shipping, and aviation industries.

People’s ability to prepare for, respond to, and recover from other severe weather events such as high winds or thunderstorms is based on many factors, including the type and age of the structures in which they live and work, whether they own or rent their homes, the building codes in place when structures were built, the location of physical assets, and the ecological health of the landscaping and trees in a community. Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Mobile homes are the most vulnerable to damage, even if tied down, and offer little protection to people inside. Additionally, actions taken before severe weather events will reduce the effects of these events. Examples include eliminating, storing, or anchoring debris, hazardous waste, and unanchored items or structures; repairing or replacing roofs; and bringing items on roofs or outside into secure buildings.

Vulnerable and Priority Populations

Environmental Justice and other priority populations are most susceptible to severe weather based on a number of factors, including their physical and financial ability to prepare for, respond to, and recover from a severe weather event. Additional factors include the location and construction quality and age of their housing, their ability to repair and maintain their housing, and whether they rent or own their homes. In general, vulnerable populations include people over the age of 65 and under the age of five; elderly people living alone; single parents; members of low-income households; renters; people with low English language proficiency; people with limited mobility or a life-threatening illness; people with underlying health conditions; and people who lack transportation, live in areas with unreliable access to power or communications, and/or live in areas that are isolated from major roads. The isolation of these populations is a significant concern if they need emergency services or if outages and roadway disruptions are lengthy. People who are not connected to warning systems via smartphones or other technologies are also more vulnerable to the impacts of severe storms.

Power outages can be life-threatening to those dependent on electricity for life support. Power outages may also result in inappropriate use of combustion heaters, cooking appliances, and generators in indoor or poorly ventilated areas, leading to increased risks of carbon monoxide poisoning. Renters and members of low-income households may also have less access to backup power (e.g., generators) during outages. People who work or engage in recreation outdoors or those without regular access to shelter, such as unhoused people, are also vulnerable to severe weather.

Health Impacts

Both high winds and thunderstorms have the potential to affect public health across the Commonwealth. High winds and thunderstorms can result in people being struck by debris or lightning, causing direct fatalities and injuries. Extreme rainfall events can affect water quality by increasing turbidity and bacteriological contaminants, leading to gastrointestinal illnesses. One study found an 8 percent increase in gastrointestinal illness in the four days following flood events (Wade et al., 2014). Research has also found that thunderstorms may cause the rate of emergency room visits for asthma to increase to five to 10 times the normal rate (Andrews, 2012). This phenomenon can be attributed to the stress and anxiety that many individuals, particularly children, experience during severe thunderstorms. The combination of wind, rain, and lightning from thunderstorms with pollen and mold spores can exacerbate asthma (University of Georgia, 2017). The rapidly falling air temperatures characteristic of thunderstorms, as well as the production of nitrogen oxide gas during lightning strikes, have both been correlated with impacts to people with asthma. Flooding events can also increase exposure to mold, especially if actions to remediate floods are not taken quickly. Mold exposure falls disproportionately on low-income people, renters, and underrepresented households, and is associated with substandard housing, lower rates of humidity control, and more frequent exposure to flood risks (Lanthier-Veilleux et al., 2016). Flooding can also mobilize contaminants and hazardous materials that are improperly stored or remediated.

5.12.2.4.2 Governance

Damage to buildings is dependent upon several factors, including wind speed; storm duration; the path of the storm track; and building construction, maintenance, and age. According to the Hazus wind model, direct wind-induced damage (wind pressures and windborne debris) to buildings is dependent upon the performance of components and cladding, including the roof covering (i.e., shingles, tiles, membrane), roof sheathing (typically wood-frame construction only), windows, and doors. Structural wall failures can occur for masonry and wood-frame walls, and whole roof systems can be uplifted due to failures at roof/wall connections. Foundation failures (i.e., sliding, overturning, uplift) can potentially take place in manufactured homes. Unanchored structures such as carports, awnings, and small boats and vehicles can be thrown during an extreme weather event, causing damage to the structures themselves and whatever they come into contact with.

Massachusetts is divided into wind load zones for three risk categories, the parameters of which are defined by the Massachusetts State Building Code (Ninth Edition). The Massachusetts State Building Code assigns risk categories based on the occupancy of a building. National wind data prepared by the American Society of Civil Engineers serve as the basis of these wind design requirements (American Society of Civil Engineers, 2021). Structures should be designed to withstand the total wind load risk based on their location. However, changes in building code and lack of maintenance may make older buildings more vulnerable to high wind loads. Refer to the Massachusetts State Building Code (Ninth Edition [780 CMR] Chapter 16, Structural Design, as amended by Massachusetts) for information on wind pressures, wind forces on roofs, and similar data.

Using ArcMap GIS software, the wind zones for Risk Category IV the SHMCAP Risk Assessment team overlaid with the 2022 Division of Capital Asset Management and Maintenance (DCAMM) facility data; the appropriate wind load zone determination was assigned to each DCAMM facility. Risk category IV buildings are designated as essential facilities and include emergency preparedness centers, communications and operations centers, designated emergency shelters, buildings with critical national defense functions, water storage facilities, air traffic control centers, and emergency or surgery treatment facilities. Not all government buildings are likely to be classified as risk category IV. However, some facilities will perform one or more of the category IV functions.
Table 5.12-4 summarizes the number of government buildings by wind zone and their estimated replacement value. Nantucket County, located 30 miles off the south coast of Cape Cod, is the only county located in the highest wind load zone in Massachusetts, which accounts for wind gusts up to 163 miles per hour. Nantucket County comprises the town of Nantucket and the community of Siasconset.

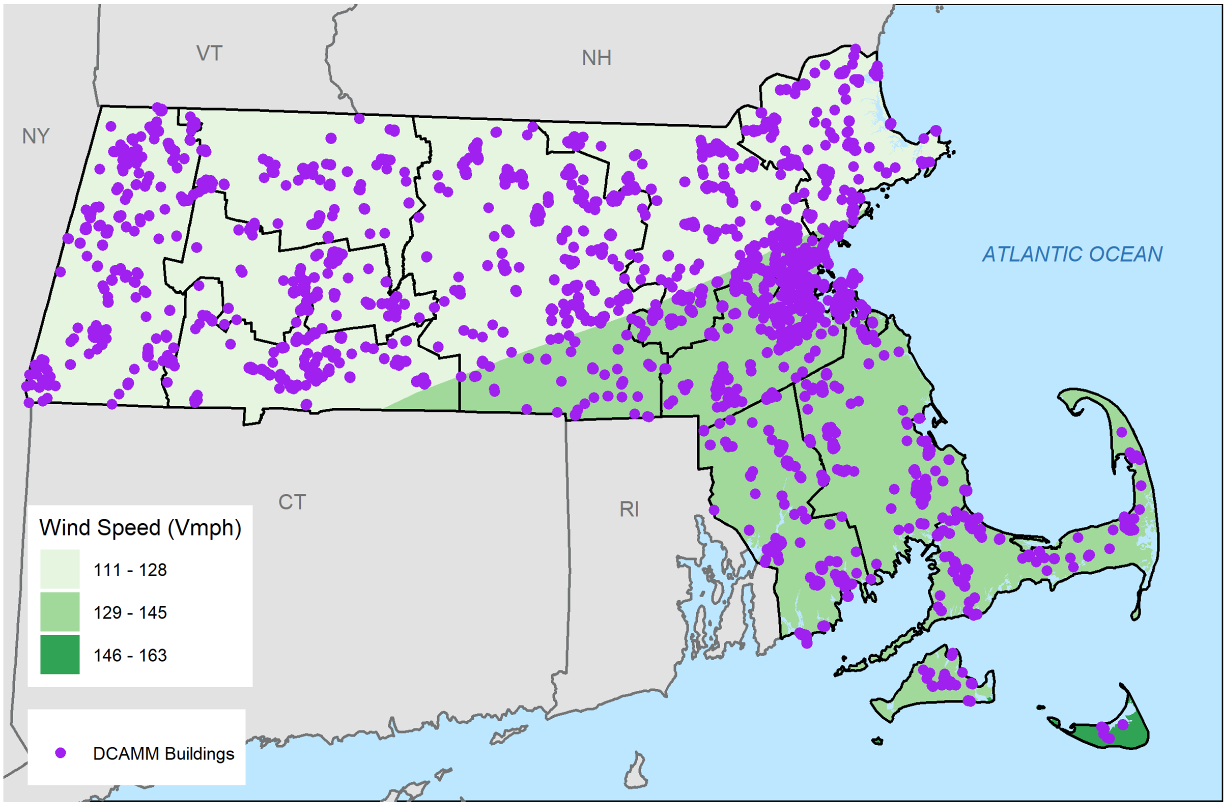
Table 5.12-4. State-Owned Buildings in Wind Load Design Zones by County

County	111–128 Vmph		129–145 Vmph		146–163 Vmph	
	Buildings	Replacement Value	Buildings	Replacement Value	Buildings	Replacement Value
Barnstable	—	—	465	$1,271,100,373	—	—
Berkshire	611	$1,261,755,122	—	—	—	—
Bristol	—	—	517	$3,577,534,423	—	—
Dukes	—	—	39	$31,569,050	—	—
Essex	577	$3,441,620,200	57	$205,481,900	—	—
Franklin	289	$588,789,550	—	—	—	—
Hampden	585	$4,479,163,943	—	—	—	—
Hampshire	710	$8,156,242,578	—	—	—	—
Middlesex	957	$6,206,252,812	396	$2,136,258,149	—	—
Nantucket	—	—	—	—	11	$18,341,000
Norfolk	—	—	781	$3,203,956,531	—	—
Plymouth	—	—	790	$4,080,320,637	—	—
Suffolk	—	—	795	$15,264,125,862	—	—
Worcester	1040	$9,341,681,700	151	$297,561,250	—	—
Total	**4769**	**$33,475,505,905**	**3991**	**$30,067,908,174**	**11**	**$18,341,000**

Note: Vmph refers to wind contours associated with wind velocity

Sources: ERG analysis using information from ASCE 7-22, 2022; Massachusetts Division of Capital Asset Management and Maintenance (2022).

Figure 5.12-6 illustrates the wind load zones and the number of facilities located in each zone. For Table 5.12-5 and for the subsequent built environment tables, all buildings exposed to higher-intensity winds should be assumed to be exposed to the lower-intensity categories. While these categories provide useful guidelines for the potential vulnerability of structures, it should be noted that winds far above 110 miles per hour occur on a regular basis in Massachusetts. Therefore, these categories should not be considered to represent the full range of possible wind conditions.



Source: ERG analysis using ASCE 7-22, 2022; Massachusetts Division of Capital Asset Management and Maintenance (2022).

Figure 5.12-6. Government buildings by wind load zones in the Commonwealth of Massachusetts.

Lifelines

Severe storm damage can temporarily interrupt state agency operations and damage facilities, resulting in delayed and disrupted services. Based on responses to the 2023 SHMCAP survey given to state agencies, these impacts would result in service delays, including postponed court dates, temporary lack of data access, delayed job placements, delayed financial assistance, and temporary lack of access to government officials (ERG, 2023). Environmental Justice and other priority populations that rely on food, housing, and economic assistance benefits could be seriously impacted by delays in certain state services. Groups of particular concern among state agencies include veterans, people who rely on unemployment and/or other government assistance, unhoused populations, elderly people, and people experiencing mental health crises. In many cases, agencies providing these services have contingencies in place to quickly recover from these delays if damage is not too widespread.

5.12.2.4.3Infrastructure

All elements of the built environment are exposed to severe weather events such as high winds and thunderstorms. While residential structures tend to be more vulnerable than commercial buildings to extreme weather damage, wood and masonry buildings in general (regardless of occupancy class) tend to experience more damage than concrete or steel buildings.

As discussed in Governance, there are three wind load zones in the Commonwealth for category IV buildings, which reflect the level of risk presented to elements essential facilities in that area. Table 5.12-5 summarizes the number of critical facilities in each wind load zone for risk category IV by county, and Table 5.12-6 shows the number of critical facilities within each wind load zone for risk category IV by facility type. Critical facilities are defined as buildings necessary for public health and safety and buildings that may face safety and emergency response challenges due to high occupancy or sensitive populations.

Table 5.12-5. Number of Critical Facilities in Wind Zones by County

County	111–128 Vmph	129–145 Vmph	146–163 Vmph
Barnstable	—	164	—
Berkshire	170	—	—
Bristol	—	155	—
Dukes	—	9	—
Essex	159	7	—
Franklin	68	—	—
Hampden	194	—	—
Hampshire	300	—	—
Middlesex	293	110	—
Nantucket	—	—	7
Norfolk	—	277	—
Plymouth	—	280	—
Suffolk	—	171	—
Worcester	362	36	—
Total	**1546**	**1209**	**7**

Note: Vmph refers to wind contour lines associated with wind velocity
Sources: ERG analysis using ASCE 7-22, 2022; Massachusetts Division of Capital Asset Management and Maintenance (2022).

Table 5.12-6, Number of Critical Facilities in Wind Zones by Facility Type

Facility Type	111–128 Vmph	129–145 Vmph	146–163 Vmph
Administration	106	68	—
Animal services	9	1	—
Cold storage	8	5	—
Communications	32	28	—
Corrections	154	198	—
Education	83	39	—
Energy facilities	124	92	—
Fire facilities	34	31	—
Health care	53	43	—
Laboratories and research	14	6	1
Maritime	24	56	—
Military facilities	51	30	—
Parks and recreation	71	26	—
Police facilities	20	21	1
Residential	439	266	5
Social services	57	37	—
Stadium	3	2	—
Transportation	23	45	—
Waste management	42	55	—
Water resources	199	160	—
Total	**1546**	**1209**	**7**

Note: Vmph refers to wind contour lines associated with wind velocity

Sources: ERG analysis using ASCE 7-22, 2022; Massachusetts Division of Capital Asset Management and Maintenance (2022).

Agriculture

Forests and agricultural crops, equipment, and infrastructure may be directly damaged by high winds. Lightning strikes can start fires that damage or destroy buildings and damage electrical equipment. High winds, lightning, extreme precipitation, flooding, and other severe weather can result in damage to and loss of farm buildings, equipment, utility and infrastructure access and assets, crops, and farm animals. Severe weather that occurs at critical milestones can reduce production, damage crops, limit access to markets, and cause the loss of farm animals.

Energy

The most common problem associated with severe weather is damage to utility infrastructure resulting in disruption to energy services. Severe windstorms causing downed trees can create serious impacts on power and aboveground communication lines. High winds caused 24 North American Electric Reliability Corporation-reported electric transmission outages between 1992 and 2009, resulting in disruption of service to 225,000 electric customers in the Commonwealth (U.S. DOE, 2021). During this same period, lightning caused nearly 25,000 disruptions (U.S. DOE, 2021). While a comprehensive report on power outages has not been produced recently for Massachusetts, severe weather events and high winds continue to be a significant cause of power outages in the Commonwealth. Between 2008 and 2017, 31 percent of electric utility outages were caused by severe weather or falling trees in Massachusetts (U.S. DOE, 2021).

Downed power lines can cause blackouts, leaving large areas without access to power, which can include heat and life-sustaining medical equipment. Loss of electricity, communication networks, and phone connections would leave populations unable to call for assistance if needed. Loss of power can also eliminate access to air conditioning and heating, which can cause heat or cold stress that can result in injuries and fatalities. This is particularly true for young and elderly people, as well as people with underlying health conditions such as asthma.

Damage to utility infrastructure (e.g., power lines, gas lines, electrical systems, communications) can result in the loss of power and communications, which can disrupt and damage business operations. Damaged infrastructure also presents its own risks. Fallen power lines may cause electrocution, particularly if part of the power line is in standing water. Water-damaged electrical equipment poses the risk of fire or electrocution if not properly repaired before re-energization. This damaged infrastructure also increases costs to utilities and consumers. Severe weather is expected to increase the cost of electrical transmission, distribution, and repair costs across Massachusetts. Impacts are highest in Middlesex County, where lighting storms and other extreme weather-related events are forecasted to be more severe. Anticipated increases in electricity costs due to increased repair costs may disproportionately impact low-income populations.

Public Safety

Public safety assets and services may experience damage, disruption, or loss due to severe weather events. The ability of personnel to provide public safety services to the community may be impaired due to power outages, roadway closures, and communication disruptions. Additionally, public safety personnel may be exposed to risks during severe weather events that result in fatalities and injuries. The ability of public safety personnel to safely carry out their duties during an extreme weather event should be considered when assessing the resilience of emergency response and public safety buildings, equipment, and fleets.

Transportation

Severe weather events can result in roads, bridges, cargo and passenger rail, and public transit being disrupted or damaged by falling trees, landslides, downed power and communication lines, flooding, or debris. During severe weather events, air and water travel is often cancelled or delayed for both passengers and cargo. Disruption and damage to transportation infrastructure can impact emergency response and evacuation and repairs to energy and communication infrastructure; it can also leave areas of the Commonwealth with limited transportation options isolated for hours or days.

Water Infrastructure

Severe weather events, including hail, extreme precipitation, wind, and flooding, mobilize debris, contaminants, and bacteria. These events can overwhelm and damage water infrastructure, including water supply, aquifers, stormwater, dams, and wastewater systems. Extreme precipitation and debris can overwhelm these systems with too much flow, and downed trees, poles, or debris can create blockage. Water systems that rely on power, such as pumps and wastewater systems, can lose function if power supply is disrupted, leading to flooding or contamination of water supply sources.

5.12.2.4.4 Natural Environment

Severe weather events can result in significant damage to forests. While impacts to the natural environment are often localized, downed trees, defoliated forest canopies, and structural changes within ecosystems can damage ecological health and destabilize food webs. Direct damage to plant species can include uprooting or destruction of trees and an increased threat of wildfire in areas with tree debris. High winds can also erode soil, which can damage both the ecosystem from which soil is removed and the ecosystem in which the sediment is ultimately deposited. Environmental impacts of extreme precipitation events are discussed in depth in Section 5.8 (Flooding from Precipitation) and often include soil erosion, the growth of excess fungus or bacteria, and direct impacts to wildlife. For example, research by the Butterfly Conservation Foundation shows that above-average rainfall events have prevented butterflies from successfully completing their mating rituals, causing population numbers to decline. Secondary hazards of extreme precipitation events include from harmful algal blooms and their associated neurotoxins and exposure to extreme changes in temperature (heat and cold). Public drinking water reservoirs may also be damaged by widespread winds uprooting watershed forests and creating serious water quality disturbances.

Lightning tends to strike tall, free-standing structures such as trees, which can result in tree damage and fires. The intense heat from lightning vaporizes the water inside of a tree, which can blow apart the tree in a small explosion. If lightning strikes a dead tree or a vegetated area experiencing dry conditions, it can quickly start a wildfire. This can happen even when lightning is accompanied by rain, as the dry air below a storm front can cause rain to evaporate quickly as it falls.

5.12.2.4.5 Economy

Severe weather events have a range of impacts on the economy, including direct damage to and loss of buildings and the cost of repairing or replacing them. Additional economic impacts may include loss of business functions, water supply system damage, inventory damage, relocation costs, wage losses, and rental losses.

Increasing extreme weather events, changes in precipitation patterns, and changes in temperature will also impact agricultural productivity. Extreme precipitation events and thunderstorms can flood fields, which results in damage and loss of crops. High winds can damage or destroy crops, reducing overall yield. Heat and pressure from lightning strikes can cause localized damage to crops and electrocute livestock. Fires started by lightning can destroy large portions of fields and orchards. Damaged equipment and reduced crop yields will reduce revenue, which may result in fewer job opportunities in the agricultural sector. Cranberries and apples, and the cultural events surrounding these crops, are an important part of Massachusetts’ identity and culture, which could also be impacted as yields change.

According to the NOAA Storms Database, between 2002 and 2022, lightning was responsible for $20.4 million dollars in damage in Massachusetts (NOAA, 2022). While most events resulted in a few thousand dollars’ worth of damage, the larger losses are associated with fires that destroyed homes and/or crops. Lightning can damage buildings; cause electrical, forest, and/or wildfires; and damage infrastructure, such as power transmission lines and communication towers.

Removing debris and repairing the buildings, infrastructure, and utilities that businesses and industries rely on can be extremely costly. Disruption and damage to transportation infrastructure due to secondary hazards such as landslides, debris, or flooding can disrupt the travel of commuters, deliveries, and customers, as well as the shipment of goods and other commerce. Large, prolonged storms can have significant economic impacts on an entire region.

Chapter 5. Risk Assessment and Hazard Analysis

Severe Winter Storms

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5.13 Severe Winter Storms

5.13.1 Severe Winter Storm Problem Statement

Massachusetts is vulnerable to severe winter storms and is highly likely to continue experiencing them at least once a year. It is uncertain how much climate change will change the frequency of winter storms, but it is likely that the intensity will increase. Winter storms affect different parts of the Commonwealth differently. Higher elevations in western and central Massachusetts experience more snow accumulation and ice storms. Eastern-facing coastal areas such as Salisbury Beach, Revere, Nahant, Scituate, and Marshfield are most susceptible to winter storm damage due to the combination of high winds, waves, and tidal surge. Sea level rise will increase the amount of flooding and damage sustained from winter storms in all coastal areas of the Commonwealth, with increases in duration, intensity, depth, and area exposed to flooding. Winter storms often cause power outages and block roads, which can isolate rural populations and reduce access to emergency services and power and communication service during a high-risk event. These impacts are especially pronounced in rural communities in western and central Massachusetts. Severe winter storms can damage natural assets such as salt marshes and forests. Significant and repeated damage may alter natural landscapes and the species makeup of ecosystems.

5.13.2 Severe Winter Storm Risk Assessment

5.13.2.1 General Background

Severe winter storms include ice storms, nor'easters, heavy snow, blowing snow, and other extreme forms of winter precipitation. Severe winter storms are a type of extratropical cyclone, which are formed when a cold mass of air meets with a warm mass of air and creates a front. Extratropical cyclones have cold air at their core and can be accompanied by either weak or strong winds.

Blizzards

A blizzard is a winter snowstorm with sustained or frequent wind gusts of up to 35 miles per hour or more, accompanied by falling or blowing snow that reduces visibility to or below a quarter of a mile (NWS, n.d.-a). These conditions must be the predominant characteristics over a three-hour period to classify as a blizzard. Extremely cold temperatures are often associated with blizzard conditions but are not a formal part of the definition. Although extremely cold temperatures are not necessary, the likelihood of a blizzard occurring increases significantly with temperatures below 20ºF. A severe blizzard is categorized as having temperatures near or below 10°F, winds exceeding 45 miles per hour, and visibility reduced by snow to near zero.

Storm systems powerful enough to cause blizzards usually form when the jet stream dips far to the south, allowing cold air from the north to clash with warm air from the south. Blizzard conditions often develop on the northwest side of an intense storm system. The difference between the lower pressure and the higher pressure to the west creates a tight pressure gradient, resulting in strong winds and extreme conditions due to the blowing snow. Blowing snow is wind-driven snow that reduces visibility to 6 miles or less, causing significant drifting. Blowing snow may be snow that is falling and/or loose snow on the ground picked up by the wind.

Ice Storms

Freezing rain is defined by liquid rain falling and freezing on contact with cold objects, creating ice buildups. While even a trace of ice can cause significant impacts, an ice storm, by the National Weather Service's definition, is a half inch of ice accretion across any location. Lesser icing events can be incorporated into either Winter Storm Warnings or Winter Weather Advisories, whenever icy conditions may lead to dangerous walking or driving conditions or can result in damage to power lines and trees.

Ice pellets are another form of freezing precipitation, formed when snowflakes fall through a shallow warmer layer of air above the surface. As they fall through the warm layer, they melt. Sleet is the result of those raindrops refreezing back into snow before they reach the surface. As a result, the observed precipitation mimics a pellet of ice. The difference between sleet and hail is that sleet is a wintertime phenomenon, whereas hail falls from convective clouds (usually thunderstorms), and often occurs during the warmer spring and summer months.

Nor'easters

A nor'easter is a storm that occurs along the East Coast of North America with winds from the northeast (NWS, n.d.-b). A nor'easter is characterized by a large counterclockwise wind circulation around a low-pressure center that often results in heavy snow or rain and high winds. A nor'easter gets its name from its continuously strong northeasterly winds blowing in from the ocean ahead of the storm and over the coastal areas.

Nor'easters can occur at any time of year, though they most often occur between September and April (NWS, n.d.-b). These weather events produce heavy snow, rain, and oversized waves that crash onto Atlantic beaches, often causing beach erosion and damage to coastal infrastructure, buildings, and habitats. More detail on the risks associated with Coastal Erosion (Section 5.4) and Coastal Flooding (Section 5.5) is available. These storms occur most often in late fall and early winter. The storm radius of a nor'easter is often as much as 100 miles across, and nor'easters can last between 12 hours and 3 days, affecting multiple tide cycles and causing extended heavy precipitation in an area. Sustained wind speeds of 20 to 40 miles per hour are common during a nor'easter, with short-term wind speeds gusting up to 50 to 60 miles per hour. Nor'easters are commonly accompanied by a storm surge equal to or greater than 2 feet.

Nor'easters begin as strong areas of low pressure either in the Gulf of Mexico or off the East Coast in the Atlantic Ocean. The low-pressure system will move either up the East Coast, into New England and the Atlantic provinces of Canada, or out to sea. A strong hurricane often causes more severe damage than a nor'easter, but historically Massachusetts has suffered more damage from nor'easters because of the greater frequency of these coastal storms (one to two per year, on average). Nor'easters can directly affect Massachusetts for a longer period than tropical storms and hurricanes—the duration of high storm surge and winds in a hurricane range from six to 12 hours, while a nor'easter can last much longer.

5.13.2.2 Hazard Description

Severe winter storms include events such as blizzards, ice storms, nor'easters, heavy and blowing snow, and extratropical cyclones.

5.13.2.2.1 Location

Although the entire Commonwealth may be considered at risk from the hazard of severe winter storms, the risks differ across Massachusetts, with higher snow accumulations and more ice storms occurring at high elevations in western and central Massachusetts and ocean moisture enhancing snowfall along the coast.

While nor'easters may affect the entire Commonwealth, the 78 coastal communities are especially vulnerable to their damaging impacts along more than 1,500 miles of varied coastline. As coastal development increases and sea level rises, nor'easters will lead to more substantial damage. Like hurricane events, the coastal areas are more susceptible to damage than other areas of the Commonwealth due to the combination of high winds, waves, and storm surge, as well as the higher density and diversity of development sited along the coast. Nor'easters are more likely to severely affect the eastern and northern facing areas of Massachusetts, including Salisbury Beach, Revere, Nahant, Scituate, Marshfield, the shorelines of the outer cape, Cape Cod Bay, and the north sides of Nantucket and Martha's Vineyard (Berman & Nemunaitis-Monroe, 2012). This differs from tropical cyclones, whose winds from the south would more strongly affect Buzzard's Bay and the south sides of the islands.

Nor'easters can bring heavy snow, which can paralyze inland cities or regions, limiting or eliminating access to some areas and disrupting power and communications. Inland areas, especially those in floodplains, low-lying areas, or development areas on historic wetlands, are at risk for flooding. Wind damage can occur throughout the Commonwealth.

5.13.2.2.2 Previous Occurences and Frequency

Snow and other winter precipitation occur often across the Commonwealth, but average annual snowfall varies greatly by location. The Boston metro area averaged 48.8 inches of snowfall a year from 2001 to 2022, while Worcester averaged 73.6 inches of snowfall a year and areas on Cape Cod averaged significantly less, at 25.3 inches a year in the same period (NWS, 2023).

Blizzards

Between 2005 and 2022, the National Oceanic and Atmospheric Administration's (NOAA's) National Climatic Data Center (NCDC) reported 61 blizzard events over 15 days. Since the NCDC reports events by county, several events can be reported to one storm system. Property damage due to the storms was reported for 11 of those days. All blizzards occurred between mid-December and mid-March, with most in January and early February.

Ice Storms

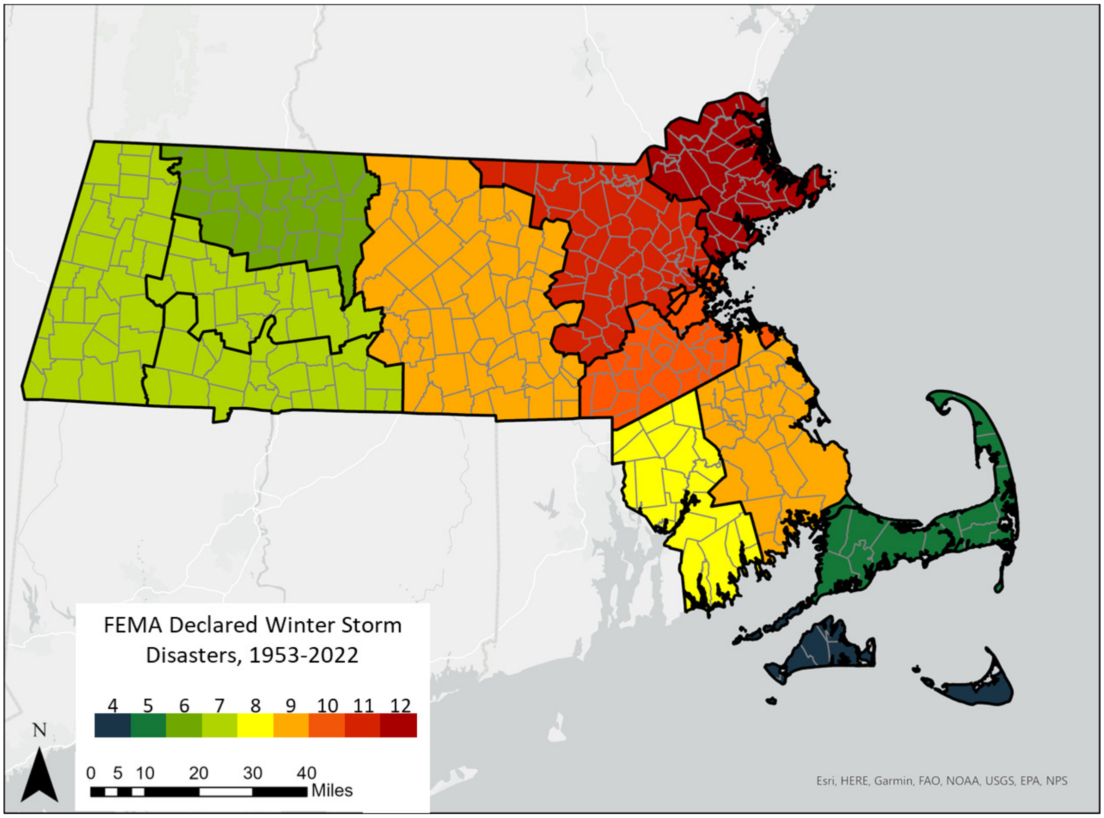
From 1998 to 2022, NCDC reported 33 ice storm events over eight days, all between December and February. Ice storms of lesser magnitudes affect the Commonwealth at least annually.

Nor'easters

Between 1973 and 2022, 112 notable winter storms occurred, 14 of which were classified as "major" or "greater" in the Northeast on the Regional Snowfall Index (RSI). These historical events are listed and described in Appendix 5.A.

Severe Winter Weather Events

There is significant overlap between winter weather disasters and other types of disasters, particularly flooding. To reduce redundancy, all FEMA declarations are listed in Appendix 5.A. For an overview of the distribution of this hazard, Figure 5.13-1 depicts the number of winter storm disaster declarations (incident type: severe ice storm or snowstorm) by county between 1953 and 2022.



Source: FEMA (2023).

Figure 5.13-1. FEMA winter storm–related declared disasters by county, 1953 to 2022.

5.13.2.2.3Severity/Intensity

Regional Snowfall Index

Snowfall is a component of multiple hazards, including nor'easters and other severe winter storms. Since 2005, the Regional Snowfall Index (RSI) has become the descriptor of choice for measuring winter events that affect the eastern two-thirds of the U.S. The RSI ranks snowstorm impacts on a scale from 1 to 5, as shown in Table 5.13-1. It is like the Fujita scale for tornadoes or the Saffir-Simpson scale for hurricanes, except that it includes an additional variable: population. The RSI is based on the spatial extent of the storm, the amount of snowfall, and the population affected (NOAA NCEI, n.d.).

The RSI is a regional index. Each of the six climate regions in the eastern two-thirds of the nation (as identified by the NOAA National Centers for Environmental Information) has a separate index, calculated according to region-specific parameters and thresholds. The RSI is important because, with it, a storm event and its societal impacts can be assessed in the context of a region's historical events. Snowfall thresholds in Massachusetts (in the Northeast region) are 4, 10, 20, and 30 inches of snowfall, while thresholds in the Southeast U.S. are 2, 5, 10, and 15 inches. Based on the RSI, the number of high-impact snowstorms (categorized as “notable” or higher) occurred at a rate of almost three per year over the last 50 years, although there is significant interannual variability in the frequency and severity of winter storms.

Table 5.13-1. Regional Snowfall Index Categories, Corresponding RSI Values, and Description

Category	RSI Value	Northeast Threshold	Description	Number of Events in New England (1973–2022)
1	1–3	Less than 4 inches	Notable	75
2	3–6	4–10 inches	Significant	23
3	6–10	10–20 inches	Major	7
4	10–18	20–30 inches	Crippling	4
5	18.0+	30+ inches	Extreme	3

Source: National Centers for Environmental Information (n.d.).

The magnitude or severity of a severe winter storm’s impacts, including a nor’easter, depends on several factors, like a region’s climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, time of occurrence during the day (e.g., weekday versus weekend), and time of season. Depending on the scale used to describe a storm, severity can also be defined in part by its social impacts, such as the number of exposed people, infrastructure damage or disruption, environmental damage, and/or the extent of economic activity affected. Communities in the Berkshires view ice storms and blizzards as part of life in western Massachusetts and expect to experience several snowstorms and a few nor’easters each year (City of North Adams, 2021).

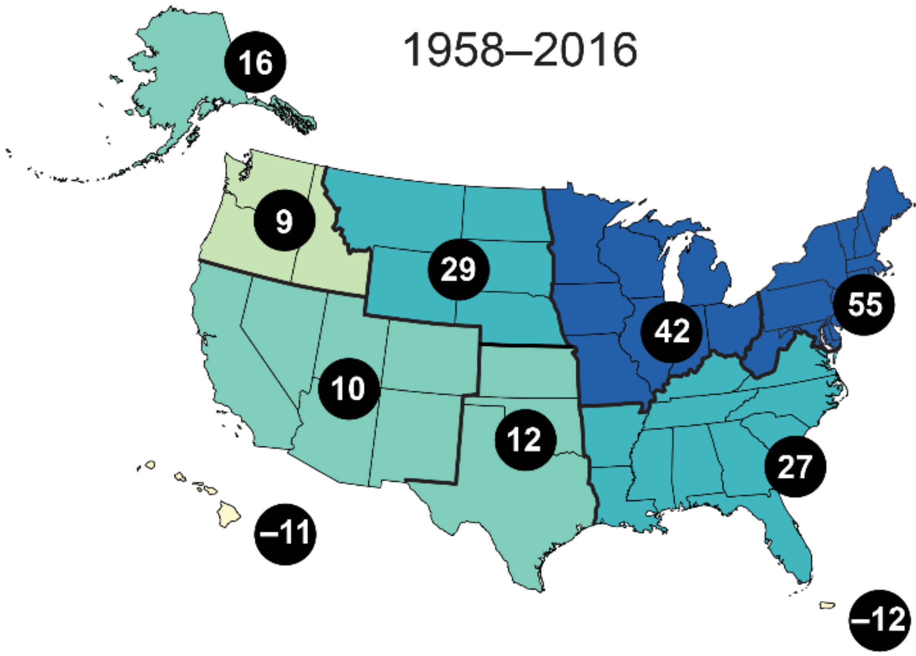
Winter storms also bring flooding to coastal areas. The severity of flooding from nor’easters and other winter storms depends on the time of occurrence relative to the lunar tide cycles (spring or neap tides) and the tide stage the maximum storm surge occurs at (high tide or low tide). For example, a nor’easter in early January 2018 coincided with the third highest tide of the 2018 storm season and the peak storm surge occurred at almost the same time as the high tide. This resulted in the third highest water level ever recorded in Boston, severely flooding areas for multiple high tide cycles (Douglas & Kirshen, 2022). On Cape Cod, this storm prompted evacuations and flooded major roadways, including Route 28, a critical lifeline for the community (Cape Cod Commission, 2018).

Potential Effects of Climate Change on Severe Winter Storms

As stated in the previous subsection, Massachusetts already experiences notable winter weather events and nor’easters every year. Therefore, it is virtually certain Massachusetts will continue to experience severe winter storms at least annually. However, it is unclear how much the frequency of these storms will change in Massachusetts over the next few decades due to climate change. Extreme weather events—including extreme precipitation events—are anticipated to occur more often as climate change occurs. Rising temperatures mean that more of this precipitation is likely to fall as rain rather than snow, However, there has been little information on the climate trends of extratropical cyclones such as nor’easters. The Greater Boston Research Advisory Group found little evidence to indicate that nor’easters and other extratropical storms will change in frequency in the region (Douglas & Kirshen, 2022). However, historical data show that the frequency of extreme snowstorms in the U.S. doubled between the first half of the 20th century and the second.

As temperatures throughout the year increase, it is possible that nor’easter events may become more concentrated in the coldest winter months when atmospheric temperatures are still low enough to result in snowfall rather than rain. Whether events are classified as nor’easters or not, storm surge impacts from all winter storms are likely to increase significantly because of sea level rise and coastal erosion.

While evidence for the frequency is not clear, climate change is likely to increase the intensity of winter storms. Increased sea surface temperature in the Atlantic Ocean due to climate change will cause air moving north over the ocean to hold more moisture. As a result, when these fronts meet cold air systems moving from the north, an even greater amount of precipitation than normal can be anticipated to fall on Massachusetts. Although no one storm can be linked directly to climate change, the severity of rain and snow events has increased dramatically in recent years. As shown in Figure 5.13-2, the amount of precipitation released by the heaviest storms in the Northeast has increased by 55 percent since 1958 (U.S. Global Change Research Program, 2018). Other research has found that increasing water temperatures and reduced sea ice extent in the Arctic are changing atmospheric circulation patterns that favor the development of winter storms in the eastern U.S. by sending more cold air to the Eastern Seaboard (Rawlins, 2022).



Source: U.S. Global Change Research Program (2018).

Figure 5.13-2. Map of observed changes in heavy precipitation.

5.13.2.2.4Warning Time

Meteorologists can often predict the likelihood of a severe winter storm or nor'easter, which allows for several days of warning time. NOAA's National Weather Service monitors potential storm events and provides extensive forecasts and information several days before a storm to help prepare for the incident. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some winter storms may develop more quickly and have only a few hours of warning time. Even with several days of warning time, there are limitations on what can be included in preparations, education, and outreach if these actions are not accompanied by longer term, structural changes to make infrastructure, utilities, buildings, communities, and government services more resilient to severe winter storms. Implementing mitigation and adaptation actions that focus on reducing the population at risk and limiting the damage and disruption to infrastructure and utilities would make the Commonwealth more resilient regardless of warning time.

5.13.2.2.5Local Context for Hazard and Vulnerability: A Review of Local Plans

The local hazard mitigation plans reviewed characterize severe winter storms, including nor'easters, as town or city-wide hazards. Winter storms are a regular occurrence in Massachusetts, and some local hazard mitigation plans note that most snow and ice storms in the region cause more inconvenience than they do property damage. However, all plans reviewed identify the potential for severe damage from these events. Damage to power infrastructure and impassable roads are impacts of major concern. Power outages and blocked roads can have several cascading impacts affecting evacuation, access to emergency services, and other public safety issues. Most plans draw primarily on the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP) for the characterization and vulnerability of this hazard. Table 5.13-2 provides some highlights of the plans reviewed.

Table 5.13-2. Highlight of Local Plans and Municipal Vulnerability Preparedness Program Planning Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Auburn Hazard Mitigation Plan Update, 2018	Storms occur regionally, and the entire town is at high risk.	Town faces limited impact (less than 10% of total [town] property [exposed to] damage).	Total estimated potential loss of $9,655,918 to residential structures, assuming 5% damage to 10% of structures.
2021 Hazard Mitigation Plan: Plymouth, Massachusetts, 2021	The entire town is at high risk for extensive damages at a communitywide scale.	Damage to utility and power lines, impassable roads, and flooding from snowmelt are major concerns.	*Not provided.*
Town of Carlisle Hazard Mitigation Plan 2021 Update, November 2021	The entire town is at risk of impacts from nor'easters and winter storms. Roads in hilly parts of town experience issues with icing and snow, impeding travel in certain areas.	Impassable streets, snow-covered sidewalks, and refreezing snowmelt cause dangerous road and walking conditions.	*Not provided.*
Town of Erving Municipal Vulnerability Preparedness Resiliency Plan and Town of Erving Hazard Mitigation Plan, 2019	The entire town is at risk of extreme winter weather. The town's two rail lines, which transport hazardous material, are a top concern.	Elderly residents, residents without landlines and in areas with poor cell service, and residents with private wells are more vulnerable to winter storm impacts.	Total estimated damage if 10% of all buildings are damaged is $54,941,253.

5.13.2.3 Secondary Hazards

Secondary hazards that can occur because of winter storms include sudden and severe drops in temperature. Winter storms can also cause flooding and the destabilization of hillsides as snow or ice melts and begins to run off. Other secondary hazards associated with severe winter storms include coastal erosion, flooding, levee or dam failure, increased risk of landslides or other land movement, the release of hazardous materials, increased risk of mold or mildew, and environmental damage.

5.13.2.4 Exposure and Vulnerability

Many severe winter storms share many characteristics with hurricane events. Both types of events can bring high winds and surge inundation that results in similar impacts on the population, built environment, and economy. Table 5.13-3 summarizes the priority impacts and high-consequence vulnerabilities related to severe winter storms using themes identified in the 2023 MA SHMCAP Risk Assessment and the 2022 Massachusetts Climate Change Assessment (MA Climate Assessment).

Table 5.13-3. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Severe Winter Weather

Sector	Priority Impacts and High-Consequence Vulnerabilities
Human	• Emergency service response delays and evacuation disruptions **(most urgent)** • Health effects from degraded air quality **(most urgent)** • Health effects from extreme storms and power outages • Increase in mental health stressors • Damage to cultural resources
Infrastructure	• Damage to inland buildings **(most urgent)** • Damage to electric transmission and utility distribution infrastructure **(most urgent)** • Damage to rails and loss of rail/transit service **(most urgent)** • Damage to coastal buildings and ports • Damage to roads and loss of road service • Loss of energy production and resources
Natural environment	• Freshwater ecosystem degradation **(most urgent)** • Coastal wetland degradation **(most urgent)** • Coastal erosion
Governance	• Reduction in state and municipal revenues **(most urgent)** • Increase in costs of responding to climate migration **(most urgent)** • Increase in demand for state and municipal government services **(most urgent)** • Damage to coastal state and municipal buildings and land

Sector	Priority Impacts and High-Consequence Vulnerabilities
Economy	• Reduced ability to work **(most urgent)** • Decrease in marine fishery and aquaculture productivity **(most urgent)** • Reduced availability of affordable housing **(most urgent)** • Economic losses from commercial structure damage and business interruptions • Damage to tourist attractions and recreation amenities

5.13.2.4.1 Human

According to the NOAA National Severe Storms Laboratory, every year, winter weather indirectly kills hundreds of people in the U.S., primarily through automobile accidents, overexertion, and exposure. Winter storms are often accompanied by strong winds, creating blizzard conditions with blinding wind-driven snow, drifting snow, and extreme cold temperatures with dangerous wind chill. These storms are considered deceptive killers because most deaths or injuries are not attributed directly to the storm. Injuries and deaths may occur due to traffic accidents on icy roads, heart attacks while shoveling snow, or hypothermia from prolonged exposure to cold.

The Northeast States Emergency Consortium developed regional hazard maps for snowfall for the Northeast, dividing snow areas by the number of days they typically experience 5 inches or more of snow each year. The highest snow areas in Massachusetts experience 4.5 to 7.4 days of more than 5 inches of snow each year. Five counties in Massachusetts have areas with more than 4.5 days of heavy snow. Worcester County has the highest number of people living in areas that experience heavy snow. See Figure 5.13-3 for a map of high-snow areas in Massachusetts.

Table 5.13-4. Population Living in High-Snow Areas

County	Days with 5 or More Inches of Snow			
	< 0.5	0.5 - 2.4	2.5 - 4.4	4.5 - 7.4
Barnstable	199,354	—	—	—
Berkshire	24,941	71,085	28,457	3,485
Bristol	356,748	183,979	—	—
Dukes	12,915	—	—	—
Essex	264,810	333,151	150,577	—
Franklin	53,509	14,144	9,304	639
Hampden	421,764	42,969	2,719	396
Hampshire	140,183	14,689	7,210	696
Middlesex	215,241	1,374,533	8,724	—
Nantucket	10,350	—	—	—

County	Days with 5 or More Inches of Snow			
	< 0.5	0.5 - 2.4	2.5 - 4.4	4.5 - 7.4
Norfolk	358,155	323,790	—	—
Plymouth	288,461	191,830	—	—
Suffolk	328,401	442,837	—	—
Worcester	100,508	554,652	160,787	8,782
Total	**2,775,340**	**3,547,659**	**367,778**	**13,998**

Source: ERG analysis using 2010 data from the Northeast States Emergency Consortium and 2020 U.S. Census data.

Heavy snow can immobilize a region and paralyze a city by shutting down air and rail transportation, stopping the flow of supplies, and disrupting medical and emergency services. Snow accumulation can cause buildings to collapse and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and unprotected livestock may be lost. In the mountains, heavy snow can lead to avalanches. Storms near the coast can cause coastal flooding and beach erosion as well as sink ships at sea.

The impact of severe winter storms on life, health, and safety is dependent upon several factors, including the location and severity of the event; the mitigation measures in place to reduce damage, disruption, and loss; and the length of warning time provided to responders and residents. Residents may be displaced or require temporary to long-term housing due to damage or loss of homes or disruption to services such as power, communications, and transportation. High winds and extreme weather can cause downed trees and damage buildings, and debris carried by high winds can lead to injury or loss of life.

Coastal populations are also exposed to storm surge and flooding caused by severe winter storms. There are several ways to define a “coastal” area in Massachusetts. For example, the Massachusetts Office of Coastal Zone Management serves 78 coastal communities that fall within its defined coastal zone boundary. The MA Climate Assessment defined coastal regions as Boston Harbor; North and South Shores; and Cape, Islands, and South Coast. The population in these regions makes up nearly 43 percent of the Commonwealth’s total population (3 million out of 7 million).

This analysis uses the framework defined by NOAA’s Office for Coastal Management to discuss human populations in coastal counties. The framework identifies coastal counties as those “that are directly adjacent to the open ocean, major estuaries, and the Great Lakes, which due to their proximity to these waters, bear a great proportion of the full range of effects from coastal hazards and host the majority of economic production associated with coastal and ocean resources” (NOAA Office for Coastal Management, n.d., p. 1). Using NOAA’s definition, eight out of the Commonwealth’s 14 counties are coastal counties, and 74 percent of the total population (5.2 million out of 7.0 million) resides in a coastal county (Table 5.13-5). Following this approach, this Risk Assessment analysis for severe winter weather is conducted at the county level.

Population Projections

Populations are estimated to grow the most in the eastern half of Massachusetts, except for Barnstable County, which is projected to lose nearly 18 percent of its 2020 population (see Table 5.13-5). By 2040, the Boston metropolitan area is expected to experience increases of over 120,000 people each in Suffolk and Middlesex counties. While the reduction in population on Cape Cod will reduce the number of people exposed to storm surge and high winds in Barnstable County, the increase in population in Boston Harbor and the North and South Shores will increase the overall population exposed to coastal effects of severe winter storms, particularly nor'easters. Populations in the western Massachusetts, where severe snow events occur, are projected to remain stable or experience modest increases. Western portions of the Commonwealth are less densely populated but also contain less redundancy in utility, infrastructure, and critical assets. Even a small increase in population may result in a lack of resources available to local authorities to prepare, respond, and adapt to severe winter storms.

Table 5.13-5. Population Projections for Counties in Massachusetts

County	Population 2020	Projection 2030[a]	Projection 2040[a]	Population Change 2020–2040
Barnstable[b]	213,505	199,466	176,007	-17.6%
Berkshire	124,571	128,548	128,063	2.8%
Bristol[b]	563,301	567,277	568,250	0.9%
Dukes[b]	17,430	19,584	19,793	13.6%
Essex[b]	787,038	816,022	827,531	5.1%
Franklin	70,267	70,925	69,477	-1.1%
Hampden	463,986	482,178	490,136	5.6%
Hampshire	161,401	165,099	166,856	3.4%
Middlesex[b]	1,605,899	1,686,641	1,736,669	8.1%
Nantucket[b]	11,212	11,804	12,212	8.9%
Norfolk[b]	703,740	765,912	797,619	13.3%
Plymouth[b]	518,597	534,464	539,424	4.0%
Suffolk[b]	801,162	900,586	950,251	18.6%
Worcester	829,212	876,966	898,111	8.3%
Total Massachusetts	6,871,321	7,225,472	7,380,399	7.4%
Coastal counties	5,221,884	5,501,756	5,627,756	7.8%

Sources: ERG analysis using data from U.S. Census, 2020; projections from UMass Donahue Institute (2018).

[a] Projections are calculated from 2010 Census data.

[b] Notes coastal counties.

Vulnerable and Priority Populations

A population's susceptibility to severe winter weather is based on several factors, including physical and financial ability to prepare for, respond to, and recover from an event. Other factors that affect vulnerability are the location, age and quality of housing and the ability to repair and maintain housing. People over the age of 65, especially if they live alone, are more susceptible to winter hazards due to their increased risk of injury and death from falls, overexertion, and/or hypothermia from attempts to clear snow and ice, as well as injury and death related to power failures. In addition, severe winter weather events can reduce people's ability to access emergency services. Lack of access to emergency services is also a concern for people with limited mobility, transit-dependent people, and people with underlying health conditions. People with limited mobility risk becoming isolated or "snowbound" if they are unable to remove snow from their homes.

Environmental Justice and other priority populations are more vulnerable due to a lack of resources to prepare for, respond to, or recover from a severe winter storm. Residents with low incomes may not have access to safe and stable housing; their housing may be less able to withstand cold temperatures (e.g., homes with poor insulation and heating supply). They may have limited access to supplies and services to allow them to shelter safely in place, such as a continuous source of power, snow removal capabilities, and automobiles that can travel in severe winter conditions. Unhoused populations are at great risk from severe winter weather events and need to be considered when planning for and responding to these events.

People who work or recreate outdoors are vulnerable to severe winter weather, particularly from storms with limited warning time. Utility workers and first responders are vulnerable to severe winter weather because they must respond to downed electrical wires, restore power, and provide emergency services during storms. Rural populations may become isolated by downed trees, blocked roadways from heavy snow falls, and power outages. Individuals with limited English proficiency may not receive adequate warning time to prepare for or evacuate storms. Table 5.13-6 summarizes state agencies' responses to the 2023 MA SHMCAP survey, providing the primary concerns related to the populations they served and the disproportionate impacts from winter storms. The responses to the survey were completed by agency staff and did not go through a formal review process.

Table 5.13-6. State Agency Responses: Primary Concerns About Winter Weather Impacts for Populations Served and Potential Disproportionate Impacts

Category	Examples of Primary Concerns
Populations served	• Injured workers • All residents, businesses, and municipalities • All municipal, campus, hospital, and environmental police and deputy sheriffs • Seafood industry workers

Category	Examples of Primary Concerns
Disproportionate impacts	• Delayed court dates or proceedings and delays in filing of important documentation subject to statutory timeframes • Impacts could be disproportionate to Environmental Justice and other priority populations, such as elderly people • Delayed response and increased need for response from emergency services • Loss of in-person services • Individuals reliant on public transportation. • All socially vulnerable populations are exposed • Communication breakdown to fishermen and aquaculture farmers

Health Impacts

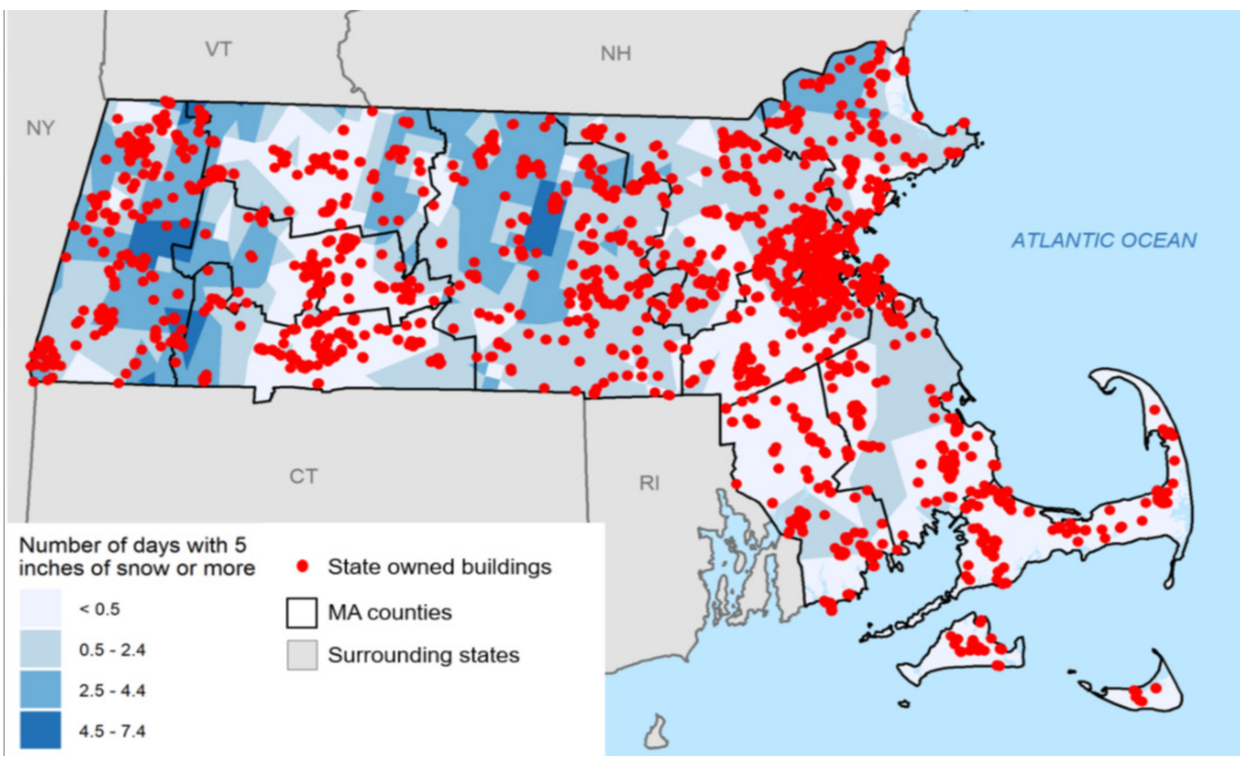
Health impacts from severe winter storms are like those described for other hazards, particularly the extreme temperatures discussed in Section 5.2 (Average/Extreme Temperatures). Cold weather, which is a component of a severe winter storm, increases the risk of hypothermia and frostbite. Exposure to cold conditions can also exacerbate pre-existing respiratory and cardiovascular conditions. Severe winter storms also present other health impacts. Power outages can be life-threatening to people dependent on electricity for life support or who need to access emergency services, as well as those who need it to keep indoor temperatures safe for inhabitants. Individuals may use generators in their homes if power service is disrupted or use the heat systems in their cars if they become trapped by snow. Without proper ventilation, these sources of power can result in carbon monoxide buildup, which can be fatal. Additionally, natural gas-fueled furnaces, water heaters, and clothes driers, and even automobile exhaust pipes, may become blocked by snow and ice, which can lead to carbon monoxide poisoning. Loss of power can also lead to hypothermia when indoor temperatures drop below safe levels. After Hurricane Sandy, there were three times as many cases of cold exposure in New York City than during the same time period in previous years (Fink, 2012). Other health impacts associated with winter storms include increased instances of food contamination and gastrointestinal disease from loss of refrigeration, as well as increased mold and mildew from flooding.

Driving during severe snow and ice conditions also be very dangerous, as roads covered in ice and snow are difficult to navigate safely and drivers can lose control. During and after winter storms, roads may be littered with debris, presenting a danger to drivers. Severe winter storms can also disrupt access to critical assets and services such as hospitals and health centers and disrupt deliveries to elder care and other health facilities.

5.13.2.4.2 Governance

State and local governments assets and services may be damaged or disrupted by freezing temperatures, high winds, flooding, and heavy snow loads. Assets and services in the coastal zone are exposed to flooding from storm surge. The damage caused by severe winter storms can result in increased costs to state and local governments to prepare for, respond to, and recover from events, including repairing damage and restoring services. Using Northeast States Emergency Consortium data for high-snow areas, the map below shows how many days each area experiences high snow levels (defined as greater than 5 inches). The data were overlaid with Massachusetts Division of Capital Asset Management and Maintenance facility data, and the resulting map is shown in Figure 5.13-3. Table 5.13-7 summarizes the number of state-owned buildings in each of the four snow bands and their total replacement value.

A surge inundation zone does not exist to estimate the number of government facilities exposed to this severe winter storm risk. However, the storm surge areas generated by the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model provide a useful proxy; Table 5.9-9 in the Hurricane/Tropical Cyclones section (Section 5.9) depicts the government buildings exposed to storm surge by both hurricanes and nor'easters in SLOSH zones by county.



Sources: Massachusetts Division of Capital Asset Management and Maintenance (2022); 2010 data from the Northeast States Emergency Consortium.

Figure 5.13-3. Map of state-owned buildings in high-snow areas.

Table 5.13-7. State-Owned Buildings in High-Snow Areas

County	Days with 5 Inches or More							
	< 0.5		0.5–2.4		2.5–4.4		4.5–7.4	
	Buildings	Replacement Value	Buildings	Replacement Value	Buildings	Replacement Value	Buildings	Replacement Value
Barnstable	460	$1,270,575,373	—	—	—	—	—	—
Berkshire	43	$514,532,350	247	$635,285,222	275	$106,023,000	46	$5,914,550
Bristol	315	$1,304,185,373	199	$2,273,349,050	—	—	—	—
Dukes	38	$31,569,050	—	—	—	—	—	—
Essex	255	$2,626,910,650	288	$723,351,900	82	$296,379,550	—	—
Franklin	163	$561,820,700	44	$8,934,650	81	$18,034,200	—	—
Hampden	484	$4,224,406,743	67	$242,675,250	32	$9,841,950	2	$2,240,000
Hampshire	587	$8,106,575,244	82	$45,862,682	41	$3,804,652	—	—
Middlesex	172	$761,068,250	1154	$7,516,693,862	24	$55,688,500	—	—
Nantucket	11	$18,341,000	—	—	—	—	—	—
Norfolk	472	$2,435,631,348	303	$766,375,183	—	—	—	—
Plymouth	636	$3,998,435,887	137	$81,709,750	—	—	—	—
Suffolk	359	$5,782,462,448	399	$9,480,163,064	—	—	—	—
Worcester	108	$241,865,600	655	$7,457,029,000	387	$1,900,303,800	41	$40,044,550

Source: Developed by ERG with 2010 data from the Northeast States Emergency Consortium; Massachusetts Division of Capital Asset Management and Maintenance (2022).

Lifelines

Power outages, damage to telecommunications infrastructure, flooding of state buildings, and transit delays and closures all impact state agencies' ability to provide lifeline services to the Commonwealth. There is significant concern regarding severe winter weather's impacts to emergency services and disaster response. The 2023 MA SHMCAP survey of state agencies asked for primary concerns and mitigation actions related to severe winter weather events; the agencies' responses are summarized in Table 5.13-8. The responses to the survey were completed by agency staff and did not go through a formal review process.

The services needed to prepare for, respond to, and recover from severe winter storms place demands on government resources; these demands will increase as these events intensify due to climate change. These resources include those needed to support the communities and assets most at risk, including Environmental Justice and other priority populations, small businesses, infrastructure, and public service and emergency responders. Increased costs to the Commonwealth include the cost of repairing storm damage, operating costs for increased emergency response, road repair costs from increased freeze-thaw cycles each winter, food security support costs, and MassHealth support costs. The increased demand may cause strain on smaller municipalities with limited resources.

Table 5.13-8. State Agency Responses: Primary Concerns About Winter Storms' Impact on Services, with Suggested Improvements

Category	Primary Concerns
Services provided	• Adjudication of disputed workers' compensation claims • Hearings and victim services • Internet and access to information • 911 services • Police officer training • Emergency response and emergency responders • Agency audits and background check services • Firefighter training; fire and explosion investigation; fire code compliance, inspections, and enforcement • Career center services • Transportation • Emergency services coordination at the federal, state, and local levels, including situational awareness and disaster recovery services • Access to health benefits, member communications, and billing • Purification plant accessibility • Communication with fishers

Category	Primary Concerns
Updates, improvements, or enhancements to address required concerns	• Conduct all proceedings virtually • Added a 911 data center outside of New England • Pivot to remote learning • Work with partner agencies to meet potential need for increased resources/staffing • Stage alternate locations, personnel, and equipment across the Commonwealth • Ensure budgets support increased frequency of events and service requests • Improve severe weather emergency response plans • Improve storm tracking and flood predictions to adequately deploy flood protections • Bolster existing storm-preparedness activities to ensure employee readiness • Utilize the System-Wide Tunnel Flood Mitigation Program to address the coastal flood risk hurricanes and nor'easters pose to tunnels • Improve communication and coordination with other agencies • Build out web-based portal services for people to increase communication abilities (e.g., text communications) • Identify sources of backup power generators to power heating systems

5.13.2.4.3 Infrastructure

All infrastructure, utilities, and other elements of the built environment in the Commonwealth are exposed to the severe winter weather hazard. Structural damage to facilities often includes damage to roofs and building frames. Heavy snowfall and accumulation can lead to roof collapse, which damages structures, poses risks to public health and safety, and results in damage and loss of contents and functions. High winds can result in snow drifts on roofs, creating uneven and dangerous snow loads. Uneven and heavy loads can be a particular problem for older homes that are not designed for heavy loads. While there are usually few to no roof collapses each year due to snow, higher-than-average snowstorm frequency with no melting periods in February 2015 led to over 160 roof collapses across Massachusetts (Schulz, 2015). Damaged facilities may not be fully operational if workers are unable to travel to ensure continuity of operations before and after a severe winter event.

Table 5.13-9 summarizes the number of critical facilities in each of the four snow bands by county, and Table 5.13-10 describes the number of exposed state facilities by type. Critical facilities are defined as buildings necessary for public health and safety and buildings that may result in safety and emergency response challenges due to high occupancy or sensitive populations. Worcester County contains the highest number of critical facilities in the highest snow band.

Table 5.13-9. Number of Critical Facilities in High-Snow Areas by County

County	Days with 5 Inches or More of Snow			
	< 0.5	0.5 - 2.4	2.5 - 4.4	4.5 - 7.4
Barnstable	161	0	0	0
Berkshire	21	74	58	17
Bristol	99	55	0	0
Dukes	9	0	0	0
Essex	74	70	17	0
Franklin	30	10	28	0
Hampden	153	30	10	1
Hampshire	263	28	9	0
Middlesex	58	329	13	0
Nantucket	7	0	0	0
Norfolk	198	77	0	0
Plymouth	225	44	0	0
Suffolk	67	83	0	0
Worcester	37	215	131	15
Total	**1402**	**1015**	**266**	**33**

Source: ERG analysis using 2010 data from the Northeast States Emergency Consortium; Massachusetts Division of Capital Asset Management and Maintenance (2022).

A map of the possible inundation zone resulting from the storm surge brought on by a nor'easter is not currently available to estimate the number of critical facilities that may be exposed to this hazard. However, the storm surge areas generated by the SLOSH model provide a useful proxy. Table 5.9-10 and Table 5.9-11 in Section 5.9 (Hurricanes/Tropical Cyclones) depict the number and count of critical facilities exposed to storm surge by both hurricanes and nor'easters in SLOSH zones.

Table 5.13-10. Table of Critical Facilities in Heavy Snow Zones by Facility Type

Facility Type	Days with 5 Inches or More of Snow			
	< 0.5	0.5–2.4	2.5–4.4	4.5–7.4
Administration	77	84	11	2
Animal services	3	2	5	0
Cold storage	9	2	2	0
Communications	33	17	8	2
Corrections	217	104	31	0
Education	81	36	4	0

Facility Type	Days with 5 Inches or More of Snow			
	< 0.5	0.5–2.4	2.5–4.4	4.5–7.4
Energy facilities	103	89	24	0
Fire facilities	32	22	9	2
Health care	58	37	1	0
Laboratories and research	10	10	0	0
Maritime	12	39	4	1
Military facilities	43	32	6	0
Parks and recreation	35	34	24	4
Police facilities	20	20	2	0
Residential	383	243	67	17
Social services	45	43	5	1
Stadium	4	1	0	0
Transportation	22	23	7	0
Waste management	50	38	9	0
Water resources	165	139	47	4

Source: ERG analysis using 2010 data from the Northeast States Emergency Consortium; Massachusetts Division of Capital Asset Management and Maintenance (2022).

Coastal buildings and ports are vulnerable to storm surge and high winds from nor'easters, which will be exacerbated by sea level rise and coastal erosion. The Boston Harbor region currently experiences about 55 percent of the average annual statewide impact from coastal flooding, and projections show that damages from coastal flooding could increase faster in the Boston Harbor region than in other areas due to projected sea level rise and the existing development footprint (Commonwealth of Massachusetts, 2022). While this analysis described above includes coastal flooding from hazards outside of winter weather, it can be used as a proxy to identify exposure to storm surge effects of winter storms. Damages to ports and marinas can also result in disruption of the industries that rely on them, including commercial fishing, cargo and goods movement, port operations, and marine transportation.

Based on results from recent published papers, current annual damages from coastal windstorms to structures and public infrastructure could approach $500 million, but with large variations from year to year (Dinan, 2017; Marsooli et al., 2019). Because of changes in storm activity attributed to climate change, wind damage could increase by up to fourfold by the end of the century. Wind damage from storms also extends beyond the coastal zone, with the highest expected damages in Middlesex County, followed by Suffolk County.

Agriculture

Severe winter weather can lead to flooding in low-lying agricultural areas, damaging crops and equipment. Ice that accumulates on branches in orchards and forests can damage trees, while the combination of ice and wind can fell trees. Storms that occur in spring can delay planting schedules. Frost that occurs after warmer periods in spring can cause cold weather dieback and damage new growth. These impacts to all plant species, including forests and crops, can reduce overall yield and revenue.

Energy

Severe weather can cause power outages during heavy snow and strong wind events, damaging transmission lines and poles and affecting large parts of the population. For example, in January 2022, strong winds from a nor'easter left over 88,000 people without access to power (Hanna et al., 2022). Addressing storm damage takes a substantial amount of resources. National Grid reported that almost 4,000 personnel in Massachusetts and Rhode Island responded to the damage and made repairs because of the January 2022 storm. Severe ice events can also take down transmission and distribution lines (National Grid, 2022). Severe winter weather can also impair a utility's ability to rapidly repair and recover the system. Damaged energy infrastructure and resulting power outages can have cascading and compounding effects if backup systems are not in place. Additionally, increased demand for services during severe winter weather events can strain utility and power systems and require utilities to reallocate service when demand begins to reach available supply.

Public Safety

Public safety buildings may experience direct loss and damage from downed trees, heavy snowfall, high winds, and flooding. Fully functional critical facilities, such as police, fire, and medical facilities, are essential for response during and after a winter storm event. Because power and communication disruptions often occur during severe winter storms, backup power and fuel storage is important for critical facilities and infrastructure. Emergency responders' ability to respond to calls may be impaired by heavy snowfall, icy roads, and downed trees; state agencies identified this as a primary concern.

These impacts can affect public health in several ways. Loss of electricity and communications can increase medical emergencies from spoiled medications or if medical equipment is unable to function. If outages are extended, they may overburden hospitals and emergency shelters as people without access to their medical equipment or medications seek care. The debris and damage from winter storms can temporarily block roads, which prevents or delays emergency responders from reaching those in need of assistance and prevents evacuations. See Section 5.5 (Coastal Flooding) for more information on the evacuation impacts of coastal flooding. Severe winter storms can also disrupt water and sewer utilities, which poses public health risks from sewage overflow and the loss of potable or running water. Winter storm damage or extended outages could also result in the closure or reduced services of some critical facilities.

Transportation

Roadways, bridges, rail, transit, and air travel are all at risk from severe winter storms, and transportation services are often disrupted by these events in the Commonwealth. Over time, roadways can be damaged from the application of salt and the thermal expansion and contraction caused by alternating freezing and warming conditions. Other types of infrastructure, including rail, aviation, port, and waterway infrastructure (if temperatures are cold enough to cause widespread freezing), can be impacted by winter storm conditions. Severe storms can disrupt public transit services, disproportionately impacting Environmental Justice and other priority populations. In Massachusetts, the rapid transit system is disproportionately relied on by low-income and underrepresented populations, with an estimated quarter of transit users relying solely on the Massachusetts Bay Transit Authority. Severe snowstorms lead to transit shutdowns to allow crews to clean tracks and shovel out stations. Travel bans during storms may also reduce people’s ability to get to work, access medical care, or get home, depending on when the storm hits. Transit shutdowns and delays have cascading effects during especially severe storms. During a 30-day period in 2015 (January 24 through February 22), the Massachusetts Bay Transit Authority experienced three systemwide shutdowns (Flynn, 2017). This had several impacts, including reduced health care access due to both patients’ and medical staff’s inability to reach provider locations. The cascading and compounding effects of the storms led to an estimated $2 billion loss in revenue and productivity in the Boston metro region (Flynn, 2017).

Water Infrastructure

Water infrastructure exposed to winter conditions can freeze or be damaged by ice. Power outages from storms may also disrupt water treatment plant operations. Damage from storms to water infrastructure can lead to sewage overflow, loss of potable water, health care facility closures, and loss of running water (Allen et al., 2018). While Massachusetts has made progress to remove combined sewer overflows and continues to improve the separation of sanitary wastewater and stormwater, water contamination is still a risk. Stormwater that enters groundwater can infiltrate wastewater lines through cracks in drainage pipes, increasing the amount of wastewater flowing to the treatment plant (Webler et al., 2013). The upkeep and management of water infrastructure is key to mitigating storm impacts. A workshop of several critical infrastructure agencies in the Lower Mystic Watershed and municipal and state agencies in Massachusetts identified the lack of functional tide gates on the ocean side of stormwater drains as a significant concern (Resilient Mystic Collaborative, 2021). If gates are corroded or missing, large amounts of seawater can back up stormwater systems during flood events, which trigger sewer overflows and flood roads and buildings.

5.13.2.4.4 Natural Environment

Winter storms are a natural part of the Massachusetts climate, and native ecosystems and species are well adapted to these events. However, changes in the frequency and severity of winter storms, compounded with other stressors, could reduce these ecosystems' ability to recover. More intense storm winds and increased precipitation will increase tree mortality (Commonwealth of Massachusetts, 2022). Loss of tree cover can increase soil erosion rates, impacting the water quality of aquatic ecosystems and damaging the forest landscape at a pace that makes adaptation challenging (Janowiak et al., 2018). Flooding from storms can also alter soil nutrient pathways, reducing the productivity of forest ecosystems. Nor'easters and hurricanes can reduce growth rates in coastal forests for about three years after a storm (Witman, 2018).These impacts could result in significant species shifts and landscape changes within Massachusetts forests.

The flooding that results when snow and ice melt can also cause extensive environmental impacts. Changes in snowmelt can lower spring river flows of aquatic ecosystems, which can impact the health and abundance of freshwater fish. Nor'easters can cause impacts similar to those of coastal flooding (Section 5.5), flooding from precipitation (Section 5.8), and hurricanes and tropical cyclones (Section 5.9). These impacts can include direct damage to species and ecosystems, habitat destruction, and the distribution of contaminants and hazardous materials throughout the environment. Severe winds, flooding, and impaired water quality can also damage and erode salt marshes and wetlands, reducing their ability to provide coastal protection during subsequent storms.

5.13.2.4.5 Economy

Severe winter weather is a risk to the entire Commonwealth, and the cost to prepare for, respond to, and recover from these events is extensive. Structural impacts from winter storms tend to include damage to roofs and building frames rather than to building contents. Heavy accumulations of ice can bring down trees, electrical wires, telephone poles and lines, and communication towers. Communications and power can be disrupted for days while utility companies work to repair the damage. Even small accumulations of ice may cause extreme hazards to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces. High amounts of snow accumulation and rapid ice melt can cause both riverine and urban flooding, as well as increase the risk of dam overtopping. Estimated losses due to flooding in the Commonwealth are discussed in Section 5.8.2 Flooding from Precipitation. Snow and ice removal and road repair from the freeze/thaw process can also be costly. Loss of utilities, interruption of transportation corridors, and loss of business functions reduce people's ability to get to work and may cause temporary business closures. These impacts may result in loss of income and revenue for many individuals and small businesses.

Similar to hurricanes and tropical storms, nor'easter events can greatly impact the economy. These impacts include loss of business functions (e.g., for tourism and recreation), damage to inventories or infrastructure (e.g., fuel supply), relocation costs, wage losses, and rental losses due to the repair or replacement of buildings.

Damage to coastal infrastructure significantly impacts aquaculture, marine fisheries, port operations, and maritime functions in Massachusetts. Disruptions and damages to processing centers and ports can prevent fishers from landing their catch and getting their catch to market. The location and distribution of seafood facilities makes this industry particularly vulnerable. For example, in early March 2018, a nor’easter swept enough sand off the northern end of Plum Island that one of two saltwater wells serving the state shellfish purification plant had to be closed (Lodge, 2018). This affected the processing and sale of clams in Essex and Gloucester, which must go through this facility before they can be sold. Without it, clam beds in the region would have to be shut down, putting fishers out of work.

Severe winter storms also impact winter recreation industries and change snow and rain patterns. Winter sports in Massachusetts are projected to become less frequent due to shortening snow seasons.

Chapter 5. Risk Assessment and Hazard Analysis

Tornadoes

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5.14 Tornadoes

5.14.1 Tornado Problem Statement

All of Massachusetts has the potential for tornado formation, with Franklin, Hampshire, Hampden, and Worcester counties, along with portions of Middlesex and Norfolk counties, (see Figure 5.14-1) historically being the most tornado-prone relative to other areas of the Commonwealth, which has limited exposure to tornadoes. On average, Massachusetts experiences one tornado a year. While this occurrence is much lower than the national average, even one tornado can cause extensive damage and result in fatalities if it strikes densely populated areas. Tornado intensity and frequency is projected to increase due to climate change. In natural environments, these events can result in permanent damage to forest ecosystems and wildlife habitat, as well as provide opportunities for invasive species to establish in the area.

5.14.2 Tornado Risk Assessment

5.14.2.1 General Background

A tornado is a narrow, violently rotating column of air that extends from the base of a cumulonimbus cloud to the ground. The observable aspect of a tornado is the rotating column of water droplets, which captures dust and debris in the column. Tornadoes are the most violent of all atmospheric storms. Tornadoes are measured on the Enhanced Fujita (EF) scale, which ranges from EF0 (light damage) with three-second gust wind speeds of 65–84 miles per hour, to EF5 (incredible damage) with three-second guest wind speeds of over 200 miles per hour. Tornadoes tend to form when cold, dry air clashes with warm, humid air.

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 (i.e., from southeast at the surface to west aloft)
- Increasing wind speed in the lowest 10,000 feet of the atmosphere (i.e., 20 miles per hour at the surface and 50 miles per hour at 7,000 feet)
- Very warm, moist air near the ground, with unusually cool air aloft
- A forcing mechanism such as a cold front or leftover weather boundary from previous shower or thunderstorm activity

Tornadoes can form along severe thunderstorm squall lines, from individual supercell thunderstorms, or from tropical cyclones. Most tornadoes occur in the late afternoon and evening hours when the temperatures are the highest. The most common months for tornadoes to occur in Massachusetts are June, July, and August, although the 1995 Great Barrington, Massachusetts, tornado occurred in May, and the 1979 Windsor Locks, Connecticut, tornado occurred in October.

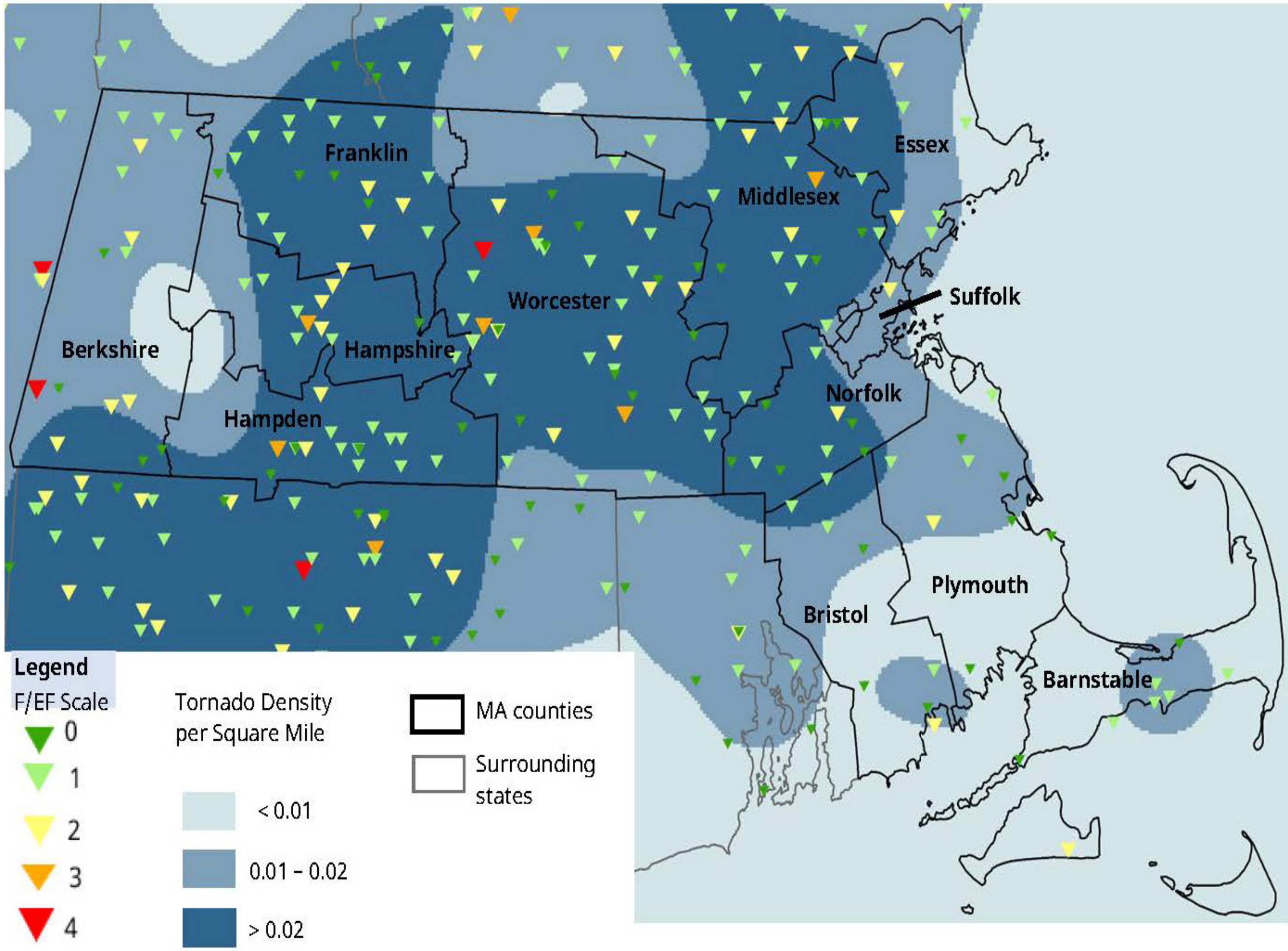
A tornadic waterspout is a rapidly rotating column of air extending from the cloud base (typically a cumulonimbus thunderstorm) to a water surface, such as a bay or the ocean. They can be formed in the same way as regular tornadoes. Tornadic waterspouts can have wind speeds of 60 to 100 miles per hour, but since they do not move very far, vessels can often navigate around them. They can become a threat to land if they move onshore.

5.14.2.2 Hazard Description

Tornadoes in Massachusetts can be caused by thunderstorms or tropical cyclones and can carry significant winds, moisture, and hail.

5.14.2.2.1 Location

The United States experiences an average of about 1,000 tornadoes per year; in 2021, there were 1,376 tornadoes across the country (Insurance Information Institute, 2022). Because Massachusetts experiences far fewer tornadoes than other parts of the country, residents may be less prepared to react to a tornado. Figure 5.14-1 illustrates the reported tornado occurrences, based on all-time initial touchdown locations across the Commonwealth, as documented in the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center Storm Events Database. To determine density in this analysis, the ArcGIS kernel density tool was used to calculate an average score per square mile using touchdowns within 100 miles of Massachusetts. The analysis indicated that the area at greatest risk for a tornado touchdown runs from central to northeastern Massachusetts.



Source: NOAA Storm Prediction Center (2022).

Figure 5.14-1. Density of reported tornadoes per square mile based on tornado occurrences (1950–2021).

5.14.2.2.2 Previous Occurrences and Frequency

Previous

Two tornadoes in Massachusetts received Federal Emergency Management Agency disaster declarations (in Springfield in 2011 and Worcester in 1953). The most destructive tornado in New England history was the Worcester tornado of June 9, 1953. The F4 tornado (see Figure 5.14-2 for a tornado severity rating guide) hit at about 3:30 p.m. The funnel quickly intensified, carving a 46-mile path of extreme damage and loss as it moved through seven towns. The tornado resulted in significant damage and loss in the communities of Barre, Rutland, Holden, Worcester, Shrewsbury, Westborough, and Southborough. The event resulted in the deaths of 90 people and injured approximately 1,200 people. The National Storm Prediction Center (SPC) has ranked this as one of the deadliest tornadoes in the nation's history. With wind speeds between 200 to 260 mph, the force of the tornado carried debris miles away, with debris from the event found in the Atlantic Ocean.

Frequency

From 1950 to 2021, the Commonwealth experienced 190 tornadoes, an average annual occurrence of 2.6 tornado events per year. Between 1995 and 2021, the average frequency of these events in Massachusetts was 2.06 events per year (NOAA Storm Prediction Center, 2022). As highlighted in the National Climate Assessment, tornado activity in the United States has become more variable, and increasingly so in the last two decades. While the number of tornado days per year has decreased, the number of tornadoes per day has increased (U.S. Global Change Research Program, 2018). Additionally, the density of tornado clusters (i.e., the number of tornadoes in an area) has increased, as has the strength of tornadoes. Observations show that the distribution of tornadoes has also shifted eastward from the areas of the country that have historically experienced these events more frequently.

Tornado records only date back to the 1950s in the United States, and there is significant variation in tornado events from year to year, making it difficult to identify long-term trends in tornadoes or accurately predict tornado frequency for the future. Additionally, tornadoes are too geographically small and localized to be accurately predicted by climate models. Therefore, connections between climate change and an increase or decrease in tornado frequencies are uncertain. However, given that tornadoes are generated from severe thunderstorms, which are predicted to increase with climate change, it is likely that tornadoes have been increasing with climate change and will continue to do so. It is possible that climate change may also cause a shift in when tornadoes occur during the year, as well as a shift in regions that are most likely to experience tornadoes (Center for Climate and Energy Solutions, n.d.; Shapiro, 2019).

The likelihood of a tornado occurring in Massachusetts depends on several factors, with weather conditions and the likelihood of severe thunderstorms being critical factors in determining the likelihood of a tornado. Around 20 percent of supercell thunderstorms produce tornadoes, but scientists are still unsure as to why one supercell thunderstorm produces a tornado and another does not. Massachusetts experiences an average of two to five tornadoes per year (NOAA NSSL, n.d.). There are no official data sources on tornado risk or probability due to the difficulty of predicting tornado occurrence and the limited number of historic events that have been reported in the Commonwealth. To better predict tornadoes, scientists need more data to be better able to study tornadoes. The average warning time for a tornado is around eight to 13 minutes (Seligmann, 2022).

While the number of tornadoes is small in Massachusetts compared to other areas of the country, the Commonwealth experiences between two to five tornadoes per year and past tornadoes have caused significant damage. Given these factors, the likelihood that a tornado event will occur within the Commonwealth is high. However, given the challenge of identifying specific parts of Massachusetts that are more at risk from tornadoes, mitigation measures to reduce the risk of high winds that tornadoes and other extreme weather events generate should focus on the assets and populations most at risk, such as mobile homes and other manufactured buildings; people with characteristics that make them most at risk from tornadoes; and lifeline infrastructure, including utilities, infrastructure, and critical assets such as hospitals and schools. Removing debris, storing hazardous waste and materials, and removing or enclosing critical equipment and assets located on roofs or outside of structures can make a significant difference in reducing the damage from tornadoes and other high-wind events.

5.14.2.2.3 Severity/Intensity

Tornadoes are among the most dangerous of local storms. If a major tornado were to strike in a populated area of the Commonwealth, damage would be significant. Fatalities could be high, many people would be displaced for an extended period of time, buildings would be damaged or destroyed, and businesses would suffer damage and loss. Additionally, utilities and infrastructure, particularly communications, energy, and rail infrastructure, could experience significant damage, disruption, and a long period of recovery of physical assets and functions, leaving people without critical services. Massachusetts ranks 35th among the states for frequency of tornadoes, 14th for frequency of tornadoes per square mile, 21st for injuries, and 12th for cost of damage.

Tornado Severity Scales

The National Weather Service rates tornadoes using the Enhanced Fujita scale (EF scale), which does not directly measure wind speed but rather the amount of damage created. This scale derives three-second gusts estimated at the point of damage based on the assignment of one out of eight degrees of damage to a range of different structure types. These estimates vary with the height of a damaged structure (damage above the ground) and exposure of the event. This method is considerably more sophisticated than the original Fujita scale, and it allows surveyors to create more precise assessments of tornado severity after an event. Figure 5.14-2 provides guidance from NOAA about the impacts of a storm with each rating.

Potential Effects of Climate Change

Current climate models predict an increase in severe thunderstorms, which have the potential to produce tornadoes. However, it is unclear if tornado frequency will increase with climate change. Some studies suggest there will be a decrease in the number of tornado days, but an increase in the number of tornadoes per day. Given that less than 10 percent of severe thunderstorms produce tornadoes, it is difficult to draw firm conclusions about the processes leading up to a tornado and how these processes might be influenced by climate change (Treisman, 2021). Additionally, given that the tornado record only dates to 1950 in the United States and varies significantly from year to year, it is difficult to identify long-term trends.

EF Rating	Wind Speeds	Expected Damage
EF-0	65-85 mph	'Minor' damage: shingles blown off or parts of a roof peeled off, damage to gutters/siding, branches broken off trees, shallow rooted trees toppled.
EF-1	86-110 mph	'Moderate' damage: more significant roof damage, windows broken, exterior doors damaged or lost, mobile homes overturned or badly damaged.
EF-2	111-135 mph	'Considerable' damage: roofs torn off well constructed homes, homes shifted off their foundation, mobile homes completely destroyed, large trees snapped or uprooted, cars can be tossed.
EF-3	136-165 mph	'Severe' damage: entire stories of well constructed homes destroyed, significant damage done to large buildings, homes with weak foundations can be blown away, trees begin to lose their bark.
EF-4	166-200 mph	'Extreme' damage: Well constructed homes are leveled, cars are thrown significant distances, top story exterior walls of masonry buildings would likely collapse.
EF-5	> 200 mph	'Massive/incredible' damage: Well constructed homes are swept away, steel-reinforced concrete structures are critically damaged, high-rise buildings sustain severe structural damage, trees are usually completely debarked, stripped of branches and snapped.

Source: *Explanation of EF-Scale Ratings (2011)*

Figure 5.14-2. Guide to tornado severity.

5.14.2.2.4 Warning Time

Tornado watches and warnings are issued by the local National Weather Service office. A tornado watch is issued when conditions in the region are favorable for tornadoes. Watches are usually issued several hours in advance for larger areas (e.g., multiple counties). A tornado warning means a tornado has been sighted or indicated by weather radar. The current average lead time for tornado warnings is 13 minutes (Seligmann, 2022). Occasionally, tornadoes develop so rapidly that little, if any, advance warning is possible. This limited warning time, combined with the severe damage and loss that can result from tornadoes, makes this hazard a high risk for causalities, injuries, and significant damage and loss if buildings, infrastructure, and utilities are not built to withstand the severity of the event or if the event is extremely severe and difficult to mitigate. Therefore, limiting the risks associated with tornadoes should focus on mitigation measures such as building codes and construction approaches to reduce risk, rather than relying on the evacuation of populations.

5.14.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

The local hazard mitigation plans reviewed by the Risk Assessment team acknowledge the considerable destruction that tornadoes can cause when they touch down. For the most part, the plans note that severe tornadoes are unlikely to occur in the Commonwealth, and even severe tornadoes will likely only cause localized damage. However, the town of Springfield’s Municipal Vulnerability Preparedness (MVP) program planning report dedicates more discussion to the vulnerability of its residents, given its experience with an EF3 tornado in 2011. All plans reviewed noted that tornadoes are more likely to occur in central to northeastern Massachusetts, and therefore some areas of the Commonwealth are more likely to experience a tornado than others.

Table 5.14-1.Highlight of Local Plans and MVP Program Planning Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Town of Erving Hazard Mitigation Plan, October 2019	If a tornado were to occur in Erving, it could affect 10% to 50% of the town.	If a major tornado were to strike in the populated areas of Erving, damage could be widespread. Fatalities could be high, people could be displaced, and buildings could be destroyed or damaged.	Total estimated potential loss for 10% damage to structures in Erving is $52,941,253.
Local Multi-Hazard Mitigation Plan 2017 Update, town of Swansea, August 2017	Exact locations are unpredictable and may occur anywhere.	Small tornadoes may occur, causing localized damage. A damaging tornado is unlikely to occur.	If 5% of buildings are damaged, total estimated damage is $56,087,000.
Town of West Stockbridge Hazard Mitigation Plan (draft), October 2021	The county is in a low-risk area with an average of one tornado watch per year.	The entire region including, the town of West Stockbridge, has the potential for tornado formation. The plan states that areas with higher-than-average tornado frequency face additional risk.	*Not provided*
Springfield Community Resilience Building Workshops: Summary of Findings, May 2017–June 2018	Springfield experienced an EF3 tornado in 2011.	After the tornado, residents of color reported feeling like majority white neighborhoods received faster assistance from the Massachusetts Department of Public Works than their predominantly African American and Hispanic neighborhoods.	The city secured $17 million in National Disaster Recovery funds for rebuilding after the tornado.

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Municipal Vulnerability Preparedness Plan: Findings and Recommendations, city of Worcester, 2019	Tornadoes have occurred most frequently in the Connecticut River Valley and western Worcester County.	The plan indicates local concern for loss of life, tree and power line damage, and personal property loss.	*Not provided*

5.14.2.3 Secondary Hazards

The most significant secondary hazards associated with tornadoes include increased flood risks due to debris that blocks drainage and culverts, as well as the loss of ground cover and trees. Increased wildfire risk may result from the loss and damage of trees and ground cover. Tornadoes have also been known to introduce and spread invasive species. The damage to the natural and built environment can increase the risk of landslides and erosion prior to the restoration and rehabilitation of these landscapes. Damage to urban tree cover from tornadoes can potentially increase urban heat island effects. For example, A tornado-impacted neighborhood in Springfield went from 40 percent tree cover to 1 percent cover. Temperature increases of 4°F have been observed in tornado-affected neighborhoods due to tree loss. Tornadoes can also result in the release of toxic contaminants into waterways, wetlands, and communities, thus posing a risk to public health and ecological resources. Large hail commonly accompanies a tornado, and heavy rain can overwhelm stormwater infrastructure and natural drainage systems, contributing to flood risk.

5.14.2.4 Exposure and Vulnerability

Table 5.14-2 below summarizes the priority potential impacts of tornadoes in the Commonwealth using themes identified in the 2023 Massachusetts State Hazard Mitigation and Climate Adaptation Plan Risk Assessment based on information from analysis, research, and information from past events in the Commonwealth and the United States.

Table 5.14-2. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Tornadoes

Sector	Priority Impacts and Vulnerabilities
Human	• Entire population of Massachusetts is exposed to tornado hazards • People who reside in less stable housing (such as mobile homes) are at risk • Emergency service response delays and evacuation disruptions from extreme storms, leading to injuries and loss of life and

Sector	Priority Impacts and Vulnerabilities
	requiring health, safety, and traffic first responders **(most urgent)**
Governance	• Loss of or damage to government buildings.
Infrastructure	• Damage to water infrastructure and power lines
Natural environment	• Forest health degradation **(most urgent)**
Economy	• Economic losses from commercial structure damage and business interruptions

5.14.2.4.1 Human

The entire Commonwealth has the potential for tornado formation, and therefore the entire population of Massachusetts is exposed to the risk of a tornado. However, residents of areas described above as having higher-than-average tornado frequency face increased risks. Residents of areas exposed to tornadoes may be displaced or require temporary to long-term shelter. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life.

There are 3,563,721 people living in high tornado density zones. The largest number of people in a high tornado density zone is 1,359,837 in Middlesex County (1,632,002 residents in the county total).

As part of the 2023 SHMCAP process, Massachusetts state agencies completed a survey where they identified their primary concerns for populations served and potential disproportionate impacts from tornadoes. Table 5.14-3 below summarizes agency responses.

Table 5.14-3. State Agency Responses: Primary Concerns About Tornado Impacts on Populations Served and Potential Disproportionate Impacts

Category	Primary Concerns
Population served	• Injured workers • Municipalities, campus police officers, deputy sheriffs, hospital police officers and environmental police • Active state employees and their dependents; active municipal employees and their dependents; state retirees and their dependents; quasi-state agency and housing authority employees and their dependents and surviving spouses
Potential disproportionate impacts	• Delayed response and increased need for response • Greater impacts to those reliant on public transportation • Impacts dependent on severity and location of event (populations within the Socially Vulnerable Population Index are likely to experience disproportionate impacts, as they typically reside in less safe and undesirable areas and have a more difficult time recovering following disaster events)

Category	Primary Concerns
	• If there is loss of power, communications to customers could be disrupted • Delays in court dates or proceedings • Delays in filing of important documentation subject to statutory timeframes

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Population Projections

By 2030, the population of Massachusetts is expected to increase by 20,000 to 70,000 people, with the largest population growth occurring in Middlesex County (projected increase of 70,000 people by 2030). The population of Barnstable County is expected to decrease by 5,000 people by 2030 (UMass Donahue Institute, 2018). By 2040, the population of Massachusetts is expected to increase by 20,000 to over 120,000 people, with the largest population growth occurring in Middlesex County (projected increase of over 120,000 people by 2040). Given that Middlesex County has a historic tornado density of more than 0.02 per square mile, which is a high historic tornado density for the Commonwealth, it is possible that the increased population of this county may result in increased exposure to tornadoes. However, given the infrequent occurrence of tornadoes in Massachusetts and the difficulty in predicting the locations where tornadoes will occur, this relationship is not conclusive.

Vulnerable Populations

According the Massachusetts Environmental Justice Map, environmental justice populations are neighborhoods with one or more of the following criteria (Massachusetts Executive Office of Energy and Environmental Affairs, n.d.):

- The annual median household income is 65 percent or less of the statewide annual median household income
- Minorities make up 40 percent or more of the population
- 25 percent or more of the households identify as speaking English less than “very well”
- Minorities make up 25 percent or more of the population
- The annual median household income of the municipality in which the neighborhood is located does not exceed 150 percent of the statewide annual median household income

Priority populations are people or communities who are disproportionately impacted by climate change due to life circumstances that systematically increase their exposure to climate hazards or make it harder to respond. In addition to factors that contribute to environmental justice status (i.e., income, race, and language), other factors like physical ability, access to transportation, health, and age can indicate whether someone or their community will be disproportionately affected by climate change. This is driven by underlying contributors such as racial discrimination, economic disparities, or accessibility barriers that create vulnerability.

Geospatial analysis comparing environmental justice block groups in Massachusetts (using the 2021 Massachusetts Environmental Justice Map) with historic tornado touchdown events from NOAA SPC shows that there are 1,439,300 people living in environmental justice Census blocks in high tornado hazard zones, 1,504,074 people living in these blocks in medium tornado hazard zones, and 153,875 people living in these blocks in low tornado hazard zones. Middlesex County has the largest number of people living in environmental justice Census blocks in high tornado hazard zones (524,215 people).

Tornadoes can also cause power outages, which can be life-threatening to those who are dependent on electricity for life support or electric medical devices. Power outages can also lead to increased risk of carbon monoxide poisoning. Individuals with limited communication capacity, such as those with limited internet or phone access or limited English proficiency, may not be aware of impending tornado warnings. The isolation of these populations is a significant concern, as is the potential insufficiency of older or less stable housing to offer adequate shelter from tornadoes. People over the age of 65 and under the age of five are often more difficult to evacuate ahead of tornadoes, as are communities in institutional settings such as prisons, elder care facilities, hospitals, shelters, and youth homes. First responders responsible for evacuation, fire, and medical response units are at risk. Hospital facilities and nursing homes are vulnerable. People without access to financial resources often lack the resources to prepare for, respond to, or recover from events that cause significant damage, such as tornadoes. Another population that is often more at risk from high-consequence hazard events like tornadoes are renters, who often lack the authority and resources to ensure that their homes are constructed and maintained to reduce risk.

Health Impacts

The primary health hazard associated with tornadoes is the threat of direct injury from flying debris or structural collapse, as well as the potential for an individual to be lifted and dropped by the tornado's winds. After the storm has subsided, tornadoes can present unique challenges to search and rescue efforts because of the extensive and widespread distribution of debris. The distribution and release of hazardous materials, toxics, and contaminants, including asbestos-containing building materials, fuels, and paints, can present an acute health risk for ecosystems, waterways, personnel cleaning up after a tornado, residents, and habitats in the affected area. The duration of exposure to contaminated material may be far longer if it is released in drinking water reservoir; groundwater aquifers; or natural systems such as waterways, ponds, wetlands, and rivers. According to the Environmental Protection Agency (EPA), properly designed storage facilities for hazardous materials can reduce the risk of those materials being spread during a tornado (U.S. EPA, 2021). Many of the health impacts described for other types of storms, including lack of access to hospitals, carbon monoxide poisoning from generators, and mental health impacts from storm-related trauma, also occur as a result of tornado activity. Additional sources of vulnerability can materialize if hospital facilities and nursing homes are damaged by a tornado.

5.14.2.4.2 Governance

To analyze how tornadoes could affect state facilities, the Risk Assessment team overlaid Division of Capital Asset Management and Maintenance (DCAMM) data with zones of historic tornado tensity. There are 7,432 buildings in the high- and medium-intensity zones (tornado densities above 0.02 and 0.01 tornadoes per square mile, respectively), while 1,330 are in the low-intensity zone (0 to 0.01 tornadoes per square mile). Overall, Middlesex and Worcester Counties have the greatest number of government buildings within the defined tornado zones.

Table 5.14-4 identifies both the county and the replacement cost value of the state-owned buildings located in the defined tornado hazard areas. Replacement values assume 100 percent loss to each structure and its contents. In addition to impacts to Commonwealth-owned businesses, Commonwealth land may incur the loss of trees.

Table 5.14-4. State-Owned Properties Exposed to Tornado Hazard Zones by County

County	High		Medium		Low	
	Count	Replacement Value	Count	Replacement Value	Count	Replacement Value
Barnstable	—	—	66	$322,777,050	399	$948,323,322
Berkshire	32	$5,657,600	538	$1,249,742,622	41	$6,354,900
Bristol	52	$38,462,100	243	$2,809,576,373	222	$729,495,950
Dukes	—	—	—	—	39	$31,569,050
Essex	237	$1,285,103,900	357	$2,300,051,850	40	$61,946,350
Franklin	237	$577,746,700	52	$11,042,850	—	—
Hampden	554	$4,461,490,493	17	$6,222,500	14	$11,450,950
Hampshire	691	$8,152,157,728	19	$4,084,850	—	—
Middlesex	1,237	$7,960,306,111	116	$382,204,848	—	—
Nantucket	0	—	—	—	11	$18,341,000
Norfolk	436	$2,613,334,447	306	$571,916,583	39	$18,705,500
Plymouth	11	$43,167,350	334	$2,941,887,954	445	$1,095,265,332
Suffolk	18	$47,153,863	697	$14,652,688,187	80	$564,303,811
Worcester	977	$9,125,312,050	214	$513,930,900	—	—
Total	**4,482**	**$34,309,892,343**	**2,959**	**$25,766,106,569**	**1,330**	**$3,485,756,165**

Sources: Analysis conducted by ERG using information from Massachusetts Division of Capital Asset Management and Maintenance (2021) (facility inventory); SPC (2021).

In addition to the direct loss of buildings, a tornado event in Massachusetts would result in a significant increase in the need for Commonwealth services and support. During the event, services would include search and rescue, coordination of evacuation of both institutional and residential settings, and mobilization of support to restore utilities and infrastructure, with a priority on communications and energy infrastructure and services. After the event, activities would include debris collection and removal, coordination to repair utilities and infrastructure, rehabilitation and restoration of damaged natural areas, assistance to community members displaced from homes or institutional settings, cleanup of contaminated areas, and coordination with federal and local governments. Pre- and post-disaster, Massachusetts state and local government services might include ensuring that buildings that house critical functions and environmental justice and priority populations are designed to be resilient to tornadoes. Additionally, the Commonwealth should ensure that asset types that are most at risk due to construction type, age, or other characteristics—such as manufactured housing, homes with aboveground or no foundations, and tilt-up manufacturing and industrial warehouses—have measures in place to mitigate as much of the risk as possible from tornadoes.

Lifelines

Tornadoes have the potential to disrupt or affect all community lifelines within their path. The high winds associated with tornadoes often affect telephone poles and power lines (affecting energy and communications lifelines), and can damage homes, shelters, and medical facilities. Transportation lifelines can be damaged by high winds and affected by fallen trees or other debris that block roadways, railroads, or runways. Facilities that house hazardous materials could be damaged by high winds or falling debris, which might release hazardous materials that can harm the environment and humans. A high intensity tornado would have significant impacts on lifeline infrastructure and facilities, posing risks to human safety, public health, and emergency response. Depending on the path of a tornado and warning time available, evacuation, fire, and medical response units can be at risk.

5.14.2.4.3 Infrastructure

All critical facilities,[1] utilities, and infrastructure are exposed to tornado events. Hail, rain, and wind can create flying debris and contribute to flash flooding, which can damage water infrastructure. Aboveground power lines are frequently damaged in tornado events. The number of state critical facilities and utility and infrastructure assets located within the defined tornado hazard zones are listed in Table 5.14-5. Impacts to these assets can result in significant disruptions for communities, businesses, and institutions; the restoration of these functions and services should be a

[1] Critical facilities analyzed included: administration, animal services, cold storage, communications, corrections, education, energy, fire, health care, laboratories and research, maritime, military, parks and recreation, police, residential, social services, stadium, transportation, waste management, and water resources facilities.

priority to reduce impacts across the Commonwealth. Designing and locating these assets to reduce their risk would help make other sectors more resilient to extreme storm and high wind events (including tornadoes), particularly the human, economy, and environment sectors. According to the city of Somerville 2022 hazard mitigation plan, buildings that are constructed prior to current building codes may be more vulnerable to tornado-related damages (City of Somerville, 2022). According to the town of Adams hazard mitigation plan, the town strictly adheres to the Massachusetts building code, which was last updated in 2018. Part of the Commonwealth building code requires buildings to withstand specific wind speeds. While the town of Adams hazard mitigation plan does not specifically call out tornadoes in relation to this 2018 building code, it can be inferred that structures built before 2018 may not be built to withstand the high wind speeds associated with tornadoes (Town of Adams, 2019). Therefore, updating or retrofitting critical facilities and buildings constructed before 2018 would make these structures more likely to withstand the impacts from tornadoes and other extreme storms and high wind events.

Table 5.14-5. Critical Facilities Exposed to Tornado Hazard Zones by County

County	High	Medium	Low
Barnstable	—	16	148
Berkshire	2	157	11
Bristol	9	91	55
Dukes	—	—	9
Essex	68	88	10
Franklin	46	22	—
Hampden	181	9	4
Hampshire	297	3	—
Middlesex	367	36	—
Nantucket	—	—	7
Norfolk	200	76	1
Plymouth	2	140	138
Suffolk	4	142	25
Worcester	335	63	—
Total	**1,511**	**843**	**408**

Sources: Analysis conducted by ERG using data from Massachusetts Division of Capital Asset Management and Maintenance (2021) (facility inventory); SPC (2021).

Massachusetts Commonwealth agencies completed a 2023 SHMCAP survey with questions about their primary concerns for the services they provide, as well as what updates, improvements, or enhancements they need to address the impacts of tornadoes. Table 5.14-6 below summarizes agency responses.

Table 5.14-6. State Agency Responses: Primary Concerns About Tornadoes' Effects on Services, with Suggested Improvements

Category	Concerns/Improvements
Services provided	• Inability of consumers, business, and municipalities to receive phone and cable service if power lines are down • Delays in 911 services • Disruptions in communications, access to health benefits, and billing
Updates, improvements, or enhancements to address concerns	• Work with carriers to assess vulnerable infrastructure (e.g., cell towers) that serve 911. The State 911 Department added a data center outside of New England to address this risk. • Ensure that IT infrastructure and learning management systems continue to progress even if there is a pivot to remote learning. • Build buildings and structures to withstand high winds. • Improve communication and coordination with other agencies that manage back-ups; continue to build out web-based portal services for members to increase communication abilities.

Source: ERG (2023).
The responses to the survey were completed by agency staff and did not go through formal review.

Agriculture

Forestry and agricultural crops, livestock, equipment, and infrastructure may be directly affected by tornadoes. High winds from tornadoes can rip up crops; expose hazardous materials; damage farm machinery, buildings, barns, and siloes; and create large amounts of debris. High intensity tornadoes (EF2 and above) can be deadly for livestock and other animals. In some cases, livestock can ingest tornado debris, which may cause sickness or death in livestock (Hirsch, 2013).

Energy

Tornadoes often damage and bring down power lines and poles adjacent to roads and cause significant damage to substations (Urbint, 2022). Damage to aboveground transmission infrastructure can result in extended power outages.

Public Safety

Public safety facilities and equipment may experience direct loss, damage, or disruption from tornadoes. Shelters and other critical facilities that provide services for people whose property is uninhabitable following a tornado may experience overcrowding and inadequate capacity to provide shelter and services.

Transportation

Tornadoes can cause transportation failures such as damage and loss of roads, bridges, and rail; these failures are mainly associated with secondary hazards, such as landslide events. Tornadoes can cause significant damage to trees and power lines, block roads and rail with debris, incapacitate transportation, isolate populations, and disrupt ingress and egress. Of particular concern are bridges and roads providing access to isolated areas and the elderly. Prolonged obstruction of major routes due to secondary hazards, such as landslides, debris, or floodwaters can disrupt the shipment of goods and other commerce.

Water Infrastructure

The hail, wind, debris, and flash flooding associated with tornadoes can cause damage to water infrastructure, such as storage tanks, hydrants, residential pumping fixtures, and distribution systems. This can result in loss of service or reduced pressure throughout the system (U.S. EPA, 2015) and disrupt water service and supply. Water and wastewater utilities are also vulnerable to potential contamination due to chemical leaks from ruptured containers; the release of toxic materials into waterways and aquifers; and debris in water bodies, aquifers, and reservoirs. Ruptured service lines in damaged buildings and broken hydrants can lead to loss of water and pressure (U.S. EPA, 2015).

5.14.2.4.4 Natural Environment

Damage and disruption to native species and habitats can occur if a tornado uproots and transports vegetation and habitat. Trees and vegetation may be uprooted and transported, or root systems may be damaged, causing significant damage to the surrounding habitat. As felled trees decompose, the dry matter may increase the threat of wildfire in vegetated areas. Additionally, the loss of root systems increases the potential for soil erosion. Disturbances created by blowdown events may also affect the biodiversity and composition of forest ecosystems. Invasive plant species are often able to quickly capitalize on the resources (such as sunlight) available in disturbed and damaged ecosystems. This enables them to establish quickly with less competition from native species. Loss of urban tree cover due to tornadoes can contribute to temperature increases. For example, a tornado-impacted neighborhood in Springfield went from 40 percent tree cover to 1 percent tree cover following a tornado. Temperature increases of 4°F have been observed in tornado-affected neighborhoods due to tree loss (UMass Amherst, 2011).

In addition to damaging existing ecosystems, material and debris transported by tornadoes can also cause environmental damage and loss in surrounding areas. The distribution of asbestos-contaminated building materials or other hazardous waste to natural areas or bodies of water can result in significant and lasting damage to these areas, impairing public health and ecosystems. Public drinking water reservoirs may also be damaged by widespread winds uprooting watershed forests and creating serious water quality disturbances. All debris that is carried into natural lands and waters can result in significant damage to the health of soils, water, vegetation, and habitats; the debris removal process can increase this damage. Reducing the risk of releasing toxics and distributing debris before a tornado can significantly reduce the damage and loss to the environment from these events.

5.14.2.4.5 Economy

Tornado events are typically localized; however, economic impacts to affected areas can be significant. Types of impacts may include loss of business functions, water supply system damage, damage to inventories, relocation costs, wage losses, and rental losses due to the repair or replacement of buildings. Tornadoes can also damage and disrupt utilities and infrastructure services, impairing business operations and people’s ability to work. Recovery and clean-up can also be costly. The damage inflicted by past tornadoes in Massachusetts varies widely, but the average damage per event is approximately $3.9 million. The total cost of property damage from 2021 tornadoes in Massachusetts was $49,000.

Because of differences in building construction, residential structures are generally more susceptible to tornado damage than commercial and industrial structures. Wood and masonry buildings in general, regardless of their occupancy class, tend to experience more damage than concrete or steel buildings. Manufactured homes are the most vulnerable to damage, even if tied down, and offer little protection to people inside.

Chapter 5. Risk Assessment and Hazard Analysis

Tsunamis

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5.15 Tsunamis

5.15.1 Tsunamis Problem Statement

All coastal areas of Massachusetts are exposed to the threat of tsunamis. Populations within the tsunami inundation zones are most vulnerable to tsunamis; characteristics such as age, mobility challenges, linguistic isolation, low income, and being unhoused also increase a person's risk. The warning time associated with an event would have a significant impact on outcomes. If an event occurs in a distant location, communities may have hours to evacuate inland or toward higher ground. Evacuation can be difficult or impossible in areas where roads, bridges, utilities, and power generation and communication facilities are damaged by a tsunami. Tsunami events often result in damage, disruption, and loss for coastal communities, businesses, natural habitats, homes, and critical infrastructure and utilities, as well as impacts on public health and safety. These events can also mobilize pollutants. Tsunamis can uproot trees and plants, cause floating debris, and destroy habitats such as bird nesting sites. Sensitive and hard-to-evacuate assets such as hospitals, elder care facilities, prisons, animal care facilities, elementary schools, and preschools should receive special consideration, as should members of priority communities, including people without vehicle access, members of low-income or single-parent households, renters, and linguistically isolated people.

5.15.2 Tsunamis Risk Assessment

5.15.2.1 General Background

A tsunami is a major onshore surge of water, or a string of waves created by the displacement of a large volume of water. This displacement can be caused by several types of events, including earthquakes, volcanic eruptions, landslides, glacier calving, and meteorite impacts. Tsunamis can move hundreds of miles per hour in the open ocean and can come ashore at speeds of about 30 miles per hour, with waves as high as 100 feet or more (North Carolina Emergency Management, n.d.). The height of a tsunami wave is related to the strength of the event that generated the tsunami and to the configuration of the ocean bottom along the tsunami's path.

A mediastinum has similar characteristics to a tsunami, but is generated by fast-moving air pressure disturbances or weather events, such as squall lines and frontal passages (Bailey et al., 2014; NOAA, 2015). The waves generated by the storm move toward the shore and are amplified by coastal features (NOAA, 2023). Although observed to have shorter wave heights (6 feet) than tsunamis, meteotsunamis' waves, flooding, and currents can cause significant damage (NOAA, 2015, 2023). Meteotsunamis waves can last from couple hours to a day (NOAA, 2015, 2023).

According to the National Oceanic and Atmospheric Administration (NOAA), tsunamis are most often generated by earthquakes in marine and coastal regions. Major tsunamis are produced by large, shallow earthquakes associated with the movement of oceanic and continental plates. Tsunamis occur more often along the Pacific Coast; however, tsunamis can impact other U.S. coastlines as well.

Tsunamis have resulted in massive casualties and health impacts (both direct and indirect) throughout the world. During a tsunami event, direct mortality can occur as individuals drown in the floodwaters or are struck by fast-moving debris. Health impacts that follow a tsunami can result from contaminated food and water supplies, strained hospitals, and medical facilities, and impacted essential infrastructure (e.g., energy, water, wastewater, transportation).

5.15.2.2 Hazard Description

The tsunami hazard in Massachusetts includes traditional tsunamis caused by earthquakes, volcanoes, landslides, glaciers, and other large displacements of water which result in coastal surge, waves, and flooding. Massachusetts also experiences meteotsunamis that are the result of air pressure disturbances and result in higher-than-normal waves, stronger currents, and flooding.

5.15.2.2.1 Location

Coastal areas of Massachusetts have a small likelihood of exposure to the threat of tsunamis, but this likelihood is relatively low compared to the Pacific Coast of the U.S. According to *U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves*, the Atlantic Coast and Gulf Coast states have experienced very few tsunamis in the last 200 years (Dunbar & Weaver, 2015). The states of Louisiana, Mississippi, Alabama, Florida (the Florida Gulf Coast), Georgia, Virginia, North Carolina, Pennsylvania, and Delaware have no known historical tsunami records. Only six tsunamis have been recorded in Gulf and East Coast states. Three of these tsunamis were generated in the Caribbean—two were related to a magnitude 7+ earthquake along the Atlantic Coast; one that was reported in the mid-Atlantic may have been related to an underwater explosion or landslide.

Tsunamis could potentially travel to New England from the Caribbean, the Mid-Atlantic Ridge, the Canary Islands, or the continental shelf located offshore of the northeast U.S. coast. Each possible event is described in more detail below.

Mid-Atlantic Ridge

The closest tectonic boundary to the U.S. East Coast is the spreading (divergent) Mid-Atlantic Ridge, which is moderately tectonically active. However, according to the Maine Geological Survey, tsunamis are more likely to occur at convergent margins, and earthquake activity along the mid-Atlantic spreading system is not known to be associated with tsunami activity (Maine Geological Survey, 2004).

Caribbean Islands

The Caribbean is home to some of the most geologically active areas outside the Pacific Ocean. There is a subduction zone, called the Puerto Rico Trench, located just north of Puerto Rico. In this area, the North American Plate is being subducted beneath the Caribbean Plate, which has produced numerous earthquakes, submarine landslides, and volcanic eruptions resulting in tsunami activity. A 9.0 magnitude earthquake originating in the Puerto Rico Trench could impact the U.S. East Coast and Massachusetts within the next 250 to 2,000 years. In the Commonwealth, Martha's Vineyard, Nantucket, and the South Shore area are at the greatest risk of exposure to such an event (Grilli et al., 2022).

Canary Islands

The Canary Islands are a chain of volcanic islands located in the eastern Atlantic Ocean, just west of the Moroccan coastline. La Palma is the westernmost and youngest of the Canary Islands, and with three large volcanoes it is also the most volcanically active. Cumbre Vieja, located on La Palma, has erupted three times in the last century—in 1949, 1971, and 2021. Some researchers point to this volcano as a potential driver of tsunamis in the Atlantic Ocean, including the "mega-tsunami" hypothesis that the collapse of La Palma could generate tsunami waves up to 80 feet high. Scientists believe there are several reasons why an eruption near the Canary Island would not lead to a mega-tsunami, including the following:

- Based on recent studies of slope stability and ocean bathymetry, the Cumbre Vieja currently appears to be stable after the 2021 eruption (USGS, 2021). If the Cumbre Vieja were to collapse, the potential collapse would be piecemeal manner and projected to generate maximum wave heights of between three and seven feet along the U.S. East Coast (similar to a storm surge event) (USGS, 2021).
- While the active volcano of Cumbre Vieja on La Palma is expected to erupt again, it will likely not send a large part of the island into the ocean, though small landslides could occur.
- No mega-tsunamis have occurred in the Atlantic Ocean in recorded history.
- The colossal collapses of Krakatau (Indonesia) in 1883 and Santorini (Greece) circa 1600 BCE generated catastrophic waves in the immediate area, but hazardous waves did not propagate to distant shores. Numerical and experimental models of tsunami events driven by volcano activities and the La Palma event verify that the relatively short waves from these small occurrences do not travel as tsunami waves from a major earthquake (International Tsunami Information Center, n.d.).

North Carolina/Virginia Continental Shelf

Evidence has been found of a large submarine landslide called the Albemarle-Currituck Slide, which occurred 18,000 years ago off the coasts of Virginia and North Carolina (Driscoll et al., 2000). In this event, more than 33 cubic miles of material slid seaward from the edge of the continental shelf, most likely causing a tsunami. It is possible that a similar event could occur in the future (Driscoll et al., 2000).

Northeastern U.S. Atlantic Continental Shelf

The 1929 7.3 magnitude earthquake off the coast of Newfoundland caused a damaging tsunami along the south coast of Newfoundland, which was recorded on tide gauges along the New England coast. The 1929 earthquake was centered at the edge of the continental shelf, where a submarine landslide is thought to have caused the tsunami. Modern earthquake activity has been detected along the edge of continental shelf of Nova Scotia and New England, suggesting that these areas also could be the source of future strong earthquakes that could generate damaging tsunamis along the New England coast.

5.15.2.2.2 Previous Occurrences and Frequency

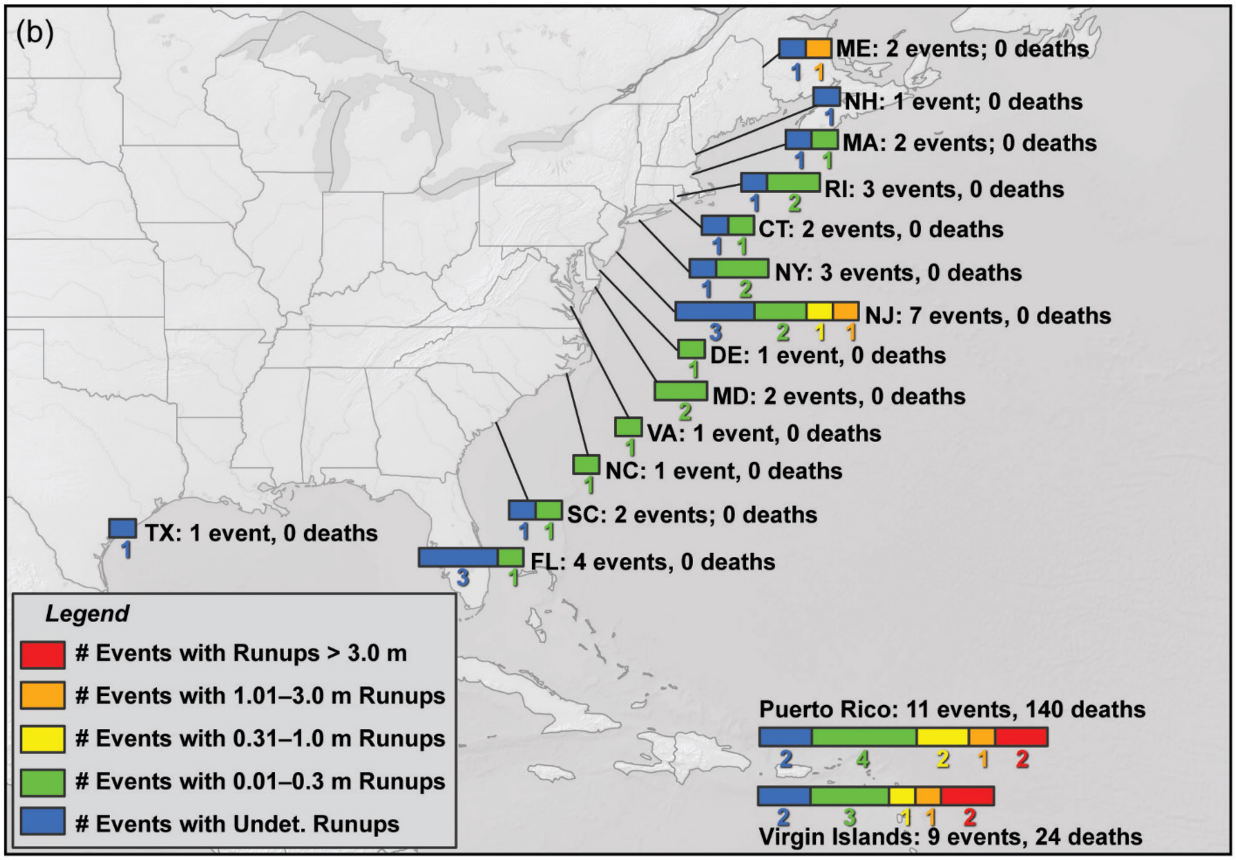
Previous

Very few tsunami events have occurred in Massachusetts history. Table 5.15-1 summarizes the findings of NOAA and U.S. Geological Survey (USGS) research on historic tsunami events and losses in the Atlantic region (Dunbar & Weaver, 2015). It includes the total number of run-ups, deaths, and damages in the U.S. Atlantic Coast (1886-2015). Since no additional tsunami events have occurred since 2018, these data are the best available. Figure 5.15-1 shows the number of run-ups, deaths, and damages from tsunami events and the total number of events causing run-up heights from 0.3 feet to more than 9.8 feet for the U.S. and its territories in the Atlantic Coast, Gulf Coast, Puerto Rico, and Virgin Islands.

Table 5.15-1. Summary of Tsunami Events and Losses in the Atlantic Region

	Location (and year of first confirmed report)	Total number of tsunami events with any observed runup	Events with undetermined runup heights	Events with runups 0.01 to 0.5 m	Events with runups 0.51 to 1.0 m	Events with runups 1.01 to 3.0 m	Events with runups > 3.0 m	Total number of runups for all tsunami events	Reported deaths	Million dollars damage reported
US. Atlantic Coast	Maine (1929)	1	1					3		
	New Hampshire (1929)	1	1					1		
	Massachusetts	1	1					2		
	Rhode Island	2	1	1				3		
	Connecticut (1964)	1	1					1		
	New York (1985)	2	1	1				7		
	New Jersey (1918)	6	3	2	1			8		
	Pennsylvania									
	Delaware									
	Maryland (1929)	1		1				1		
	Virginia									
	North Carolina									
	South Carolina (1886)	2	1	1				2		
	Georgia									
	Florida (1886)	4	3	1				5		
	Atlantic Coast Totals	**21**	**13**	**7**	**1**	**0**	**0**	**33**	**0**	**$0**

Source: Dunbar & Weaver (2015).



Source: Dunbar & Weaver (2015).

Figure 5.15-1. Total number of tsunami events in the U.S. and its territories.

According to the National Geophysical Data Center Tsunami Database, from 2000 B.C. to December 2022, there have been approximately 1,425 probable or definite tsunami events worldwide (NOAA, 2022b). Only 1.7 percent (24) of these recorded events were generated meteorologically (i.e., may have been meteotsunamis), and two of them occurred along the U.S. Atlantic Coast (once in 2013 and once in 2018) (NOAA, 2022b). Recent research indicates that there may have been more meteotsunamis than previously thought, which may have been miscategorized as resulting from other causes (NOAA, 2015).

Frequency

The low likelihood and frequency of tsunamis experienced in Massachusetts is a result of the Commonwealth's location in relation to the areas that are likely to experience tsunami-generating seismic or volcanic events. In U.S. coastal areas, while the frequency of damaging tsunamis is low compared to many other natural hazards, the impacts can be extremely high, with significant consequences to people, assets and services, the environment, and the economy. Based on past events and available data, the frequency of tsunamis occurring along the Massachusetts coastline is extremely low.

NOAA's National Geophysical Data Center compiled a list of all tsunamis and tsunami-like waves occurring on the eastern U.S. and Canada (i.e., Region 75). Between the first (in 1849) and most recent (in 2019) recorded incidents, there have been 11 recorded incidents categorized as definite or probable tsunamis (NOAA, 2022b). Of these events, six events were identified as definite tsunamis impacting the East Coast of the U.S. and Canada. Therefore, the historical frequency of tsunamis on the East Coast is approximately one event every 29 years. The last tsunami to affect the Massachusetts coastline was in 2013, when a meteotsunami impacted the New Jersey and southern Massachusetts coastlines. The 2013 meteotsunami was generated by a derecho and produced maximum wave heights of 1.8 feet at Woods Hole over 12 hours and 0.5 feet at Nantucket over nine hours (Bailey et al., 2014). The probability of future tsunami events is low based on historical data and the location and low frequency of activities that cause them (i.e., seismic, volcanic, or landslide events).

5.15.2.2.3 Severity/Intensity

Tsunamis are typically measured by their height at the shore and the maximum run-up of their waves when they strike land (USGS, n.d.). Most tsunamis are usually less than 10 feet high when they strike land. However, they can reach beyond 100 feet high if the source is nearby (NOAA, 2018). The U.S. East Coast has not experienced a major tsunami inundation event in recent history. Current understanding of the potential impact of tsunamis is based on simulations and projections. In 2020, a study developed the most up-to-date inundation maps for the U.S. East Coast based on a hypothetical 9.0 magnitude earthquake in the Puerto Rico Trench (Grilli et al., 2020). To improve understanding of risks and impacts from tsunamis, researchers and planners can consider developing a high-resolution map of areas in Massachusetts at risk for tsunami inundation and adding Massachusetts to the Federal Emergency Management Agency (FEMA) Hazus tsunami software.

Potential Effects of Climate Change on Tsunamis

The effect climate change and sea level rise will have on the frequency of tsunami events is unclear. However, initial research efforts suggest that the impacts of climate change can cause changes in the nearshore bathymetry and coastal geomorphology, which in turn may contribute to more flooding and damage (Dura et al., 2021; Weiss et al., 2022). The number of tsunamis may also increase due to sea level rise and rising temperatures that will lead to isostatic rebound. As ice melts across the world, the earth's crust is expected to rise under the reduced weight. This will cause earthquakes and submarine landslides, potentially triggering tsunamis. Rising temperatures will also lead to glacial earthquakes—glaciers collapsing in a warming climate may trigger massive landslides. Research suggests that these events would generate far more powerful tsunamis than underwater earthquakes and may increase the overall number of these events across the world.

5.15.2.2.4 Warning Time

Tsunami warning centers broadcast across multiple platforms, including local radio, television, social media, and emergency alerts on wireless phones (NOAA, 2018). The four levels of tsunami alerts in the U.S. are Information Statement, Watch, Advisory, and Warning (NOAA, 2016). Tsunamis generated by a local event (e.g., a landslide) may offer little warning, while those caused by a distant event (e.g., an earthquake or volcanic eruption) may provide hours or days of warning time. Seismic activity in the Puerto Rico Trench, for example, would allow more warning time than a local event. Clearing vulnerable areas before a tsunami reaches the coastline is critical to avoid loss of life.

In many cases, there may not be sufficient time to wait for an official alert, so recognizing natural warning signs is important. Examples of natural warning signs include rapid and unexpected recession of coastal water below the expected low tide, a strong or long earthquake, or a loud roar coming from the ocean (NOAA, 2018; Redwood Coast Tsunami Work Group, n.d.). NOAA's Deep-ocean Assessment and Reporting of Tsunami (DART) monitoring buoys can detect tsunamis early and acquire data critical to real-time forecasts (NOAA, n.d.). NOAA has placed DART stations at sites in regions with a history of generating destructive tsunamis. As of 2022, there are 41 DART buoys deployed along the Pacific Rim, Atlantic coast, Gulf of Mexico, and Caribbean Sea (NOAA, n.d.).

When tsunami waves generated by an earthquake occur, the first information available about the source of the tsunami is the seismic information from the earthquake. As the tsunami wave propagates across the ocean and successively reaches the DART systems, the systems report sea level measurements to Tsunami Warning Centers, where the warning centers process the information to produce a new and more refined estimate of the tsunami. The result is an increasingly accurate forecast of the tsunami that can be used to issue watches, warnings, or evacuations.

5.15.2.2.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

Local hazard mitigation plans have not prominently considered tsunamis. In some cases, plans that considered tsunami risk drew heavily from the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP). Information from local plans that relate to coastal hazards like storms, erosion, and sea level rise could be used to further understand the risk of hazards that impact coastlines, such as tsunamis.

For example, the *2021 Hazard Mitigation Plan: Plymouth, Massachusetts* identified tsunamis in the hazard identification plan but decided not to address the hazard. However, the town's plan includes steps to ensure that visitors are safe from potential tsunamis. The town has distributed information on evacuation routes and emergency shelters to facilities that host tourists, such as hotels, bed and breakfasts, guesthouses, and real estate agencies that provide seasonal rentals (Horsley Witten Group, 2021). The table (Table 5.15-2) below summarizes the local context and information available from local plans that considered tsunami risk.

Table 5.15-2. Highlight of Local Plans and Municipal Vulnerability Preparedness (MVP) Program Planning Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
2021 Natural Hazard Mitigation Plan Update, city of Boston, 2021	• Identifies tsunamis as a secondary geological hazard resulting from earthquakes and landslides • Highlighted the low likelihood and high risk due to the submarine topography and possibility of a submarine landslide • Coasts are less than 25 feet above sea level within one mile from the shore • Emphasized the short warning time and potential losses	• Identified risk for coastal neighborhoods such as Charlestown, East Boston, Downtown, Dorchester, Harbor Islands, and South Boston • Listed several lifelines that could be impacted in general terms	• N/A, hazard discussion did not include estimates
Hazard Mitigation Plan: 2020 Update, city of Salem, 2020	• Included tsunamis in the hazard risk summary using 2018 MA SHMCAP language • Included tsunamis as a secondary hazard under earthquakes	• Used 2018 SHMCAP language to identify the hazard as low frequency with potential for extensive damage	• N/A, local plan only included a qualitative description
MVP grant: *Climate Ready Boston Final Report*, 2016	• Not discussed in report	• Tsunamis are mentioned in a footnote about higher mortality for people with disabilities	• N/A, not discussed

5.15.2.3 Secondary Hazards

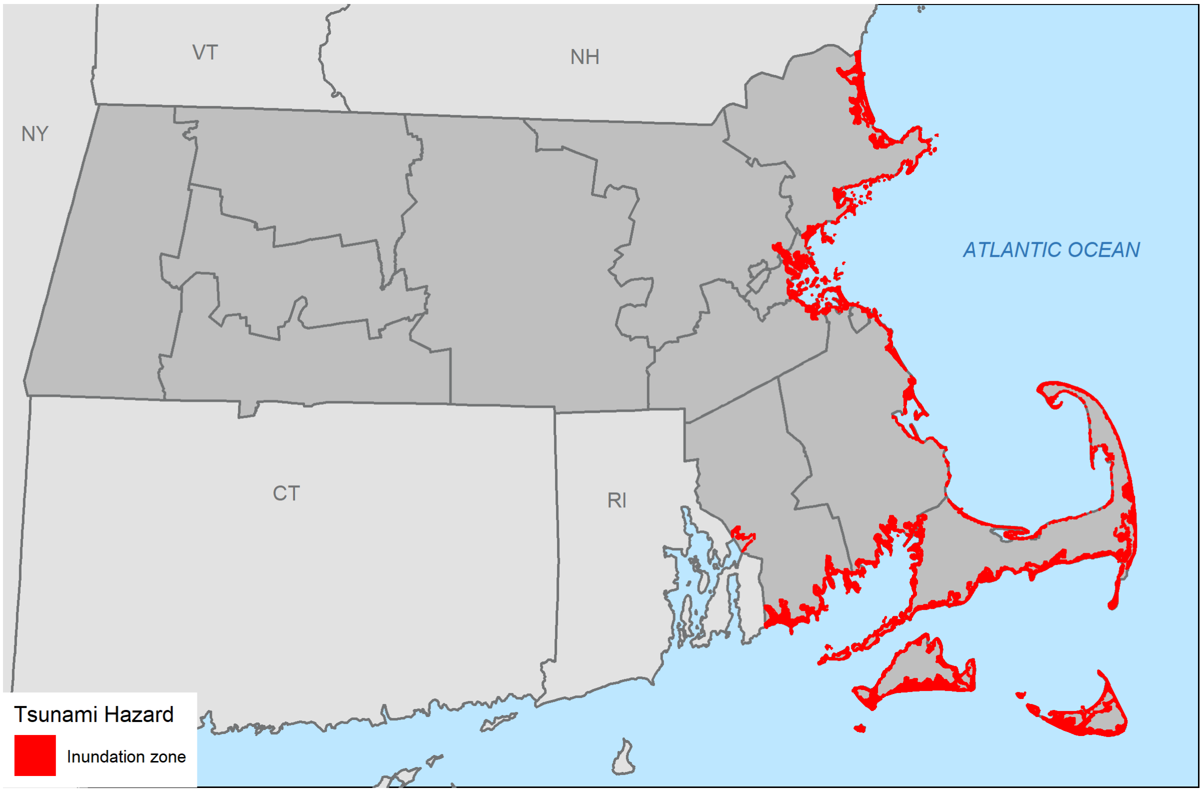
Tsunamis can contribute to several secondary impacts and effects, including:

- Coastal erosion
- Widespread flooding
- Invasive species
- Saltwater intrusion
- Loss of trees, vegetation, and natural resources
- Water quality degradation
- Mobilization of contaminants and toxics
- Reconfiguration of the shoreline

In addition to the tremendous hydraulic force of tsunami waves themselves, floating debris carried by a tsunami can endanger human lives and batter inland structures. Ships moored at piers and in harbors can be swamped and sunk or left battered and stranded high on the shore. Scouring, which sweeps away foundation material, and the impact of the waves can cause breakwaters and piers to collapse. Railroad yards and oil tanks situated near the waterfront are particularly vulnerable. Tsunamis can result in oil fires, which are spread by the waves.

5.15.2.4 Exposure and Vulnerability

Massachusetts is **unlikely** to be exposed to a tsunami. This likelihood is based on historical occurrence and projections of risks for tsunamis and meteotsunamis. Figure 5.15-2 shows the potential inundation zone from a tsunami along the Massachusetts coastline were a major tsunami event to occur. This map is based on the data Grilli et al. (2020) produced from simulations of a hypothetical magnitude 9.0 earthquake in the Puerto Rico Trench, which may be the most likely source of potential tsunamis on the U.S. East Coast.



Source: Grilli et al. (2020).

Figure 5.15-2. Tsunami hazard zones.

It is unlikely that tsunamis and meteotsunamis will affect areas with an elevation greater than 100 feet above sea level and areas more than 3 miles away from the coast. However, tsunamis can have significant impacts on human health, the built environment, infrastructure, the natural environment, and economies. Table 5.15-3 summarizes the potential impacts of tsunami events in the Commonwealth using themes identified in the 2022 Massachusetts Climate Change Assessment, as well as information related to past events in the Commonwealth and across the U.S.

Table 5.15-3. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Tsunamis

Sector	Priority Impacts and Vulnerabilities
Human	• Loss of human life • Emergency service response delays and evacuation disruptions (applies to events leading to injuries and loss of life and requiring health, safety, and traffic first responders) **(most urgent)** • Increase in mental health stressors **(urgent)** • Reduction in food safety and security **(urgent)** • Damage to cultural resources **(urgent)**

Sector	Priority Impacts and Vulnerabilities
Infrastructure	• Damage to rails and loss of rail/transit service **(most urgent)** • Reduction in clean water supply **(urgent)** • Damage to coastal buildings and ports **(urgent)** • Damage to electric transmission and utility distribution infrastructure **(urgent)**
Natural environment	• Freshwater ecosystem degradation **(most urgent)** • Forest health degradation **(most urgent)** • Soil erosion **(urgent)** • Loss of urban tree cover
Governance	• Increase in demand for state and municipal government services **(most urgent)** • Increase in need for state and municipal policy review and adaptation coordination **(urgent)**
Economy	• Reduced ability to work **(most urgent)** • Decrease in agricultural productivity **(urgent)** • Damage to tourist attractions and recreation amenities **(urgent)** • Economic losses from commercial structure damage and business interruptions **(urgent)**

Source: MEMA & EEA (2022).

5.15.2.4.1 Human

Over 74 percent (5.2 million of 7.0 million) of Massachusetts residents live along the coastline (NOAA, 2022a). In the event of a tsunami generated in or near the Commonwealth, there would be little warning time. Approximately 232,021 people live in the 192 Environmental Justice communities that are located in the tsunami hazard zone, where there would be inundation from a potential tsunami event (MassGIS, 2022). By 2040, a majority of coastal counties may experience an increase in population (except for Barnstable County, where there may be a decline) (UMass Donahue Institute, 2018). As new development occurs and people settle along the Massachusetts coastline, the number of communities vulnerable to potential tsunami events will also increase.

As part of the 2023 MA SHMCAP process, Massachusetts state agencies completed a survey where they identified their primary concerns for populations served and potential disproportionate impacts from tsunamis. Table 5.15-4 lists some of the primary concerns.

Table 5.15-4. State Agency Responses: Primary Concerns About Tsunami Impacts on Populations Served and Potential Disproportionate Impacts

Category	Primary Concerns
Populations served	• General public • Injured workers
Disproportionate impacts	• Delayed response and limited resources to respond • Delays in court dates or proceedings • Disproportionate impacts to those reliant on public transportation • Disproportionate impacts to the elderly

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

Vulnerable and Priority Populations

The populations most vulnerable to tsunamis include the following community groups who reside near beaches, low-lying coastal areas, tidal flats, and river deltas that empty into ocean-going waters:

- **Environmental Justice and other priority communities will have challenges in responding and recovering during the aftermath of a tsunami:** People in poverty, members of single-parent households, renters, cost-burdened households, low-income households, unhoused people, and isolated communities/communities with limited access to resources needed to evacuate and recover.
- **Priority population groups are sensitive to any changes to critical lifelines:** People over age 65, people under age five, people with underlying health conditions, people with disabilities, and people who are dependent on public transit.
- **Population groups with limited or lack of access to information and understanding of warning systems for tsunamis:** People with low English proficiency, linguistically isolated people, underrepresented racial or ethnic communities, people over age 65, and people under age five.

In the event of a tsunami generated in or near the Commonwealth, there would be little warning time, so more of the population would be left vulnerable without time to evacuate. The degree of vulnerability of the population exposed to a tsunami event is based on several factors:

- Is there a warning system?
- What is the lead time of the warning?
- What is the method of warning dissemination?
- Will the people evacuate when warned?
- Are evacuation routes widely known and clearly marked?

For this assessment, the population vulnerable to possible tsunami inundation is the same as the exposed population.

Health Impacts

Tsunamis have resulted in massive casualties, injuries, and health impacts (both direct and indirect) throughout the world. During a tsunami, direct mortality can occur as individuals drown in the floodwaters or are struck by fast-moving debris. According to the Centers for Disease Control and Prevention, as tsunamis recede, the strong suction of debris being pulled into densely populated coastal areas can cause additional deaths and injuries (CDC, 2013). Following a tsunami, health concerns include contaminated food and water supplies (discussed in Section 5.15.2.4.3), limited shelters for displaced people, impacts to lifelines (e.g., access to medical care, electricity, communications, and transportation), and exposure to environmental hazards (e.g., pollutants, insects, and any extreme weather events happening concurrently) (CDC, 2013).

5.15.2.4.2 Governance

The impact of waves and scouring associated with debris carried in the water could be very damaging to structures located in a tsunami's path. The most vulnerable structures are those located along the coast, those within the first half-mile inland of tsunami impact, structures with basements, structures with limited or no foundations, belowground assets, infrastructure, and utilities. As with the exposed population, all state buildings within the tsunami inundation zone are exposed to tsunami hazard for the purposes of the 2023 MA SHMCAP analysis. Table 5.15-5 summarizes the number and estimated replacement cost value (structure and contents) of state-owned buildings within the tsunami inundation zone.

Table 5.15-5. Replacement Cost Value of State-Owned Buildings in Tsunami Risk Areas

County	Number of Buildings	Replacement Cost Value (Structure and Contents)
Barnstable	76	$ 359,806,522
Bristol	86	$ 231,252,350
Dukes	9	$ 11,790,250
Essex	76	$ 429,586,700
Middlesex	15	$ 33,117,600
Nantucket	2	$ 946,000
Norfolk	51	$ 9,277,000
Plymouth	148	$ 196,477,650
Suffolk	274	$ 3,334,100,898

Sources: Massachusetts Division of Capital Asset Management and Maintenance (2022); Grilli et al. (2020).

Impacts to government structures and operations due to a tsunami may cause:

- Delays in spill clean-up response, emergency response, and assessment of potentially hazardous conditions
- Delays in technical assistance for affected drinking water, which may cause delayed public health orders (e.g., boil water, do not drink, and/or do not use orders)
- Lack of environmental laboratory testing services for environmental assessment
- Delays in providing background environmental information to assess and respond to a critical concern
- Delays in technical assistance for affected wastewater facilities, which may cause severe environmental hazards due to overflows and potential public health issues from raw sewage releases
- Delayed approvals for clean-up work in wetlands (when needed)
- Potential delays in debris management (including asbestos and construction and demolition debris disposal)
- Potential delays in responding to solid waste disposal and recycling capacity issues

Table 5.15-6 outlines agency responses to the 2023 MA SHMCAP survey regarding primary concerns for services they provide and activities undertaken/planned to address these concerns.

Table 5.15-6. State Agency Responses: Primary Concerns About Tsunamis' Effects on Services, with Suggested Improvements

Category	Concerns/Improvements
Services provided	• Delayed emergency service coordination at the federal, state, and local levels • Delayed 911 services • Disruptions to agency audits and background check services • Disruptions to adjudication of disputed workers' compensation claims • Disruptions to transportation
Updates, improvements, or enhancements needed to address concerns	• Improve severe weather emergency response plans • Collaborate with partner agencies to increase resources and staffing • Coordinate with phone carriers to assess vulnerable infrastructure that serves 911 (e.g., cell towers) • Conduct proceedings virtually

Source: ERG (2023).

The responses to the survey were completed by agency staff and did not go through formal review.

5.15.2.4.3 Infrastructure

All elements of the built environment within the tsunami inundation zones are at risk from a tsunami event. Assets such as hospitals, elder care facilities, prisons, animal care facilities, and schools are most vulnerable during a tsunami as they require special care and coordination. Below- and at-grade infrastructure, utilities, and buildings are also at great risk. Table 5.15-7 and Table 5.15-8 summarize the number of state-owned critical facilities per county and by type.

Table 5.15-7. Number of Critical Facilities Exposed to Tsunami Exposure Area by County

County	Number of Exposed Critical Facilities
Barnstable	21
Bristol	16
Dukes	2
Essex	5
Middlesex	4
Nantucket	2
Norfolk	1
Plymouth	50
Suffolk	48

Sources: Massachusetts Division of Capital Asset Management and Maintenance (2022); Grilli et al. (2020).

Table 5.15-8. Number of Critical Facilities Exposed to Tsunami Exposure Area by Type

Type of Facility	Number of Exposed Critical Facilities
Administration	7
Communications	3
Corrections	2
Education	5
Energy facilities	11
Fire facilities	4
Laboratories and research	2
Maritime	12
Military facilities	3
Parks and recreation	9
Police facilities	7
Social services	10
Transportation	7

Type of Facility	Number of Exposed Critical Facilities
Waste management	4
Water resources	19

Sources: Massachusetts Division of Capital Asset Management and Maintenance (2022); Grilli et al. (2020).

Agriculture

Tsunamis that flood farmland could have a devastating and long-term impact on cropland and livestock. Flooding will lead to an increase in soil salinity and potential pollutants (e.g., heavy metals) and debris across the farmland. Tsunamis may also destroy irrigation infrastructure and farming equipment. Massachusetts coastal counties produce a total annual market value of $245 million, which is approximately 52 percent of the state’s market value in agricultural products sold (Massachusetts Department of Agricultural Resources, 2017); much of this value could be damaged or lost in the event of a large tsunami.

Energy

The force of tsunami waves can also impact aboveground utilities by knocking down power lines and radio/cellular communication towers. Power generation facilities can be severely damaged or destroyed by both the velocity impact of the wave action and the inundation of floodwaters. Electrical components located below or at grade can also be damaged. Widespread and long-lasting power outages would likely occur after a large tsunami event.

Public Health

Like inland and coastal flood events, tsunamis affect public health by increasing potential exposure to mold and toxic substances. Hospitals and medical facilities that are impacted by a tsunami would have limited capacity to care for patients due to flooding, loss of power, or physical damage. They would also have difficulty caring for and evacuating the patients in their care.

Public Safety

Flooding and damage caused by a tsunami would greatly impact public safety, which is an important component in managing tsunami-related emergencies. As shown in Table 5.15-8, seven state-owned police facilities and four fire departments are exposed to the tsunami hazard. Municipally owned facilities within the tsunami hazard zone are also vulnerable. Responding to damage and disruption of public safety assets and facilities while also dealing with disruptions to transportation, access, communication, and other services would put an incredible strain on public safety services during the initial response timeframe.

Transportation

Roads are the primary resource for evacuation to higher ground before and during a tsunami event. Once a tsunami comes onto land, flooding and debris from the event will damage and disrupt all transportation systems and networks that are exposed to the hazard, making roads and rail impassable during and after the initial event. Bridges are often damaged or destroyed by tsunami events due to the forces transmitted by the wave run-up and the impact of debris carried by the wave action. Other transportation elements that would incur significant damage are underground infrastructure, tunnels, rail stations, and electric components necessary to maintain and operate the systems.

Water Infrastructure

Water infrastructure (e.g., water treatment plants located within the tsunami inundation zone) is significantly vulnerable to this hazard. Tsunamis have the potential to contaminate water supplies, cause salinity intrusion into aquifers and groundwater, overwhelm stormwater and drainage systems, and cause major damage and disruption to utility assets and functions. Widespread contamination of freshwater sources is likely, as is contamination from wastewater systems into fresh and marine water sources. It is likely that more widespread regional impacts could occur if saltwater were to inundate drinking water supplies or overburden stormwater or wastewater systems. It would take a significant amount of time to restore assets and services to normal function after a large tsunami event.

5.15.2.4.4 Natural Environment

The environmental impact of tsunamis can be widespread and devastating. The inundation of typically dry areas can reshape the area's topography, both by scouring existing sediment and by depositing sediment from other locations. In addition to these physical impacts, a tsunami can also uproot trees and other plants in its path, causing animals to lose habitats (e.g., bird nesting sites). Animals in the area could also die as a result of drowning, and marine animals could die as a result of chemicals or contaminants swept into the ocean. These chemicals and contaminants, as well as saltwater, can remain in aquifers or can percolate into groundwater supplies after the tsunami recedes, causing extensive and prolonged environmental devastation. Erosion, scouring, and contamination and debris from a tsunami creates significant and long-lasting damage to ecosystems, habitats, native species, and ecosystem functions. These impacts also contribute to secondary hazards, such as increased flood risk, additional erosion, landslides, invasive species, and effects from extreme temperatures. Table 5.15-9 lists the potential exposure of core habitats in Massachusetts to inundation from tsunami events.

Table 5.15-9. Exposed Core Habitat to Tsunami Risk

Core Habitat (acres)	Exposed to Tsunami Risk (acres)	Percent Exposed to Tsunami Risk (%)
Aquatic (316,804)	10,262	3.2%
Forest (438,475)	57	0.01%
Rare species (984,847)	50,046	5.1%
Vernal pools (241,046)	1,416	0.59%
Wetland (159,550)	1,453	0.91%

Source: MassWildlife & The Nature Conservancy (2022).

5.15.2.4.5 Economy

A large tsunami would have a significant impact on Massachusetts' coast-dependent economy. Losses include, but are not limited to, general building stock damage, business interruption/closures, airport and seaport closures, utility and transportation damage, and impacts on tourism and the tax base. Airport and seaport facilities, naval facilities, fishing fleets, and public utilities, which are often the backbone of the economy in coastal areas, generally receive the most severe damage. Until debris can be cleared, wharves and piers rebuilt, utilities restored, and fishing fleets reconstituted, communities may find themselves without fuel, food, and employment. Tsunamis can disrupt coastal systems in areas where water transport is a vital means of supply, causing far-reaching social effects.

Because there have not been any major tsunami events in Massachusetts history, it is difficult to calculate the probable cost of such an event. The FEMA Hazus Loss Estimation Software Program can estimate potential economic impacts, damage to buildings and lifelines, casualties, and other impacts from tsunamis. However, the tsunami analysis component is not available for Massachusetts. Future risk assessments can consider incorporating Hazus findings when the tool is made available for the Commonwealth.

Chapter 5. Risk Assessment and Hazard Analysis

Wildfires

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5.16 Wildfires

5.16.1 Wildfire Problem Statement

The ecosystems most at risk from wildfires in the Commonwealth are pitch pine, scrub oak, and oak forests. Due to vegetation, sandy soil, and wind conditions, Barnstable, Essex, Plymouth, Hampshire, Norfolk, and Hampden counties are the most fire prone. Climate change projections anticipate an increase in the risk for drought, warmer temperatures, and increased invasives. These impacts from climate change will result in dry, damaged, and more flammable vegetation, meaning the risk of wildfire throughout the Commonwealth is likely to be heightened. Wildfires can cause considerable damage and loss of life to communities living at the wildland-urban interface (WUI), including impacts to public health, ecosystems not adapted to fire, water sources, infrastructure, and buildings in these areas. Fire poses direct risks to structures, emergency workers, and people living in or near exposed areas, as well as indirect risks to public health due to smoke. The economic consequences of wildfires can be substantial, both due to the initial loss of structures, agricultural resources, revenue from business and tourism, and natural heritage, as well as the cost of cleanup, debris removal, restoration, and rebuilding.

5.16.2 Wildfire Risk Assessment

5.16.2.1 General Background on Hazard

A wildfire is an uncontrolled, unplanned fire that spreads through natural or unnatural vegetation. Severe wildfires have the potential to threaten lives and property and can cause smoke-related accidents and illnesses. Fire is a natural process that occurs in the landscape and has helped shape the landscape and maintain the ecological integrity of many natural communities in Massachusetts. However, increased development within the wildland-urban interface (WUI), the legacy of historical fire suppression practices, climate change, and invasive insects, pests, and plants have increased the risks associated with wildfire. Wildfires in Massachusetts are caused by natural events (such as lightning) and human activity. Wildfires often begin unnoticed but spread quickly, igniting brush, trees, and potentially homes. Fast-moving fires typically occur from March to June. Deep-burning duff fires can occur in the drier months of June through November. April is historically the month in which wildfire danger is the highest. However, drought, snowpack level, and local weather conditions can impact the timing and length of the fire season.

Many human and environmental factors contribute to wildfire occurrence across the U.S. Environmental factors include temperature, soil moisture, relative humidity, wind speed, and vegetation. Research shows that climate change and rising atmospheric temperatures are creating warmer and drier conditions in the landscape. Increased periods of prolonged drought are leading to reduced soil moisture and dry vegetation, creating increasing flammability of duff and live vegetation, therefore creating more fuels with the potential to burn. Additionally, occasional periods of heavy rainfall,[1] along with increased carbon dioxide and warmer temperatures can hasten vegetation growth and therefore lead to increased fuel buildup. Warming temperatures are also leading to shorter winters, meaning reduced snowpack and earlier spring melt (Wehner et al., 2017). One study found that increased temperatures and the corresponding increase in dry fuels doubled the area burned by wildfire between 1984 and 2015 (Wehner et al., 2017).

Potential Effects of Climate Change on Wildfire

Current climate models predict that by mid-century, there will be an increase in high heat days in Massachusetts. The *2022 Massachusetts Climate Change Assessment* (MA Climate Assessment) finds that inland areas are expected to experience roughly 25 days above 90°F, and roughly 19 days above 90°F for coastal areas, which can lead to more frequent droughts. Current average high temperatures in Massachusetts are around 81°F. Worldwide, wildfires are projected to increase by 14 percent by 2030, 30 percent by 2050, and 50 percent by 2100 (World Meteorological Organization, 2022). Additionally, under the representative concentration pathway 8.5 greenhouse gas emissions future, wildfire occurrence probability in New England is projected to double by 2100 (Gao et al., 2021). Calculations for projected increases in wildfires are not currently available for Massachusetts.

Massachusetts has experienced droughts of various levels over the past decade; more detail is provided in Section 5.6 (Drought). In August 2022, roughly three-quarters of the state was declared to be in a “critical drought” status, just one level below the most severe “emergency drought” level, with the rest of the state in a declared “significant drought” status (Drought Management Task Force, 2022). The extended period of drought the Commonwealth experienced in spring 2022, along with other factors, contributed to ideal wildfire conditions and an extended fire season. Massachusetts experienced over 100 wildfires in August 2022, compared to a monthly average of less than 50 (LeMoult, 2022). Seasonal droughts such as the one experienced in 2022, are expected to become more frequent due to climate change (Commonwealth of Massachusetts, 2022).

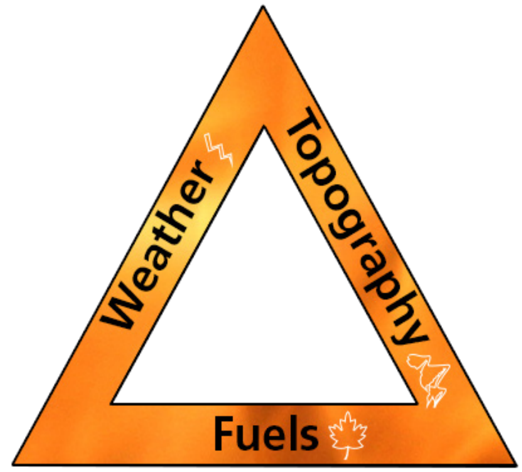
Effects of Land Management on Wildfire

Different forest management and fire suppression practices over the past few decades have altered the relationship between the human and environmental factors related to wildfires. An important and beneficial change is active land management that incorporates fire back into the landscape. Using fire to improve and enhance ecosystem health is accomplished through the safe application of prescribed fire, which helps manage invasive species, removes highly flammable material, and provides space for new

[1] On an annual basis and in most years, scientists predict that the total annual precipitation in Massachusetts will increase. However, the frequency of rainy days is more variable. As temperatures increase, the atmosphere’s moisture holding capacity increases, therefore leading to more intense rainfall on a rainy day (Commonwealth of Massachusetts, 2022).

growth. The use of prescribed fire and other active management strategies is becoming increasingly important because of the impact from an increase in the presence of invasive insect pests and plants. In 2022, there were 67 prescribed fire operations totaling over 1,940 acres in the Commonwealth (Massachusetts Department of Conservation and Recreation Bureau of Forest Fire Control, 2022)Hazard Description

Fire Risk Associated with Fire Behavior



Source: National Park Service (2017).

Figure 5.16-1. Wildfire behavior triangle.

The "wildfire behavior triangle" reflects how three primary factors influence wildfire behavior: fuel, topography, and weather (Figure 5.16-1). Each point of the triangle represents one of the three factors, and arrows along the sides represent the interplay between the factors. For example, drier and warmer weather with low relative humidity combined with dense fuel loads and steeper slopes can result in dangerous to extreme fire behavior. These three characteristics are described below (National Park Service, 2017):

- Fuel
  - Lighter fuels such as grasses, leaves, and pine needles quickly expel moisture and burn rapidly, while heavier fuels such as tree branches, logs, and trunks take longer to warm and ignite.
  - Snags and hazard trees, especially those that are diseased or dying, become receptive to ignition when influenced by environmental factors such as drought, low humidity, and warm temperatures.
  - Forests of pine plantations and unmanaged pine forests have grown to be extremely dense, creating unhealthy stands that are more susceptible to diseases and insect outbreaks. As forests die, the snags and downed woody materials provide fuel that could contribute to extreme fire and prevent suppression resources from safely accessing forests to control the burns. This is especially true in red pine plantations, which were planted during the Great Depression by the Civilian Conservation Corps. The trees in these plantations are rapidly dying of diseases and pose a fire risk on numerous state and federal properties.
  - Decades of fire exclusion—the practice of deliberately excluding or preventing fire on the landscape where fire is a natural part of the cycle—has led to a buildup of flammable vegetation (both dead and alive) that could provide fuel for extreme fire behavior in many fire-dependent ecosystems.

- Declining forest health due to outbreaks and the expanding range of forest insect pests (e.g., hemlock looper, hemlock wooly adelgid, and southern pine beetle), as well as increases in non-native invasive plant species such as woody invasive shrubs, trees, and vines, have increased fuel availability. The invasive common reed within major river systems and freshwater and brackish tidal marshes has increased availability of fuel in these areas as well.

- Weather
  - Strong winds, especially wind events that persist for long periods or have significant sustained wind speeds, can exacerbate extreme fire conditions, accelerate the spread of wildfire, and reduce wildfire suppression ability.
  - Dry spring and summer conditions, or drought at any point of the year, increases fire risk. Low dew points and reduced air moisture contribute to this risk. Similarly, the passage of a dry cold front through the region can result in sudden wind speed increases and changes in wind direction. In the spring and summer, coastal areas have strong sea breezes. These major weather factors can increase risk of fire propagation in fire-prone areas.
  - Thunderstorms in Massachusetts are usually accompanied by rainfall; however, during periods of drought, lightning from thunderstorm cells can result in fire ignition, which has been documented in different regions of the state. Thunderstorms with little or no rainfall are rare in New England but do occur.
- Topography
  - Topographic features such as canyons, ridges, chutes and saddles, and natural or constructed barriers affect fire behavior (National Wildfire Coordinating Group, n.d.).
    - When fires reach a ridgeline, the rate of spread often slows as it encounters opposing airflow coming from the other side of the ridge. However, erratic winds caused by various winds converging at the ridgetop can change fire behavior, especially if winds on one side of the ridge are stronger than on the other side.
    - Winds blowing through a chute or saddle can increase in speed as they are pushed through a constricted area and then spread out on the downwind side. These winds can cause fires to change direction and can accelerate their spread.
  - Topographic characteristics such as slope, aspect, and position on slope affect fire behavior. Aspect can also influence vegetation type. South- and west-facing aspects typically have drier soils and support more flammable vegetation. North-facing aspects tend to be wetter and have less flammable vegetation (National Wildfire Coordinating Group, n.d.).

The most dangerous wildfires in Massachusetts are crown fires (fires burning in the forest canopy) that occur in pitch pine forests. Pitch pines growing in dense stands with thick understory vegetation contribute to a risk of non-natural, extreme fires in these areas. This overgrowth of vegetation in the understory results from a lack of frequent low-intensity fires (and often periodic high-intensity stand-replacing fires). Crown fires generally cannot be stopped or controlled by firefighters because the flame lengths are too great, the fire intensity is too high, and the spotting distance is too long. Crown fires can be prevented by thinning the overstory and reducing overstory fuel depth and ladder fuels through prescribed fires and mechanical thinning treatments (Bried et al., 2015).

Fire Ecology

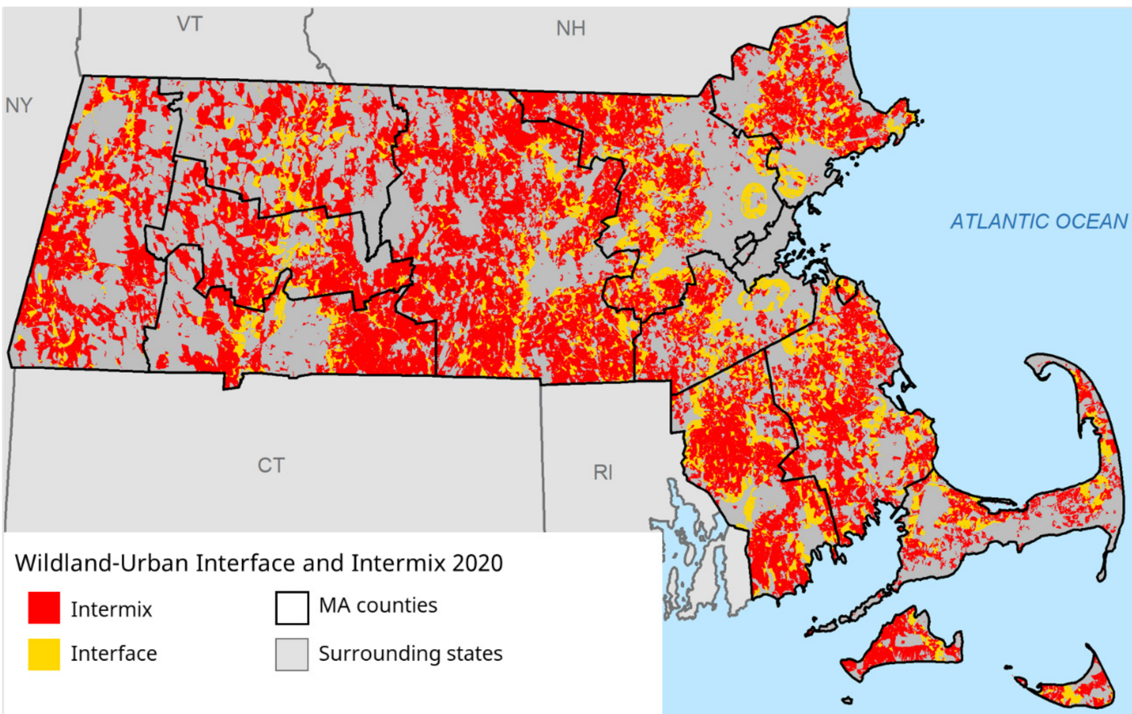
There are 30 fire-influenced natural communities in Massachusetts, over half of which are identified as Priority Natural Communities, including several communities within this subset that are of global significance (MassWildlife, 2017a). As of 2017, there were 114 rare and declining fire-influenced plants and 85 rare and declining animals that rely on fire-influenced natural communities in Massachusetts (MassWildlife, 2017b). Fire-influenced natural communities in Massachusetts include rock summits and outcroppings (e.g., Dry Riverside Bluffs, Riverside Rocky Outcrops), grasslands (e.g., Sandplain Heathland, Sandplain Grassland), shrublands (e.g., Maritime Shrubland, Maritime Oak and Pine Woodland, Pitch Pine-Scrub Oak Community, Scrub Oak Shrubland), forest and woodland communities (e.g., Mixed Oak Forest, Pitch Pine-Oak Forest/Woodland, Forest Seep Community), and wetland communities (e.g., Coastal Atlantic White Cedar Bog/Swamp, Coastal Plain Pondshore) (MassWildlife, 2017b).

Pitch pine barrens are a fire-dependent community primarily located in glacially derived sandy soils. Most pine barrens are located in southeast Massachusetts, the Elizabeth Islands, and the Connecticut River Valley. Because this community is fire-dependent, it is often considered the most fire-prone ecosystem. While this community is more likely to burn compared to other forest communities, fire is a necessary part of its landscape. It is important to distinguish between healthy fires and extreme and unnatural wildfires that are destructive to the ecosystem and surrounding uses.

Wildland-Urban Interface

The WUI is the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels. There are a number of reasons the WUI experiences an increased risk of wildfire damage. For example, wildfires can create large embers or fire brands, which can fall on or near structures, causing them to catch fire. Additionally, a structure fire could spread to nearby wildland fuel, which could then carry the fire to other structures (Gollner et al., 2015). Access and fire suppression issues on private property in the WUI can make protecting structures from wildfires difficult. This zone also faces increased risk as structures are built in densely wooded areas, so fires started on someone's property can more easily spread to the surrounding forest.

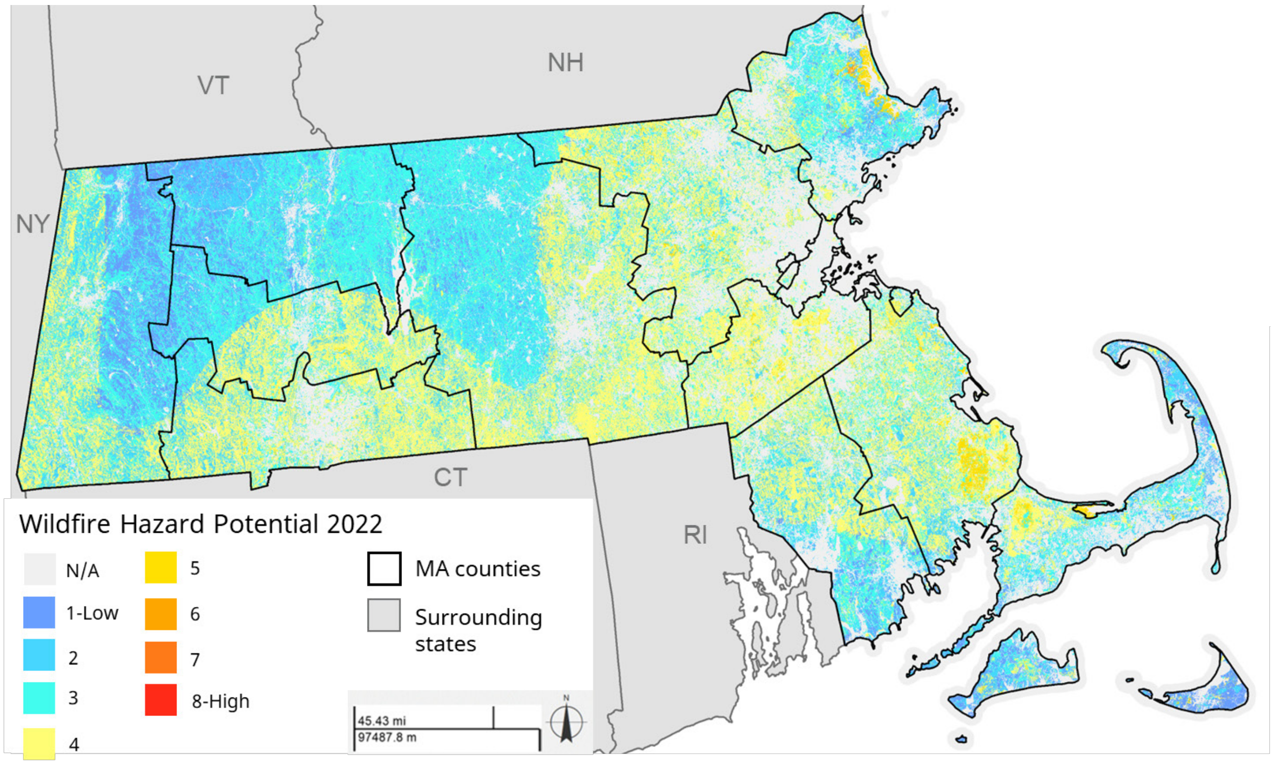
Over 60 percent (3.1 million acres) of Massachusetts is covered in forest, with 79 percent of these forests in private ownership, primarily owned by families and individuals (University of Massachusetts Amherst, n.d.). The Massachusetts Department of Fish and Game (DFG) and the Department of Conservation and Recreation (DCR) own about 10 percent of the Commonwealth's forests. Around 20 percent of land in Massachusetts (both forested land and other) is protected from development. Roughly 65 percent of the land base in the Commonwealth is characterized as WUI, as demonstrated in Figure 5.16-2. While the overall risk of extreme wildfires is low throughout the Commonwealth, this high percentage of WUI land base means that even smaller fires pose a significant risk to residents and structures in the Commonwealth.



Source: ERG analysis using data from SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin–Madison, 2020.

Figure 5.16-2. WUI for the Commonwealth of Massachusetts.

The population of Massachusetts is expected to increase by between 20,000 and 120,000 people by 2040 (with the population of Barnstable County expected to decrease by at least 30,000). Due to the already high percentage of WUI land base in the Commonwealth, this increase in population would likely increase the percentage of WUI land base in the Commonwealth. Essex and Plymouth County, which both have low to medium wildfire hazard potential (range of 1–5 wildfire hazard potential on the 1–8 scale; see Figure 5.16-3 below), both counties are expected to experience a population increase of at least 70,000 by 2040.



Source: Map created by ERG using data from Northeast-Midwest Wildfire Risk Explorer (2022).

Figure 5.16-3. Wildfire hazard potential for the Commonwealth of Massachusetts.

Fire has been used in some areas of the Commonwealth as a land management tool to accomplish both fire-dependent ecosystem restoration and hazard fuel mitigation objectives on federal, state, municipal, and private lands in Massachusetts since the 1980s. Prescribed fire is intended to mitigate high-hazard fuel loading in and around WUI zones, improve wildlife habitat, and build ecosystem resilience. Approximately 40 percent of the 427 plant and animal species listed in the Massachusetts Endangered Species Act benefit from the conditions created and maintained by prescribed fire or periodic naturally occurring, low-intensity fires (MassWildlife, 2022). The Massachusetts Division of Fisheries and Wildlife's (MassWildlife's) Prescribed Fire Management Handbook, last updated in 2017, outlines goals, procedures, and policies for implementing prescribed fire on wildlife management areas across the Massachusetts landscape. MassWildlife coordinates with DCR and other state and federal agencies, as well as private conservation organizations, tribal entities, towns, universities, and private landowners to apply prescribed fire across land ownerships (MassWildlife, 2022).

Massachusetts has been expanding its use of prescribed fire incrementally over the past two decades to improve wildlife habitat, build ecosystem resilience, promote research, and increase prescribed fire and wildland fire training opportunities. In 2022, MassWildlife safely conducted over 30 prescribed fires for ecological and training purposes throughout the state and continues to train its staff and partners annually in the safe use of prescribed fire. Other state and federal agencies that utilize prescribed fire in the Commonwealth include DCR, the Massachusetts Army National Guard, municipal fire departments, conservation and natural resource agencies, the U.S. Fish and Wildlife Service, the Department of Defense, and the U.S. Air Force. Non-governmental organizations such as The Nature Conservancy and The Trustees of Reservations, as well as private landowners, also utilize prescribed fire. In 2022, these agencies and organizations completed 74 prescribed fire operations, totaling over 2,066 acres treated (Celino, 2022).

In Massachusetts, local fire chiefs or fire wardens have jurisdictional responsibility for wildfire response on over three million acres of state, public, and private open lands. The DCR Bureau of Forest Fire Control is the state agency responsible for providing aid and assistance in the form of wildfire response expertise to the cities and towns throughout the Commonwealth. The Bureau will help coordinate efforts with a range of entities, including MassWildlife, national interagency systems, fire departments, local law enforcement agencies, the Commonwealth's county and statewide civil defense agencies, and mutual aid assistance organizations. Local fire chiefs have jurisdiction over all fires in the Commonwealth, including those on state lands.

Bureau units respond to all wildfires that occur on state-owned forestland and are available to municipal fire departments for mutual assistance. Bureau firefighters are trained to national standards in wildland fire suppression, planning, fire weather, fire behavior, and overall risk management. Massachusetts also benefits from mutual aid agreements with other state and federal agencies. The Bureau is a member of the Northeastern Forest Fire Protection Commission, a commission organized in 1949 by the New England states, New York, and four eastern Canada provinces to provide resources and assistance in the event of large wildfires. Massachusetts DCR also has a long-standing cooperative agreement with the U.S. Department of Agriculture's Forest Service, both for providing qualified wildland firefighters for assistance throughout the U.S. and for receiving federal assistance within the Commonwealth.

5.16.2.1.1 Location

The following areas and ecosystems in the Commonwealth have notable risk from extreme wildfire hazard:

- According to the *2021 Hazard Mitigation Plan: Plymouth, Massachusetts*, the Myles Standish State Forest and the Pine Hills are at high risk. While the Myles Standish Forest is permanently protected, the surrounding Pine Hills are prone to fires and some of the largest fires in the Commonwealth have occurred here. Therefore, fires in these areas pose a risk to communities in the surrounding areas (Horsley Witten Group, 2021).

- Martha's Vineyard, Nantucket, and Cuttyhunk are home to ecosystems that include pine barrens and maritime grasslands, which can be extremely flammable (SWCA Environmental Consultants, 2021).
- Coastal and inland marshes which have been invaded by non-native *Phragmites*, including several major river systems that have been invaded by common reed, particularly in the eastern parts of the Commonwealth.
- Scattered pine barrens in the WUI in the Connecticut River Valley.

According to the 2022 wildfire hazard potential map for the Commonwealth (see Figure 5.16-3 below), nine counties within the Commonwealth had areas of medium wildfire hazard potential (hazard potential numbers of 4–6). Areas in Barnstable, Essex, and Plymouth counties show the highest wildfire hazard potential in the Commonwealth. Some areas of the Commonwealth, such as parts of Essex County, are at high risk for brush fires, which are usually smaller than wildfires and burn no more than the underbrush of a forested area. As noted in the city of Salem's local hazard mitigation plan, while these fires are typically smaller than wildfires that burn in the forests, they still present a hazard due to their potential to spread into developed or inhabited areas (Metropolitan Area Planning Council, 2020).

Other portions of the Commonwealth are also susceptible to wildfire hazards, particularly at the WUI. The SILVIS Lab at the University of Wisconsin–Madison Department of Forest Ecology and Management classifies exposure to wildfire hazard as "interface" or "intermix." Intermix communities are those where housing and vegetation intermingle and where the area includes more than 50 percent vegetation and has a housing density greater than one house per 16 hectares (approximately 6.5 acres). Interface communities are defined as those in the vicinity of contiguous vegetation, with more than one house per 40 acres and less than 50 percent vegetation, and within 1.5 miles of an area of more than 500 hectares (approximately 202 acres) that is more than 75 percent vegetated. Figure 5.16-1 above illustrates the WUI and intermix for 2020.

5.16.2.1.2 Previous Occurrences and Frequency

Previous Occurrences

Several notable wildfires have occurred in Massachusetts history, although none has ever resulted in a disaster declaration by the U.S. Federal Emergency Management Agency. Wildfires in the Commonwealth tend to be around five acres. Due to the relatively small size of the incidents compared to larger fires in California and other parts of the West, it can be difficult to consistently track and record these fires since they are not federally declared events. As such, it is difficult to compile a consistent historical record of wildfires for the Commonwealth. In 2017, DCR began working to improve fire reporting data. Therefore, the most accurate wildfire data for the Commonwealth is available starting for 2017. As of November 28, 2022, 1,027 fires had burned 2,716 acres in 2022. Large fires in Essex County (164 fires burned 603.9 acres total) and Worcester County (153 fires burned at least 446.7 acres total) contributed to 2022 being the largest fire year of the past six years in terms of acres burned (Massachusetts Department of Conservation and Recreation, 2022). Fire occurrences for the Commonwealth from 2017 to 2022 are summarized in Table 5.16-1 below.

Table 5.16-1. Fire Occurrences in Massachusetts by County, 2017–2022

County	2017		2018		2019		2020		2021		2022[a]	
	# Fires	Acres	# Fires	Acres	# Fires	Acres	# Fires	Acres	# Fires	Acres	# Fires	Acres
Barnstable	144	86.4	187	50.5	23	18.2	121	41.6	171	47.1	185	32.7
Berkshire	49	92.4	23	18.8	10	13	10	2.5	56	966.6	26	49.9
Bristol	45	62.3	26	22.8	—	—	65	53.1	38	21.4	57	43.4
Dukes	1	8	12	3	2	1.1	11	3	12	5	7	1.5
Essex	52	63.3	47	27.7	37	63.2	147	35.4	103	155	207	592.2
Franklin	39	20.8	30	15.5	13	10.4	71	118.8	56	26.7	48	23.3
Hampden	128	44.5	139	69	—	—	147	98.4	43	40.5	103	101.6
Hampshire	28	24.8	27	22.8	11	1.3	41	56.5	13	4.7	15	22.8
Middlesex	35	26	87	32	69	33.1	293	170.5	265	129.1	96	102.7
Nantucket	3	0.75	—	—	1	0.25	5	0.65	—	—	4--	.8--
Norfolk	106	46.5	35	8.7	—	—	44	28.5	28	13.3	63	115.6
Plymouth	391	134.8	291	87.3	—	—	168	86.2	153	99.6	163	57.1
Suffolk	—	—	6	1.5	—	—	—	—	—	—	1	0.25
Worcester	168	88.81	98	113.4	53	27.9	230	202.72	196	168	156	431.2
Total	**1,242**	**721.4**	**1,008**	**473.2**	**281**	**248.4**	**1,353**	**897.8**	**1,134**	**1,676.9**	**1,196**	**1,785**

Sources: Massachusetts Department of Conservation and Recreation (2018, 2019, 2020a, 2020b, 2021); 2022 data represent fires from January 1, 2022 through December 31, 2022.

Table 5.16-2 below is an additional, partial list of large wildfires in Massachusetts history dating back to 1836.

Table 5.16-2. Partial List of Large Wildfires in Massachusetts, 1836–2022

Year	Location	Acres
1836	Pocasset/Sandwich	5,760
1843	North Falmouth/West Barnstable	7,680
1866	Monument/Sandwich	4,200
1875	Martha's Vineyard	7,000-10,000
1887	Bourne	25,000
1900	Plymouth/Carver	32,000
1909	Bourne/Falmouth	10,000
1909	Martha's Vineyard	10,000
1916	Martha's Vineyard	12,000
1923	Bourne	25,000
1927	Townsend State Forest	16,000
1927	Erving to Wendell	7,000
1927	Montague Plains/Village of Lake Pleasant	(*No acreage data available, destroyed Village of Lake Pleasant*)
1927	Martha's Vineyard	6,400
1930	Barnstable	16,600 (97 fires)
1932	Sandwich	4,000
1953	Mashpee	1,300
1935	Martha's Vineyard	4,000
1937	Bourne	300
1937	Hyannis	2,000
1937	Falmouth	1,500
1937	Montague	1,200
1938	Sandwich	5,000
1938	East Sandwich	1,500
1939	Martha's Vineyard	4,000
1941	Marshfield	550 buildings destroyed
1944	Montague	>1,000
1946	Camp Edwards	50,000
1946	Martha's Vineyard	5,120
1957	Plymouth	15,000

Year	Location	Acres
1957	Montague	475
1959	Camp Edwards	3,000
1963	Plymouth	530
1964	Plymouth	5,500
1964	Sandwich/Bourne	1,300
1965	Sandwich	5,000
1965	Martha’s Vineyard	1,200
1966	Plymouth/Wareham	535
1982	Camp Edwards	2,280
1986	Camp Edwards	1,334
1988	Camp Edwards	1,480
1995	Russell	1,100
1997	Camp Edwards	1,100
2000	South Hadley	310
2000	Erving	140
2001	Ware	400
2010	Russell	320
2021	Clarksburg	947
2022	Rockport	156

Sources: Clark & Patterson (2003); Massachusetts Department of Conservation and Recreation (2020b, 2021, 2022, 2022).

Frequency

As discussed above, several factors (such as weather and temperature) affect the potential for extreme wildfires. Because some conditions (e.g., ongoing land use development patterns, location, fuel sources, forest management practices) exert changing pressure on the WUI zone, it is difficult to predict the likelihood of a wildfire in a particular location in a probabilistic manner. While it is difficult to develop an accurate, reliable, probabilistic prediction of the annual likelihood of a wildfire happening in a determined location, understanding the risk factors that make a wildfire more likely can help communities consider and manage risk.

While wildfires in the West are generally at much larger scales than in the Northeast, according to the Northeast Region Cohesive Wildland Fire Management Committee, the Northeast Area (Maine to Minnesota and Missouri to Maryland) has the largest number of wildfires year after year compared to other regions; the Northeast region sees over 11,000 wildfires per year, burning an average of 130,000 acres (Northeast Regional Cohesive Strategy Committee, 2019). In the past six years (2017 to November 2022), the Commonwealth experienced a total of 6,045 fires that burned at least 6,733.8 acres.

Climate change is influencing changes in wildfire frequency and behavior. More frequent and more severe droughts, as well as temperature increases, are driving an increase in fires that burn more intensely than in previous years. Over the past six years (2017 to 2022), the number of wildfires in Massachusetts has fluctuated and has decreased since 2020. However, the number of acres burned has increased significantly; in 2022, 1,994.7 more acres burned than in 2017 (Massachusetts Department of Conservation and Recreation, 2022).

5.16.2.1.3 Severity/Intensity

The National Wildfire Coordinating Group defines seven classes of wildfires:

- Class A: 0.25 acre or less
- Class B: more than 0.25 acre, but less than 10 acres
- Class C: 10 acres or more, but less than 100 acres
- Class D: 100 acres or more, but less than 300 acres
- Class E: 300 acres or more, but less than 1,000 acres
- Class F: 1,000 acres or more, but less than 5,000
- Class G: 5,000 acres or more

Unfragmented and heavily forested areas of the Commonwealth are vulnerable to wildfires, particularly during droughts. However, wildfires are part of the history of these forests and are not, by themselves, a risk. Risk is determined by the conditions and context within which the wildfire occurs. Conditions are being influenced by climate change, with droughts, invasive species, and extreme heat all increasing and affecting wildfire risk. The context of surrounding land use also increases the risk. The greatest potential for significant damage to life and property from fire exists in areas designated as WUI areas. A WUI area defines the conditions where development has been placed in or adjacent to wildlands and forestlands. These development areas have been sighted in lands that have burned throughout history. The presence of development within and adjacent to wildlands and forestlands makes managing these lands challenging and significantly increases the risk associated with wildland fires, even those that are historically beneficial and necessary in fire-dependent ecosystems.

Fire intensity is measured by the energy released from the fire as well as characteristics such as flame length. A commonly used measure of fire intensity is fireline intensity, which refers to the rate of heat transfer per unit length of fire (measured in kW m^{-1} or kilowatt meters) and measures the energy released from the flame (Keeley, 2008). Fireline intensity tends to correlate with flame length.

Fire severity is a quantitative measure of the effects of fire on an ecosystem that measures the loss of or change in aboveground and belowground organic matter. Fire severity is described on a spectrum ranging from unburned/low severity to moderate severity and to high severity (Berger et al., 2018). Fire severity measurements can vary depending on the ecosystem in which the fire burns. In forests, fire severity is measured based on canopy loss or tree mortality. In shrublands, where all aboveground biomass is usually burned, the same fire severity measures used in forests are generally not relevant. In these cases, ecosystem indicators of fire severity may include resprouting success and seed bank survivorship (Keeley, 2008).

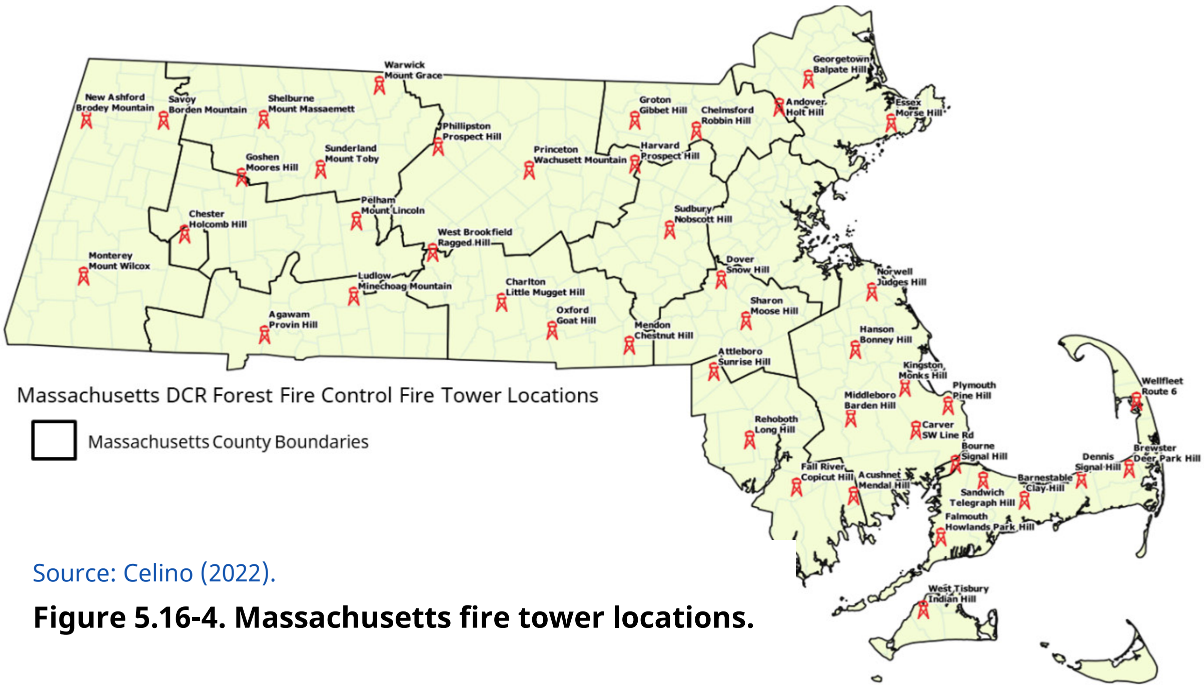
Most fires that occur in Massachusetts are around five acres (Class B). Despite their relatively small size, these fires can pose significant risks to residents and structures in the Commonwealth due to the high percentage of land in Massachusetts that is classified as being within the WUI [see Section 5.16.2.1 (General Background) for more detail].

5.16.2.1.4 Warning Time

Early detection of wildfires is a key part of the Massachusetts DCR Bureau of Forest Fire Control's effort to provide warning time and allow for evacuation and fire response to preserve buildings and structures. Bureau observers who staff 22 of the 42 fire towers statewide are trained in early detection. During periods of high fire danger, the Bureau conducts county-based fire patrols in forested areas. These patrols assist cities and towns in prevention efforts and allow for the quick deployment of mobile equipment to respond to wildfire. Figure 5.16-4 below displays the Bureau's fire control districts and fire towers in Massachusetts. (Massachusetts Department of Conservation and Recreation Bureau of Forest Fire Control, 2022)

The Bureau calculates fire danger ratings daily using the National Fire Danger Rating System, which measures fuel moisture, air temperature, wind speeds, herb stages,[2] and relative humidity to calculate the burn and spread index. During periods of significant fire risk, weather forecasters coordinate with fire weather state contacts to communicate warnings, which are calculated in a similar way to the daily fire ratings and look at the current conditions (wind, relative humidity, and temperature), long-term dryness (based on the Keetch-Byram Drought Index), and the vegetation status (e.g., herb stage).

[2] Herb stages correlate to the seasons of the year. Herb Stage 1 is typically from late fall to early spring, when fuels have been exposed to prolonged periods of full sunlight. Herb Stage 2 occurs in the spring when leaves begin to emerge on trees and shrubs and in the fall when leaves and shrubs start to lose their leaves; this is known as the "transition stage." Herb Stage 3 typically occurs during the summer, ranging from when leaves are fully out on trees and shrubs to the beginning of leaves dropping (RI DEM, n.d.)



Source: Celino (2022).

Figure 5.16-4. Massachusetts fire tower locations.

Wildfires can ignite and spread rapidly under conditions of high heat, drought, low dew count, and high winds, and residents may have little warning time to prepare and respond to a wildfire within or adjacent to their community. The speed in which wildfires can ignite makes preparation and mitigation strategies critical to reduce risks to life and property and provide residents, businesses, and wildfire responders with more time to evacuate. Building codes requiring the use of roof, fence, and outbuilding materials that are nonflammable or fire resistant, as well as requirements to clear vegetation away from homes and structures, are critical mitigation measures to reduce risk to individual properties, firefighters, and the surrounding ecosystem.

5.16.2.1.5 Local Context for Hazard and Vulnerability: A Review of Local Plans

Many of the local hazard mitigation plans reviewed considered wildfire as a potential hazard, although many identified a low risk to their region based on low historical rates or a low wildfire risk rating from the U.S. Department of Agriculture. Of those plans that identified significant wildfire risk, development in the WUI and drought were significant factors exacerbating the risk of wildfire. Table 5.16-3 below provides examples of how wildfire was treated in three plans under review.

Table 5.16-3. Highlight of Local Plans Reports

Plan Name	Location-Specific Hazard Information	Vulnerability Information	Dollar Value of Local Assets
Town of Erving Hazard Mitigation Plan, October 2019	Most residents live in or near heavily forested areas, leading to large potential risks from wildfire.	The most vulnerable populations include emergency responders, those living near the WUI, and those who would have difficulty evacuating, including people with mobility limitations.	Damages to infrastructure from wildfires could total over $50 million.
2021 Natural Hazard Mitigation Plan Update, city of Boston, 2021	Brushfires occur within the city of Boston, with a significant fire roughly every five to 50 years. Smoke and air pollution from fires can pose a health risk to the population.	Ten percent of highly vulnerable tracts in Boston are at elevated risk of wildfires. Those who cannot evacuate quickly are at greatest risk.	The Great Boston Fire of 1872 caused $3–4 billion of damages in today's dollars.
2021 Hazard Mitigation Plan: Plymouth, Massachusetts, 2021	A large portion of Plymouth is forested, particularly due to the Miles Standish State Forest. Plymouth's WUI is expanding and is at elevated risk of wildfire due to highly flammable pitch pine and scrub oak.	Suburban neighborhoods at the WUI are very vulnerable to wildfire.	Not provided.

5.16.2.2 Secondary Hazards

Wildfires can generate a range of secondary hazards. Wildfires can contaminate reservoirs due to ash and debris. Insect outbreaks can also occur in pine forest systems following a fire (Watts et al., 2022). In addition, wildfires contribute to atmospheric carbon dioxide accumulation, thereby contributing to global warming and increasing the risks associated with climate change.

5.16.2.3 Exposure and Vulnerability

The MA Climate Assessment identified priority impacts to key sectors from climate change in the Commonwealth. Table 5.16-4 below summarizes the priority impacts most related to wildfire hazard in the Commonwealth using themes identified in the 2023 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP) Risk Assessment based on information from analysis, research, and past events in the Commonwealth and the U.S.

Table 5.16-4. Priority Impacts and High-Consequence Vulnerabilities to Key Sectors from Wildfire

Sector	Priority Impacts and Vulnerabilities
Human	• Health effects from degraded air quality **(most urgent)** • Emergency service response delays and evacuation disruptions (**most urgent)** • Increase in mental health stressors • Damage to cultural resources
Infrastructure	• Damage to electric transmission and utility distribution infrastructure (**most urgent)** • Damage to inland buildings **(most urgent)** • Damage to roads and loss of road service • Loss of energy production and resources
Natural environment	• Forest health degradation **(most urgent)** • Shifting distribution of native and invasive species • Soil erosion
Governance	• Higher costs of responding to climate migration **(most urgent)** • Increased demand for state and municipal government services **(most urgent)** • Increased need for state and municipal policy review and adaptation coordination • Damage to inland state and municipal buildings and land
Economy	• Reduced ability to work **(most urgent)** • Reduced availability of affordably priced housing **(most urgent)** • Economic losses from commercial structure damage and business interruptions • Damage to tourist attractions and recreation amenities • Decreased agricultural productivity

5.16.2.3.1 Human

Disruption, damage, and loss from wildfire in the human sector includes effects on human physical and mental health, injury, and mortality of residents, workers, students, visitors, and responders in areas at risk from wildfire. Additionally, there is potential for damage to, or loss of homes located in, WUI or intermix areas. As previously mentioned, roughly 65 percent of the land base in the Commonwealth is characterized as WUI [see Figure 5.16-2 in Section 5.16.2 (Wildfire Risk Assessment)]. As discussed in the Dukes County Community Wildfire Protection Plan, roofs or siding made of wood shingles are especially vulnerable to fire (SWCA Environmental Consultants, 2021). Roofs are the most vulnerable to ignitions as firebrands or embers can blow from wildfires onto roofs and ignite a fire. Additionally, debris that has built up and dried out in gutters or downspouts could ignite if a firebrand lands there.

To estimate the population exposed to wildfire hazard, the wildfire hazard potential data was overlaid upon the 2020 U.S. Census population data. In total, 1,076,472 people live in majority moderate wildfire hazard zones; there are no high wildfire hazard potential zones in Massachusetts. Table 5.16-5 below summarizes the estimated population within the defined hazard areas by county.

Table 5.16-5. Population in Wildfire Hazard Zones in Massachusetts by County

County	Moderate	Low	None
Barnstable	13,185	60,296	140,964
Berkshire	15,857	66,964	45,154
Bristol	85,925	110,503	364,609
Dukes	—	6,145	11,167
Essex	30,060	131,523	622,093
Franklin	—	59,528	18,074
Hampden	96,950	11,280	359,641
Hampshire	62,817	28,685	71,276
Middlesex	206,432	28,690	1,365,720
Nantucket	—	4,602	6,566
Norfolk	167,563	1,521	531,353
Plymouth	173,978	55,335	285,990
Suffolk	804	278	795,523
Worcester	222,901	148,601	453,270
Total	**1,076,472**	**713,951**	**5,071,400**

Sources: ERG analysis using data from NWRAP (2022) and U.S. Census Bureau (n.d.).

Massachusetts state agencies completed a survey as part of the 2023 MA SHMCAP where they identified their primary concerns for populations served by state agencies and potential disproportionate impacts from wildfires. Agency responses are summarized in Table 5.16-6 below. The responses to the survey were completed by agency staff.

Table 5.16-6. Examples of State Agency 2023 Responses to Primary Concerns for Population Served and Potential Disproportionate Impacts for Wildfire

Category	Examples of Primary Concerns
Population served	• Injured workers • Municipalities, campus police officers, deputy sheriffs, hospital police officers, and environmental police • All residents, businesses, and municipalities
Disproportionate impacts	• Disproportionate impacts to environmental justice and other priority populations such as the elderly, people living in rural areas, people reliant on public transportation, and everyone included in the Social Vulnerability Index • Delay in court dates or proceedings; delays in filing important documentation subject to statutory timeframes

Vulnerable and Priority Populations

All individuals whose homes or workplaces are in wildfire hazard zones are exposed to wildfire risk. The level of risk is related to a number of factors, including mitigation measures taken by individuals and communities around structures and critical assets. Underlying social vulnerability factors increase risk among exposed populations. For wildfires, these populations include people over the age of 65 and under the age of five, people who have low English proficiency or who are linguistically isolated, transit-dependent populations, people with underlying health conditions, people with disabilities, underserved and under-resourced communities, isolated or hard-to-access communities, single-parent households, renters, housing cost–burdened and/or low-income households, unhoused populations, and underrepresented race or ethnic populations. Geospatial analysis comparing MA Environmental Justice block groups with wildfire risk shows that there are 2,158 block groups (2,869,096 people) located in “no hazard” areas, 84 block groups (101,909 people) located in “low hazard” areas, and 74 block groups (129,463 people) in “moderate hazard” areas. To complete this analysis, the wildfire hazard potential geospatial data from the Northeast-Midwest Wildfire Risk Explorer was overlaid with block group data from the 2021 Massachusetts Environmental Justice map, or MassGIS.

Firefighters and first responders are vulnerable to wildfires, particularly in circumstances where there are multiple threats and objectives associated with the wildfire. Risk is exacerbated if these emergency workers are required to protect structures that are spread throughout the landscape, if residents have not evacuated, or if roads and access routes are compromised by evacuees or the fire. Outdoor and agricultural workers are exposed to greater amounts of wildfire smoke compared to other populations. Residents with pets or livestock face additional challenges in evacuating, or may be reluctant to evacuate, if they cannot easily transport and find shelter with their animals. Other facilities that are at higher risk and are harder to evacuate include hospitals, schools, elder care facilities, correctional facilities, farms, zoos, and large-capacity use areas such as parks, campsites, and crowded venues.

Health Impacts

As identified by the MA Climate Assessment, smoke and air pollution from wildfires can be a severe health hazard. Smoke generated by wildfires consists of visible and invisible emissions containing particulate matter (soot, tar, and minerals), gases (water vapor, carbon monoxide, carbon dioxide, and nitrogen oxides), and toxics (formaldehyde and benzene). Emissions from wildfires depend on the type of fuel, the moisture content of the fuel, the efficiency or temperature of combustion, and the weather. Other public health impacts associated with wildfire include difficulty in breathing, reactions to odor, and reduced visibility. Due to the high prevalence of asthma in Massachusetts, there is a high incidence of emergency department visits when respiratory irritants like smoke envelop an area. Wildfires may also threaten the health and safety of those fighting the fires. First responders are exposed to dangers from the initial incident and the aftereffects of smoke inhalation and heat-related illness.

Outside the area of immediate impact, sensitive populations, such as those with compromised immune systems or cardiovascular or respiratory diseases, can suffer health impacts from smoke inhalation. Individuals with asthma are more vulnerable to the poor air quality associated with wildfires. Health effects to humans because of degraded air quality were identified as the number one urgent impact to the human sector in the MA Climate Assessment. As wildfire frequency increases with climate change, health impacts associated with poor air quality due to wildfire smoke are expected to continue and potentially worsen. People exposed to wildfire hazards are also exposed to the risk of direct loss of life and injury.

Another consideration of wildfire hazard health impacts is the availability of hospital and health care facilities. In remote and rural areas of the Commonwealth, access to hospitals and health care facilities can be difficult and limited, making the injuries and health effects potentially more significant.

5.16.2.3.2 Governance

Wildfires can damage, disrupt, or destroy government structures and operations, including infrastructure, utilities, telecommunications, and power generation. Table 5.16-7 summarizes the number of state-owned buildings located in wildfire hazard areas within each county and provides the total replacement value according to the Division of Capital Asset Management and Maintenance (DCAMM). This figure assumes 100 percent loss to each structure and its contents. This estimate is considered high because structure and content losses generally do not occur to the entire inventory exposed.

In addition to physical assets, state agencies also provide many non-physical functions and services associated with land management, mitigation strategies, emergency preparedness and response, outreach and education to communities and local governments, and other efforts. The costs to prepare, respond to, and recover from wildfires can be very high across all scales of government and governance from community organizations to local governments, to regional planning agencies, to the state.

Table 5.16-7. State-Owned Buildings in Wildfire Hazard Zones

County	Moderate		Low		None	
	Count	Replacement Value	Count	Replacement Value	Count	Replacement Value
Barnstable	72	$34,789,450	146	$44,271,950	247	$1,192,038,972
Berkshire	119	$21,700,522	248	$63,547,250	244	$1,176,507,350
Bristol	66	$44,014,100	82	$101,169,900	369	$3,432,350,423
Dukes	1	$180,000	13	$3,058,400	25	$28,330,650
Essex	73	$17,996,900	90	$97,068,000	471	$3,532,037,200
Franklin	2	$1,592,500	139	$38,507,750	148	$548,689,300
Hampden	128	$62,604,050	74	$121,607,650	383	$4,294,952,243
Hampshire	90	$63,717,150	105	$103,232,584	515	$7,989,292,843
Middlesex	189	$99,815,600	133	$109,598,400	1,031	$8,133,096,960
Nantucket	—	—	4	$1,792,00	7	$16,549,000
Norfolk	157	$2,120,279,600	75	$76,767,050	549	$3,006,909,881
Plymouth	160	$67,953,266	61	$139,585,015	569	$3,872,782,354
Suffolk	66	$24,874,550	99	$1,037,997,384	630	$14,201,253,927
Worcester	128	$85,410,700	298	$278,802,200	765	$9,275,030,050
Total	**1,251**	**$644,928,389**	**1,567**	**$2,217,005,533**	**5,953**	**$60,699,812,156**

Sources: ERG analysis using data from DCAMM, 2022 (facility inventory); Northeast-Midwest Wildfire Risk Assessment, 2022.

Lifelines

Wildfires, especially those in the WUI, have the potential to disrupt or impact all community lifelines within the fire perimeter. Wildfire poses a threat to emergency responders, residents, workers, and visitors, as well as to all infrastructure and utility assets and services within the vicinity of a wildfire. Damage and disruption to roads, communications, and energy production and transmission services can pose an additional threat to public safety. Damage to roads (discussed in the Transportation section below) poses an additional threat to public safety if emergency responders are unable to access affected populations, which is of particular concern in remote areas with limited accessways in and out of communities. Debris associated with wildfires can be toxic and pose risks for pollution to soils, air, and waterways, including groundwater and aquifers.

Hazardous material releases during a wildfire also poses risks. Containers storing hazardous materials could rupture during wildfires due to excessive heat and can cause rapid escalation of fires to unmanageable levels in the short term. In addition, these materials contaminate surrounding areas, saturating soils, and seeping into surface waters to cause severe and lasting environmental damage.

5.16.2.3.3 Infrastructure

This planning effort considers all elements of the built environment located in WUI and intermix areas are considered exposed to the wildfire hazard. Table 5.16-8 summarizes the number of critical facilities exposed to wildfire hazards in the Commonwealth by type. Table 5.16-9 summarizes the number of critical facilities exposed to wildfire by county for all the facility types in Table 5.16-8.

Table 5.16-8. Critical Facilities in Wildfire Hazard Zones by Type

Critical Facility Type	Moderate	Low	None
Administration	15	19	140
Animal services	—	3	7
Cold storage	—	1	12
Communications	17	19	24
Corrections	17	15	320
Education	2	5	115
Energy facilities	37	28	151
Fire facilities	22	19	24
Healthcare	5	3	88
Laboratories and research	—	2	19
Maritime	5	15	60
Military facilities	5	1	75
Parks and recreation	25	28	44
Police facilities	3	3	36
Residential	93	116	501
Social services	16	12	66
Stadium	1	—	4
Transportation	6	8	54
Waste management	25	14	58
Water resources	112	114	133
Total	**406**	**425**	**1,931**

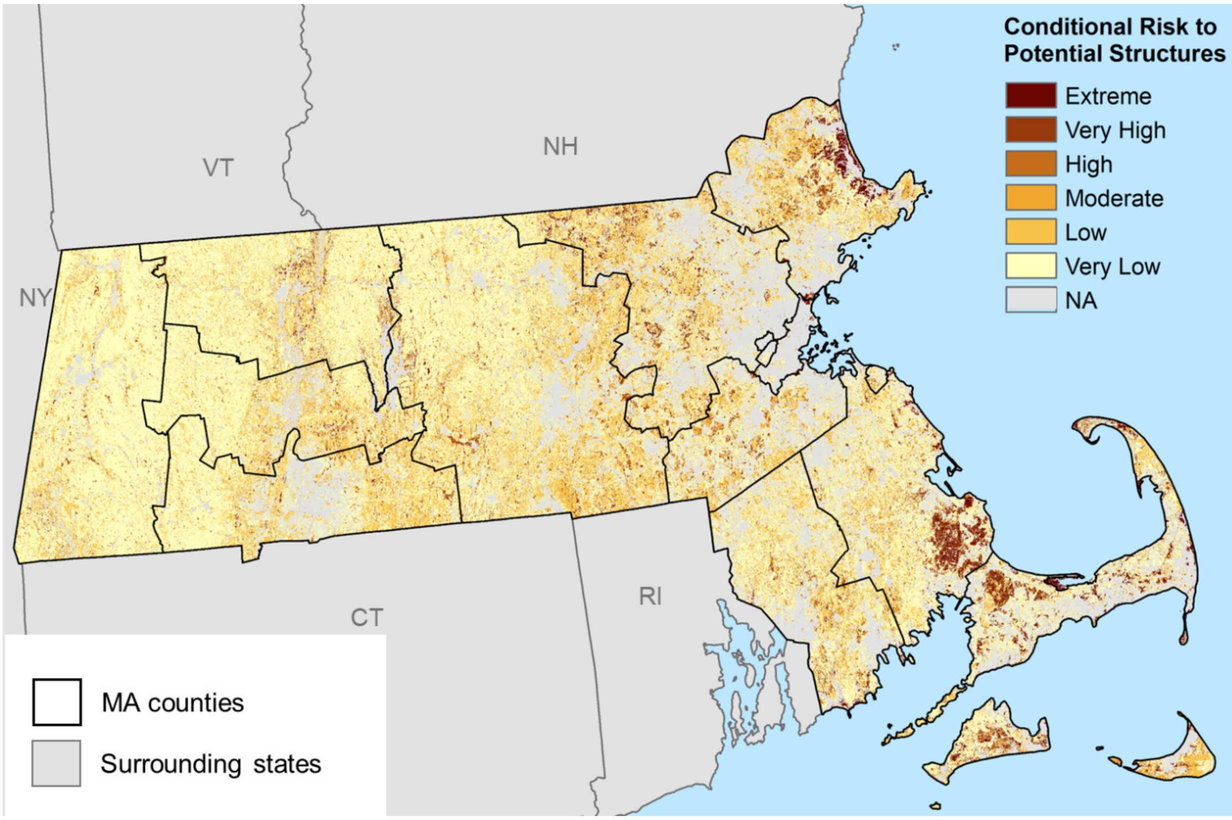
Sources: ERG analysis using data from DCAMM, 2022 (facility inventory); Northeast-Midwest Wildfire Risk Assessment, 2022.

Table 5.16-9. Critical Facilities in Wildfire Hazard Zones by County

County	Moderate	Low	None
Barnstable	30	57	77
Berkshire	31	61	78
Bristol	20	31	104
Dukes	—	2	7
Essex	20	22	124
Franklin	1	30	37
Hampden	43	26	125
Hampshire	20	24	256
Middlesex	59	36	308
Nantucket	—	3	4
Norfolk	72	19	186
Plymouth	52	18	210
Suffolk	7	12	152
Worcester	51	84	263
Total	**406**	**425**	**1,931**

Sources: ERG analysis using data from DCAMM, 2022 (facility inventory); Northeast-Midwest Wildfire Risk Assessment, 2022.

Figure 5.16-5 below illustrates the conditional risk to potential structures, which "represents the potential consequences of fire to a home in a given location, if a fire occurs there and if a home were located there" (NWRAP, 2022). This metric "integrates wildfire intensity with generalized consequences to a home on every pixel, but does not account for the actual probability of fire occurrence" (NWRAP, 2022).



Source: ERG analysis using data from SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin–Madison, 2020.

Figure 5.16-5. Conditional risk to potential structures in Massachusetts, 2022.

Agriculture

As described above, while Massachusetts does not experience wildfires at the same magnitude as some western states do, wildfires do occur and are a threat to the agriculture sector. The forestry industry is especially vulnerable to wildfires. Barns, other wooden structures, animals, and farm equipment are susceptible to wildfires. As is true for most fire-adapted or fire-reliant ecosystems, occasional low-intensity fires can benefit the land by encouraging and making room for new sprouts to grow. These types of fires also benefit forests by promoting important tree species such as oaks and hickories and can reduce the risk of damaging fires (e.g., high-intensity) in timber stands (Brose et al., 2013). Prescribed fire is also used in certain types of agriculture in Massachusetts to encourage new sprouts to grow, or as a kind of "sanitation" method to efficiently kill insects and weeds in the field. In Massachusetts, prescribed burning is most often used in blueberry and raspberry patches, or as a way to prune fruit trees (Fairhaven Fire Department, n.d.). Fire is also used to maintain pastures and improve forage quality and pollinator habitat.

Energy

There are 37 energy facilities located in moderate wildfire hazard areas in the Commonwealth. Distribution and transmission lines located within wildfire risk zones will likely be damaged and result in a disruption of power and energy to the affected service areas, which may be larger than the area directly affected by the fire. In the event of a wildfire, oil or gas pipelines could act as a fire fuel source and lead to a catastrophic explosion. Trees that are downed during a wildfire could block or damage roads, culverts, and bridges.

Public Health

As discussed in Section 5.16.2.3.1, wildfires impact air quality and public health, and they can result in injury or death. Wildfire poses acute risks of smoke inhalation, falling debris and embers, and ignition risk.

Public Safety

Wildfire is a threat to emergency responders, residents, workers, and visitors, as well as all infrastructure within the vicinity of a wildfire. Damage and disruption to roads, communications, and energy services can pose an additional threat to public safety, as emergency responders and service providers are unable to access affected populations. Disaster debris associated with wildfires is often toxic and poses risks to soils, air, and waterways, including groundwater and aquifers. This toxic and contaminated debris increases risks to affected communities during and after the fire.

Transportation

Roads, bridges, and railroads can be both directly and indirectly affected by wildfires. Wildfires can engulf transportation corridors, making them temporarily impassable, and can result in disruption due to downed trees or power lines, as well as other debris that blocks and damages infrastructure. Some transportation routes may be impacted by wildfire smoke, causing temporary closures of major routes or traffic accidents due to lack of visibility. Transportation routes that get blocked by wildfire or debris can pose significant risk to residents and people requiring emergency services, as well as wildfire responders and those evacuating the event. This risk is particularly present in remote areas with limited accessways in and out of communities. There are six transportation facilities located in moderate wildfire hazard areas in the Commonwealth. Transportation facilities include bridge locks, marine and water transportation facilities, bridges, and transit stations, according to the DCAMM facilities inventory. While wildfires do not typically affect bridges directly, they can create conditions in which bridges are blocked, primarily due to fallen trees. A total of 26,281 miles of road in Massachusetts are exposed to wildfire hazard in the WUI and intermix areas (Massachusetts Department of Transportation, 2022; NWRAP, 2022).

Water Infrastructure

Wildfire can result in direct damage to or disruption of water infrastructure, as well as increasing demand for local water supplies, resulting in significant withdrawal of water over a short amount of time. Indirectly, wildfires can contaminate water supplies, including groundwater, aquifers, and rivers, due to increased sediment, debris, and toxic materials. These stresses on water infrastructure and supply could result in local water pressure and supply problems.

5.16.2.3.4 Natural Environment

Fire is a natural part of many ecosystems and serves important ecological purposes, including facilitating the nutrient cycling from dead and decaying matter, removing diseased plants and pests, and regenerating seeds or stimulating germination of certain plants. In fact, most fires are beneficial to the native ecosystems, and there are more species and ecosystems threatened due to fire exclusion than by wildfire.

However, in some situations, high-intensity or high-severity fires can have negative impacts on the environment. Isolated populations of rare species may be eradicated if their entire habitat is burned at once in extremely severe or intense fires. In combination with other stressors and disturbance, fire can facilitate the invasion of wetlands by phragmites, an invasive, non-native, fire-tolerant species. If invasive species establish themselves after a wildfire, they can outcompete the native species, which can lead to a decrease in overall biodiversity of a site or ecosystem and threaten or cause extinction of these species over time, as well as increasing the cost of managing these non-natives.

Widely practiced fire exclusion practices have contributed to a dramatic decline in oak ecosystems in the Commonwealth. The causes of decline include threats from non-native insects such as spongy moth and winter moth, native and non-native diseases, and periodic droughts. The lack of forest regeneration after an incident can be attributed to a lack of forest management (e.g., cutting), deer overpopulation, and human interference that reduces of naturally occurring fires from the landscape (Pulido et al., 2013). The lack of fire in oak systems causes mesophication—a process that occurs when fire is removed from a fire-dependent forest such as oak, causing the once open, “fire-tolerant forests to shift to closed, shade-tolerant, fire-sensitive forests” (University of Nebraska–Lincoln, n.d.). Mesophication allows for species such as maples, white pines, birches, aspen, and other generalist species to establish in oak systems. Many of these species have flat leaves that hold in moisture, which over time, makes the site more moist, shaded, and unsuitable for oaks and associated species (Alexander et al., 2021).

Severe wildfires can have negative impacts to animal habitat and disrupt fragile forest ecosystems. The Massachusetts BioMap tool maps core habitat across the Commonwealth, including rare species and forest, aquatic, wetland, vernal pool, and natural communities. The “forest core” layer represents the most intact (i.e., least fragmented) forest habitat in the Commonwealth (MassWildlife and The Nature

Conservancy, 2022). The forest core includes 439,500 acres (out of a total 3.1 million forested acres) of core habitat, 70 percent (308,600) of which are protected (MassWildlife and The Nature Conservancy, 2022). To identify the area of forest core habitat in wildfire hazard areas, the Northeast-Midwest Wildfire Risk data were combined with the forest core data; there are 123 forest core acres in majority low wildfire hazard zones, and 102 forest core acres in moderate wildfire hazard zones.

Hazardous material releases during a wildfire also pose risks. During uncontrolled wildfires, containers storing hazardous materials could rupture due to excessive heat and cause rapid escalation of fire to unmanageable levels in the short term. In addition, these materials can contaminate surrounding areas, saturating soils and seeping into surface waters to cause severe and lasting environmental damage.

To reduce the potential impacts on the natural environment from high-intensity, extreme wildfires while ensuring that natural or prescribed beneficial fires are used in Massachusetts to increase biodiversity and ecosystem health, active management and prescribed burns should be widely used in combination in the Commonwealth.

5.16.2.3.5 Economy

Wildfire events can have major economic impacts on a community, both from the initial loss of structures and the subsequent loss of revenue from destroyed businesses and a decrease in tourism. Individuals and families also face economic risk if their home is damaged or lost in a wildfire. The exposure of homes to this hazard is widespread, given the high percentage of WUI land base in the Commonwealth (67 percent). Additionally, wildfires can require significant funding for fire response efforts and can involve hundreds of operating hours on fire apparatus and thousands of person-hours from volunteer firefighters. There are also many direct and indirect costs to local businesses that provide volunteers to serve as responders to these fires. There can be significant costs associated with cleanup and restoration of natural and recreational areas after a fire, in addition to costs for debris management and removal.

Wildfires can cause disruptions to land-based economies such as the timber industry, the outdoor tourism industry, and fisheries. On average, 18,285 acres of forest in Massachusetts have commercial timber harvest each year (Harvard Forest, 2020). The price of timber varies in the state depending on species type, in addition to other factors. However, damage to commercial timber lots due to wildfire could spell significant economic losses for timber lot owners as well as timber harvesters.

Chapter 5. Risk Assessment and Hazard Analysis

References

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5.17.1 References for Section 5.1 (Risk Assessment Introduction)

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Appendix 6.A:
Survey Respondents

The table below lists all agencies that submitted responses to the survey, as well as the categories of physical and nonphysical assets and functions that the agencies selected in their responses.

Responding Agency	Physical and Nonphysical Assets and Functions Selected
Appellate Tax Board	• Other (*no additional description provided*)
Board of Registration in Medicine	• Other (licensure in the practice of medicine and acupuncture and the regulation of these professions)
Bureau of the State House	• Communication • Critical facilities and services • Recreation, open space, natural areas, and working lands • Other (additional entities at the State House including but not limited to the State Library, Art Collections, General Court, Constitutional Offices, and the Office of the Governor)
Civil Service Commission	• *No response to survey question*
Commonwealth Corporation	• Communication
Department of Agricultural Resources State Reclamation Mosquito Control Board	• Community • Critical facilities and services • Hazardous materials sites and contaminated lands • Ports and maritime • Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure
Department of Career Services	• *No response to survey question*
Department of Children and Families	• Community • Critical facilities and services
Department of Conservation and Recreation	• *No response to survey question (note that due to an existing vulnerability assessment, DCR responded to a shorter version of the survey)*
Department of Conservation Services	• Recreation, open space, natural areas, and working lands
Department of Correction	• Communication • Community • Critical facilities and services • Hazardous materials sites and contaminated lands • Ports and maritime • Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure

Responding Agency	Physical and Nonphysical Assets and Functions Selected
Department of Criminal Justice Information Services	• Communication
Department of Developmental Services	• Community • Critical facilities and services
Department of Early Education and Care	• Community
Department of Elementary and Secondary Education	• *No response to survey question*
Department of Energy Resources	• Utilities and infrastructure
Department of Family and Medical Leave	• *No response to survey question*
Department of Fire Services	• Communication • Critical facilities and services • Hazardous materials sites and contaminated lands
Department of Housing and Community Development	• *No response to question (note that due to an existing vulnerability assessment, DHCD responded to a shorter version of the survey)*
Department of Industrial Accidents	• Communication • Other (office furniture, telecommunication equipment, IT equipment, including PCs, laptops, and more)
Department of Labor Relations	• *No response to question*
Department of Labor Standards	• Critical facilities and services
Department of Mental Health	• Critical facilities and services
Department of Public Health	• Community • Critical facilities and services • Hazardous materials sites and contaminated lands • Recreation, open space, natural areas, and working lands
Department of Public Utilities	• Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure
Department of Revenue	• Community
Department of Telecommunications and Cable	• Communication

Responding Agency	Physical and Nonphysical Assets and Functions Selected
Department of Transitional Assistance	• Community
Department of Unemployment Assistance	• *No response to survey question*
Department of Veterans' Services	• Community • Critical facilities and services • Recreation, open space, natural areas, and working lands
Department of Youth Services	• Community • Critical facilities and services
Division of Administrative Law Appeals	• Community
Division of Apprentice Standards	• Community • Other (approve programs and individuals to apprentice in most construction and building trades essential to maintenance and construction of essential infrastructure, including pipefitting, plumbing, and electricity)
Division of Banks	• Community
Division of Capital Asset Management and Maintenance	• Communication Community • Critical facilities and services • Hazardous materials sites and contaminated lands • Utilities and infrastructure
Division of Ecological Restoration	• Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure
Division of Fisheries and Wildlife	• Community • Critical facilities and services • Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure
Division of Insurance	• Other (Physical office space located at 1000 Washington Street, Boston, MA. Office supplies and equipment leased to same location. In addition, DOI has the physical records stored offsite at Iron Mountain.)
Division of Marine Fisheries	• Communication • Community • Ports and maritime • Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure
Division of Standards	• Community

Responding Agency	Physical and Nonphysical Assets and Functions Selected
Executive Office of Administration and Finance	• *No response to survey question*
Executive Office of Education	• Other (*no additional description provided*)
Executive Office of Elder Affairs	• Community
Executive Office of Energy and Environmental Affairs	• Recreation, open space, natural areas, and working lands • Utilities and infrastructure
Executive Office of Health and Human Services	• Community • Critical facilities and services
Executive Office of Housing and Economic Development	• Other (we don't directly manage these properties—we assist in communities in developing these assets through financial assistance)
Executive Office of Labor and Workforce Development	• Community • Critical facilities and services
Executive Office of Public Safety and Security	• Communication • Community • Critical facilities and services • Other (the EOPSS Agency buildings and assets)
Executive Office of Technology Services and Security	• Communication • Critical • Other (IT infrastructure and IT support of agencies that directly work in the above categories across the EOTSS branch)
Group Insurance Commission	• Communication • Community
Human Resources Division	• Other (HR government function)
MA Environmental Policy Act Office	• Community • Critical facilities and services • Hazardous materials sites and contaminated lands • Ports and maritime • Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure
MA National Guard	• Communication • Critical facilities and services • Hazardous materials sites and contaminated lands • Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure
MA State Police Crime Lab	• Communication • Critical facilities and services

Responding Agency	Physical and Nonphysical Assets and Functions Selected
Massachusetts Bay Transportation Authority	• Communication • Critical facilities and services • Hazardous materials sites and contaminated lands • Ports and maritime • Transportation and mobility • Utilities and infrastructure • Other (The MBTA works cooperatively with municipalities to lease out on 99-year leases for bike paths along former rail corridors. The MBTA also leases land to developers for 75-year and 99-year leases.)
Massachusetts Commission for the Blind	• *No response to survey question*
Massachusetts Department of Agricultural Resources	• Critical facilities and services • Hazardous materials sites and contaminated lands • Recreation, open space, natural areas, and working lands
Massachusetts Department of Environmental Protection	• Critical facilities and services • Hazardous materials sites and contaminated lands • Ports and maritime • Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure
Massachusetts Department of Transportation	• Critical facilities and services • Recreation, open space, natural areas, and working lands • Transportation and mobility • Utilities and infrastructure
Massachusetts Emergency Management Agency	• Communication • Critical facilities and services
Massachusetts Environmental Police	• Communication • Critical facilities and services • Ports and maritime • Recreation, open space, natural areas, and working lands • Transportation and mobility
Massachusetts Office of Business Development	• *No response to question*
Massachusetts Office of Disability	• Other (*no additional description provided*)
Massachusetts Office of International Trade and Investment	• Other (*no additional description provided*)
Massachusetts Office of Travel and Tourism	• *No response to question*

Responding Agency	Physical and Nonphysical Assets and Functions Selected
Massachusetts Port Authority	• Critical facilities and services • Ports and maritime • Recreation, open space, natural areas, and working lands • Transportation and mobility
Massachusetts Rehabilitation Commission	• Community • Critical facilities and services
MassGIS	• Critical facilities and services • Other (MassGIS maintains and provides street, parcel, structure and address data to the 9-1-1 department to assist in emergency response services on a weekly basis. In addition, MassGIS collects and redistributes much of the mapped data mentioned above such as hospitals and schools for use by anyone for analysis.)
MassHealth	• Other (office space that members may visit)
Municipal Police Training Committee	• Communication • Critical facilities and services • Transportation and mobility • Utilities and infrastructure • Other (The MPTC oversees and manages the database for law enforcement officers in the Commonwealth. This information is necessary for the POST Commission to issue certifications to these officers.)
Office for Refugees and Immigrants	• Community
Office of Coastal Zone Management	• Ports and maritime • Recreation, open space, natural areas, and working lands
Office of Consumer Affairs and Business Regulation	• Other (*no additional description provided*)
Office of Fishing and Boating Access	• Recreation, open space, natural areas, and working lands • Other (OFBA boat ramps provide an important role in providing access to on water emergencies)
Office of Public Safety & Inspections	• Community • Critical facilities and services • Ports and maritime • Transportation and mobility
Office of the Chief Medical Examiner	• Critical facilities and services • Other (the OCME responds to death scenes of individuals who die from environmental factors)
Operational Services Division	• *No response to survey*
Parole Board	• Critical facilities and services

Responding Agency	Physical and Nonphysical Assets and Functions Selected
Public Employee Retirement Administration Commission	• *No response to survey*
Rail and Transit Division	• Transportation and mobility
Sex Offender Registry Board	• Communication
Soldiers' Home in Chelsea	• Critical facilities and services
Soldiers' Home in Holyoke	• Critical facilities and services
State 911 Department	• Communication • Critical facilities and services
State Library of Massachusetts	• Other (*no additional description provided*)

Appendix 7.A:
2023 SHMCAP Action Development Worksheet

2023 Agency Actions

Executive Office	Lead Agency	Action Title	Action Description	Inter-agency Coordination	Priority Level (from Action Scorecard; *drop down - high, medium, low*)	Action Status (2023) *(drop down)*	Funding Source	Funding Status *(drop down)*	Completion Timeframe *(drop down)*	Partners	Climate Assessment Priority Impacts and additional vulnerabilities: Select ONE impact across sectorms from the drop-down list.					Scale	2023 SHMCAP Goals (Mark "x" on all the goals relevant to the action)					
											Human (#1)	Infrastructure (#1)	Natural Environment (#1)	Governance (#1)	Economy (#1)		Goal 1: Collaboration, Communication,	Goal 2: Science-based and Informed	Goal 3: Resilient State Assets and Services	Goal 4: Implement Adaptation	Goal 5: Climate mitigation	Goal 6: Resilient and Equitable Infrastructure,
A&F	A&F	Standardize approach to identifying resiliency needs for state capital planning purposes	Work with agency experts to develop a standard approach for easily identifying the resilience need(s) a proposed Capital Investment Plan (CIP) investment is helping to address and the anticipated resiliency outcomes associated with the investment.	In order for this action to be effective, close collaboration with other state agencies will be necessary, particularly those with an understanding of needs at local	Medium	In Development	Staff Time	Planned - There is funding identified but not yet	Less than 3 years	DCAMM, MEMA, EEA, Office of Climate Innovation and				Damage to Coastal State and Municipal Buildings and Land			X		X	X	X	
A&F	A&F	Standardize approach to aggressively leveraging federal resources	Develop a coordination strategy to effectively pursue federal funding opportunities related to climate and resiliency, focusing on new opportunities, such as those stemming from BIL/IIJA and IRA.	In order for this action to be effective, close collaboration with other state agencies will be necessary, particularly those with	Medium	Not started	Staff Time	Planned - There is funding identified but	Less than 3 years	Gov Office Director of Federal Funds and				Increase in Costs of Responding to Climate			x		x	x	x	
A&F	DCAMM	Incorporate hazard and climate change vulnerability into capital planning, master planning, and facilities management functions	Incorporate climate change vulnerability, resilience, and adaptation standards into capital planning and at the outset of projects with client agencies. Complete the RMAT Climate Resilience Design Standards and Guidelines Tool and DCAMM climate resilience assessments during project planning. Refer to these assessments during project design and master planning exercises to identify planning horizons and specific high-priority threats. Continue to revise and update the existing DCAMM resilience assessment process as appropriate utilizing RMAT-supported climate data sets, and integrate climate change and natural hazard vulnerability information into an asset management system	Consider identifying the agencies that have can assist DCAMM with the assessments and standards.	Medium	In Progress	SHMCAP Impler	Potential fundin	Greater than 5 years					Damage to Coastal State and Municipal Buildings and Land					x	x		
A&F	DCAMM	Incorporate earthquake risk assessments into project planning	In an asset management system, identify buildings with particular risk from earthquakes, especially masonry bearing-wall buildings and buildings in identified soil liquefaction zones. Utilize these assessments during major renovation projects to identify and address specific high-priority threats to state buildings. Incorporate IEBC Chapter A1 earthquake risk assessments into the early-stages of major renovation projects on unreinforced masonry bearing-wall buildings.	No comments.	Medium	Not started	SHMCAP Impler	Potential fundin	Less than 3 years			Damage or loss of unreinforced masonry buildings due to earthquakes.							X			
A&F	DCAMM	Address the risk of extreme heat to building occupants	Identify buildings in areas designated by RMAT-supported climate data sets as being at high risk of extreme heat and track these vulnerabilities in an asset management system (CAMIS). Refer to this information with client agencies during capital planning and at the outset of new projects to address risks of extreme heat to occupants, especially at buildings that house vulnerable populations within the DCAMM portfolio, when feasible. Prioritize use of heat pumps for heating and cooling.	No comments.	Medium	Not started	SHMCAP Impler	Potential fundin	Greater than 5 years		Health and Cognitive Effects from Extreme Heat							x		x		x
EOEEA	CZM	Develop guidance on flow path analyses and impacts of channelized flow to buildings	Terrain alterations (e.g., fill and landscaping walls) can impact how floodwaters flow through floodplains. Low-cost methods for conducting flow path analyses through developed areas will be reviewed. Thresholds (e.g., velocities and depths) for damages to buildings due to channelized flow will be identified. This information will be presented in a guidance document or fact sheet for project proponents, consultants, and reviewers.	No comments.	Medium	In Development	CZM in-kind ser	Potential funding	Less than 3 years	Partner with EEA/DCR Flood Hazard Management Program & FEMA		Damage to Coastal Buildings and Ports			disruption, or loss of coastal infrastructure such as seaports, airports, and maritime industries.	Coastwide		X	X			
EOEEA	CZM	Develop best practices for the redesign of seawalls and revetments	Coastal structures like seawalls and revetments exist to protect buildings and infrastructure along the coast. Over 1,300 publicly-owned coastal structures need to be repaired or reconstructed. Beaches, coastal banks, and other coastal landforms associated with these structures have also eroded. CZM will convene an interdisciplinary work group with expertise in coastal engineering, geology, ecology/nature-based approaches, and planning to: (1) review design plans for coastal structures at risk of failure and those recently repaired or reconstructed, and (2) recommend best practices for redesign of critical coastal structures and those with the potential for improvement of landform function. Structure height with respect to sea level rise and storm surge projections will be a focus of the review and recommendations. There will be opportunities for engagement with coastal communities.	Local and regional municipalities and organizations.	Medium	In Development	CZM in-kind services & SHMCAP implementation funding	Potential funding	Less than 3 years	Partner with EEA Dam & Seawall Grant Program & DCR Waterways		Damage to Coastal Buildings and Ports			Damage, disruption, or loss of coastal infrastructure such as seaports, airports, and maritime industries.	Coastwide		X	X			
EOEEA	CZM	Assess vulnerability and preservation potential of coastal cultural resources from sea level rise and erosion	Coordinate with the MA Historical Commission, MA Board of Underwater Archaeological Resources, coastal communities, and federally- and state-recognized MA Tribes to support a vulnerability assessment of cultural resources along the coast including built resources, archaeological sites (pre- and post-contact period), and inundated and exposed coastal landforms. State agency, municipal, and Tribal consultation is critical to increase our understanding of coastal cultural resource types, locations, and their vulnerability to identify opportunities for shoreline restoration and adaptive management responses to preserve these valuable natural resources.	Tribal is already identified.	High	In Progress	CZM in-kind services, NOAA Project of Special Merit funding & SHMCAP implementation funding	Planned - There is funding identified but not yet allocated	Less than 3 years	Partner with MA Board of Underwater Archaeological Resources and MA Historical Commission	Damage to Cultural Resources		Coastal Erosion			Coastwide	X	X	X	X		X

EOEEA	CZM	Update coastal bank erosion hazard mapping and integrate with the MA Coastal Erosion Viewer	Coastal bank erosion and vulnerability are not reflected in existing coastal hazards maps for Massachusetts such as shoreline change maps. CZM will update a pilot 2016 coastal bank erosion hazard mapping product for the Massachusetts coastline. The update will include analysis using 2018 LIDAR data and more recent elevation data, if it becomes available, to look at areas of the coast experiencing high, moderate, and low magnitudes of coastal bank erosion, and have the potential to affect existing and future land uses. This coastal bank erosion hazard mapping product will be integrated into the MA Coastal Erosion Viewer. CZM will conduct outreach on the final product to coastal municipalities and organizations.	Local and regional municipalities and organizations.	Medium	In Development	EEA/CZM in-kind services & SHMCAP implementation funding	Potential funding	3-5 years	MassDEP was a partner on the original study		Damage to Coastal Buildings and Ports	Coastal Erosion			Coastwide		X	X	X		
EOEEA	CZM	Update the Shoreline Change Project and erosion hot spots	Delineate a new mean high-water shoreline for the MA coast (post 2018) and update rates of change. Add new data to the MA Coastal Erosion Viewer. Also, use the erosion rates and other data (e.g., coastal bank erosion hazards and MyCoast reports) to update the erosion hot spots identified in the 2015 Report of the Coastal Erosion Commission.	No comments.	Medium	In Development	EEA/CZM State Bond Capital funds	Potential funding	3-5 years	Partner with USGS		Damage to Coastal Buildings and Ports	Coastal Erosion			Coastwide		X	X	X		
EOEEA	CZM	Support adaptation of roads in salt marshes	Roads exist coast-wide in salt marshes to provide access to homes, businesses, and recreational areas. These roads have impacted coastal resources, restricted tidal flow, and altered hydrology. Sea level rise and coastal storms will flood many of these roads at increasing frequency and depths in the future. There is a need to characterize the problem to support management efforts. CZM will conduct a GIS analysis to identify roads through salt marshes, length, ownership, purpose, ACEC jurisdiction, elevation, vulnerability, and other relevant factors. This information will be summarized in a fact sheet. The fact sheet will also describe impacts of traditional methods to elevate roads in salt marshes.		Medium	In Development	CZM in-kind services & SHMCAP implementation funding	Potential funding	Less than 3 years	MassDEP and MassDOT				Increase in Need for State and Municipal Policy Review and Adaptation Coordination		Coastwide		X	X	X		
EOEEA	CZM	Advance salt marsh conservation and restoration	Advance the conservation and restoration of salt marshes, coordinating closely with partners (EEA, DEP, DER) and stakeholders, through the following activities: (1) Facilitation of Land Acquisition for Marsh Migration - CZM will utilize existing tools and data (SLAMM) to prioritize undeveloped areas that are modeled to be suitable for future salt marsh migration and pursue federal funding opportunities to support acquisition of priority parcels; (2) Advance understanding of beneficial reuse of sediments to restore and maintain salt marsh habitat - CZM will convene an expert stakeholder group to explore the science and practice of beneficial reuse of dredged sediments for salt marsh restoration. Opportunities for beneficial reuse that are environmentally sound, economically feasible, and permittable in Massachusetts will be the focus; (3) Implement new grant program to support monitoring and adaptive management of applied salt marsh restoration techniques - CZM will build capacity for salt marsh restoration through a targeted grant program to specifically support monitoring and adaptive management of novel restoration strategies to improve understanding of these techniques, ensure scientific rigor, and improve the ability to evaluate success.		High	In Progress	CZM in-kind services, NOAA grant funding & SHMCAP implementation funding	Potential funding	3-5 years	EEA, DEP, DER, DCR (WBNERR)			Coastal Wetland Degradation		Decrease in Marine Fisheries and Aquaculture Productivity	Coastwide	x	x	x	x	x	x
EOEEA	CZM	Support new program to initiate coastwide monitoring of ocean acidification, water temperature, and dissolved oxygen	Develop and implement a coastwide monitoring network to observe long term trends in water temperature, dissolved oxygen, and ocean acidification.	No comments.	Medium	In Progress	CZM in-kind services & Massachusetts	There is funding identified but	Less than 3 years	DMF			Marine Ecosystem Degradation		Marine Fisheries and Aquaculture	Regional		X				
EOEEA	CZM	Develop and implement recommendations to increase community access and equity for grants targeting coastal water quality, habitat, and resilience	Undertake an equity analysis of grant funded projects to date through the Coastal Pollutant Remediation, Coastal Habitat and Water Quality, and Coastal Resilience grant programs. The analysis will include a review of previously funded projects, participating municipalities, stakeholders, and regions in addition to an assessment of potential barriers to funding. The analysis will inform the development of recommendations to increase equity and access to grant funding that will be implemented in future funding rounds of the CHWQ and Coastal Resilience grant programs, which will help build capacity to improve and protect water quality, habitat, and resilience in underserved communities.	Local municipalities and jurisdcitions, regional organizations, MVP program	Medium	In Development	CZM in-kind services	Potential funding	Less than 3 years	MassDEP		Damage to Coastal Buildings and Ports	Marine Ecosystem Degradation		Decrease in Marine Fisheries and Aquaculture Productivity	Coastwide			X	X		X
EOEEA	CZM	Conduct Rapid Assessment Survey for marine species	In 2023, coordinate a Rapid Assessment Survey focusing on the Gulf of Maine and Buzzards Bay regions. Roughly every five years since 2000, CZM has helped coordinate teams of scientific experts to periodically conduct a rapid assessment of marine species, including invasive animals and plants that have been introduced by human activity and have the capacity to harm the environment, economy, and public health. The last survey was conducted in 2018.	No comments.	Medium	In Progress	CZM, DCR, Massachusetts Bays National Estuary Partership, Casco Bay Estuary Partnership &	Potential funding	Less than 3 years	DCR, DMF			Shifting Distribution of Native and Invasive Species		Decrease in Marine Fisheries and Aquaculture Productivity	Coastwide		X				
EOEEA	DCR	Inventory and categorize shade shelters on DCR sites, and strategically improve shading and cooling structures in parks, prioritizing those located in Environmental Justice communities	Use DCR's Asset Management Modernization Program to inventory shade shelters and cooling structures that exist on DCR sites. Work to increase and/or improve shade and cooling structures, prioritizing Environmental Justice communities that experience disproportionate exposure to extreme heat.	Local municipalities and jurisdcitions, regional organizations, MVP program	High	Not started	DCR Operating	Planned - There is funding identified but not yet allocated	Less than 3 years	Local municipalities and CBOs	Health and Cognitive Effects from Extreme Heat					Statewide		X	X	X		X

EOEEA	DCR	Complete and intergrate DCR's Cultural Resource Inventory	DCR's Office of Cultural Resources and GIS office developed a GIS-based data layer and data collection app to enable DCR to inventory and map the cultural resources under its stewardship, with a goal of identifying those sites most vulnerable to climate change impacts. DCR will integrate its Cultural Resource Inventory data with the Asset Management Modernization Program to assist the agency with planning and prioritization efforts. DCR will share results of its inventory with CZM for consideration and integration into their Coastal Cultural Resources Vulnerability Assessment.	CZM	Medium	Not started	SHMCAP Implementation	Potential funding	Less than 3 years	CZM	Damage to Cultural Resources					Statewide		X	X			
EOEEA	DCR	Expand DCR's Greening the Gateway Cities program into four Environmental Justice communities to mitigate heat island effects as well as combat adverse effects of climate change, reduce energy costs, absorb and filter pollutants, and decrease water runoff	The Greening the Gateways Cities Program is currently in 23 out of the 26 Gateway cities. Within the next five years, the program will expand into additional cities that are Environmental Justice communities with low urban canopy cover. In total, the program's ten tree planting teams will be planting 400 trees per year, with an overarching goal to plant at least 4,000 trees per year in Environmental Justice neighborhoods within the Gateway Cities.	Local municipalities and jurisdcitions, regional organizations, MVP program	High	Not started	EEA Cap E053 Greening the Gateway Cities/ DCR Operating	Potential funding	3-5 years	Municipalities (we will list specific ones, if desired. Please advise)		Loss of Urban Tree Cover				Statewide			X	X	X	X
EOEEA	DCR	Utilize consistent climate change data and projections to complete a Division of Water Supply Protection (DWSP)-specific climate vulnerability assessment by 2028	Utilizing the latest climate data from the 2022 Massachusetts Climate Assessment and the DCR Climate Change Vulnerability Assessment, the DCR's Division of Water Supply Protection (DWSP) will initiate a sub-watershed scale assessment adding data for sensitivity and adaptive capacity measurements to match DWSP's specific mission and management goals. This assessment will inform prioritization of capital planning decisions and designs, identify opportunities for resilience and climate adaptation, and identify hazards and constraints at the sub-watershed level. This assessment is the first step to make the Commonwealth's water supply lands climate resilient.	This project would be broadly beneficial to local and regional municipalities and organizaitons. Consider engaging to let them know you are conducting this work and share its findings.	Medium	Not started	MWRA Trust	Potential funding	Greater than 5 years	MWRA & Federal Agencies		Reduction in Clean Water Supply				Statewide		X	X	X		X
EOEEA	DCR	Complete Climate Change Vulnerability Assessment of DCR's Parkways System to support the DCR Parkways Master Plan	The Parkways Climate Vulnerability Assessment will provide a critical first step planning-level flood risk information specific for the historic DCR Parkways system by identifying risks from flooding under future climate scenarios, aligning with the 2022 Massachusetts Climate Assessment. This assessment will supplement the 2020 DCR Parkways Master Plan to add long-term considerations in the context of the exposure to extreme weather and climate effects, and adaptive capacity. The assessment will inform DCR's planning efforts to make these parkways resilient to the effects of climate change.	No comments.	High	In Development	SHMCAP Implementation/ Operating	Secured – Funds are committed	Less than 3 years	Local municipalities		Damage to Roads and Loss of Road Service				Regional		X	X	X	X	X
EOEEA	DCR	Finalize development of prioritization decision-making methodology to repair or remove dams to implement FEMA's High Hazard Potential Dam Program	Develop a screening-level, risk-based, decision-making methodology to prioritize the portfolio of DCR-Office of Dam Safety's eligible high hazard potential dams that are reported to be in poor or unsafe condition for repair or removal in order to mitigate risk and abate public safety threats associated with these dams.	DCR, Masswildlife	High	In Progress	High Hazard Potential Dam Grant (HHPD FEMA) & DCR Cap R012 Dam Safety and Inspection	Secured – Funds are committed	Less than 3 years	FEMA		Increased Risk of Dam Overtopping or Failure				Statewide		X	X	X		X
EOEEA	DCR	Integrate DCR's Stormwater Best Management Practices (BMPs) into DCR's Design Review Process	In October 2022, DCR created its Stormwater Design Handbook as a supplement to DEP's Stormwater Handbook. Formalizing the incorporation of these best management practices into DCR's Design Review Process will ensure that every DCR project considers and manages stormwater in a way that responds to the anticipated increased precipitation from climate change that poses a threat to freshwater ecosystems under DCR's stewardship.	No comments.	Medium	Not started	DCR Cap: R033 (Storm Water Mgmt Program) or Operating	Potential funding	3-5 years				Freshwater Ecosystem Degradation			Statewide		X		X		X
EOEEA	DCR	Conduct coastal wetland modeling and restoration assessments for DCR's coastal wetlands to support planning and restoration efforts	Assessments documenting and analyzing hydrology, existing conditions, watershed functions, and existing stormwater capacity will be paired with future projections for stormwater and sea level rise. These assessments will help identify mitigation and restoration actions, such as naturalizing the stream, managing stormwater, and improving hydrology of saltmarshes. In 2023, DCR will begin assessments in Belle Isle Marsh Reservation and Town Line & Linden Brook. DCR's coastal wetlands assessment results will be shared with CZM for consideration and integration into their salt marsh migration land acquisition strategy.	DCR, CZM	High	Not started	DCR Cap: R102 (Habitat Conservation and Restoration) or Operating; SHMCAP Implementation Funding	Potential funding	3-5 years	CZM			Coastal Wetland Degradation			Regional		X	X	X	X	X
EOEEA	DCR	Enhance the Continuous Forest Inventory program by integrating collection and analysis of forest soils data, as well as increase the application of CFI data to promote data-driven, adaptive, and strategic forest planning	In the next five years, expand and increase funding of the Continuous Forest Inventory (CFI) program to include sampling forest soils for physical and chemical properties to better understand the effects of climate change and forest management strategies on soil properties, health, and carbon dynamics. The new soil data collected by DCR's CFI program will also inform the implementation of the Commonwealth's Healthy Soils Action Plan and Resilient Lands Initiative. The CFI program is a strategic, systematic sample of forests under DCR's stewardship. The program started in the late 1950s and provides over 6 decades of data, including information on the status and trends of DCR's forest land and enables projections of future scenarios to evaluate tradeoffs. It also provides data on resiliency and adaptive capacity; forest health; and growth, yield, and mortality of attributes including carbon. CFI data play a critical role in understanding the resiliency of our forests to stressors and disturbances at a broad scale; and will be used in/with a variety of decision support tools to prioritize strategic action to reduce vulnerabilities.	Statewide action collaboration	Medium	Not started	SHMCAP Implementation	Potential funding	Greater than 5 years				Forest Health Degradation			Statewide		X		X	X	X
EOEEA	DCR	Develop an Invasive Species Emergency Response Plan for invasive pest species, including federally regulated species, that pose a significant risk to forest resources by 2025	DCR's Bureau of Forestry will develop a detailed response plan for newly introduced invasive species, as well as those pests of regulatory concern with high risk of introduction. The plan will outline emergency response operations to respond to emerging pests, including the eradication or mitigation actions to be taken, long-term goals, and key programs and positions involved.	CZM, MassWildlife	Medium	Not started	DCR Cap R102 (Habitat Conservation and Restoration) or	Potential funding	3-5 years	Federal Agencies MDAR, MassWildlife			Shifting Distribution of Native and Invasive Species			Statewide		X		X	X	

EOEEA	DCR	Increase public outreach and education around forest health impacts and DCR's Forest Health Program	Over the next 5 years, the Forest Health Program will expand its public outreach capabilities, increase the number of citizens reached through direct messaging, and streamline public reports of forest threat issues. To achieve these goals, there is a need to increase GIS support for the Forest Health Program to respond to the increased need for interpretive materials for public education and integrating public reports into field staff digital mapping tools. The Forest Health Program monitors and manages forests	CZM, MassWildlife	Medium	Not started	Federal Funding (BILA)	Potential funding	3-5 years	MDAR, MassWildlife			Forest Health Degradation			Statewide	X	X				
EOEEA	DCR	Preserve vulnerable cultural resources	DCR's Office of Cultural Resources will launch a pilot study to identify cultural resources under DCR's care that are most vulnerable to climate change impacts. This pilot program will design and implement up to two protection measures, relocate, or/remove sensitive resources and/or interpret for future generations. DCR will thoroughly document best practices.	CZM, tribes, local municipalities	Medium	Not started	ARPA	Secured – Funds are committed	Less than 3 years						Damage to Tourist Attractions and Recreation Amenities	Statewide		X	X			
EOEEA	DCR	Implement climate resilience measures for the New Charles River and Amelia Earhart dams	Design and construct flood resilience projects at Amelia Earhart Dam and associated lands, including Draw Seven Park. Complete Long-term Resiliency Study led by USACE for New Charles River Dam (anticipated completion: 2025).		High	In Progress	ARPA, partially funded	Secured – Funds are committed	Greater than 5 years	USACE, local municipalities, Mystic River Watershed Association, Charles River		Increased Risk of Dam Overtopping or Failure				Regional	X		X	X		X
EOEEA	DCR	Redesign, configure, and implement a strategic capital planning and capital project delivery	Redesign the existing capital planning process and invest in technology to support improved planning and project delivery. This critical redesign will increase transparency		High	In Progress	ARPA	Secured – Funds are committed	Less than 3 years			Damage to Roads and Loss of Road Service				Statewide		X	X	X	x	X
EOEEA	DEP	Grant opportunities for food/agriculture sectors to improve energy efficiency, adopt renewable energy and reduce GHG emissions (CERP)	Increase access to reliable energy for food-producing and food-distribution entities through the Clean Energy Results Program's Gap Energy Grant. The grant supports installation of reliable energy-efficient equipment and access to renewable energy generation project benefits. DEP can work with its sister agencies MDAR and MassWildlife to reach more food producing entities so that they can incorporate energy efficient and clean energy conservation measures into their businesses. The existing program includes criteria encompassing energy resilience and climate resilience	DOER, MDAR and possibly Mass Fisheries'	High	In Progress	In the short term (round 3 of grants) , the Gap Energy Grant has been funded through the	Planned - There is funding identified but not yet allocated	Less than 3 years	MDAR, Fish and Wildlife	Reduction in Food Safety and Security					Statewide				x	x	x
EOEEA	DEP	Develop updated Wetlands restoration guidance and regulations to improve climate resilience	Develop updated inland and coastal wetlands protection and restoration guidance and/or regulations that improve climate resilience at project, local, and regional /watershed scales. Establish permitting pathways, policies, or guidance to encourage 1) protection / restoration of coastal wetland resource areas including education on new coastal floodplain standards, removal of tidal flow restrictions to restore full extent of salt marshes, restoration of salt marsh ecosystem functionality, migration of salt marshes, dunes, and other coastal resource areas, and address other related	CZM and DCR	High	In Progress	This activity would be conducted with state personnel, and possibly supplemented	Planned - There is funding identified but not yet allocated	3-5 years	DCR, Conservation Commissions, other state and federal agencies, non-profits, private			Coastal Wetland Degradation			Coastwide	x	x	x	x	x	x
EOEEA	DEP	Develop a GIS mapping tool for climate coastal and inland wetlands to identify resource area vulnerability corridors	Design, develop, and maintain a mapping tool of coastal and inland floodplains and other wetland resource areas that identifies current and future "climate vulnerability corridors". The mapping tool will include data layers for risks (such as storm damage, sea levels affecting marshes, and others), land use (such as infrastructure), and cadaster information (such as ownership, EJ populations, wetlands restrictions, and conservation	CZM and DCR	High	In Development	This activity would be conducted with state personnel, and	Potential funding	Less than 3 years	MA CZM			Freshwater Ecosystem Degradation			Statewide	x	x	x	x	x	x
EOEEA	DEP	Amend the Massachusetts Contingency Plan to require consideration of climate change impacts as reasonably foreseeable site conditions during site cleanup and remedy selection	Incorporating consideration of EJ consideration is not a part of this regulatory proposal and would have to be developed with legal input. Other MassDEP guidance addresses outreach to affected EJ populations (public involvement provisions and technical assistance grants). In addition the Licensed Site Professional Assoc. developed a toolkit	No comments.	High	In Development	The 21E program is privatized and relies on	Secured – Funds are committed	Less than 3 years	Licensed Site Professionals (LSPs), parties conducting			biodiversity, habitats, and native species due to climate			Statewide	x	x	x	x		x
EOEEA	DEP	Integrate climate change and decarbonization considerations into oil spill preparedness and response activities under Massachusetts Oil Spill Prevention & Response Act (MOSPRA)	MassDEP and its contracted consultant have met with climate experts and other stakeholders to identify and prioritize impacts of climate trends, projections, and policies and programs for oil spill risk, prevention, and response. The final report, anticipated in December 2023, will include findings and recommendations. Recommendations may affect the deployment of resources from funds collected	Coastal industries and ports, CZM, Coast Guard and Harbor Masters	High	In Progress	Activity is funded by the Oil Spill Prevention and Response	There is funding identified but not yet allocated	3-5 years	oil spill response plans/strategies are updated, partners could			Marine Ecosystem Degradation			Coastwide	x	x	x	x	x	x
EOEEA	DEP	Update Erosion and Sediment Control Guidelines~~;~~ and other policies to minimize erosion from work in Wetlands Resource Areas	Update the Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas (1997, reprinted in 2003), and develop a policy to reinforce that controls during construction are required when alterations occur in wetland resource areas and promote implementation of controls outside of wetland resource areas—to	CZM	High	In Development	DEP Operating; SHMCAP Implementation Funds	Potential funding	5 years	would likely consult with EPA during the development			Soil Erosion			Statewide	x	x	x			x
EOEEA	DEP	Implement Water Management Act regulatory updates (including water restrictions during droughts)	Implement newly promulgated Water Management Act regulations for addressing water restrictions by issuing registrations with new water conservation conditions for registered withdrawers during declared droughts (conservation). When a drought is declared by the Secretary, affected registrants will be required to implement	No comments.	High	In Development	Conservation restrictions will be implemented	Secured – Funds are committed	Greater than 5 years	Registered water users and permittees		Reduction in Clean Water Supply				Statewide	x	x	x	x		x
EOEEA	DEP	Update Chapter 91 regulations to improve resiliency of public trust tidelands and waterways	Develop and promulgate updated Chapter 91 regulations to ensure that potential impacts of sea level rise are considered in the project review and licensing process. Initiate technical development and stakeholder consultation for policy and/or regulatory revisions to address broader climate resilience issues to protect public trust	CZM, EEA	High	In Development	This action will be conducted with state personnel.	Planned - There is funding identified but not yet	3-5 years	MA CZM/other state agencies and key stakeholders (waterfront	Damage to Cultural Resources	Damage to Coastal Buildings and Ports	Coastal Wetland Degradation	Increase in Costs of Responding to Climate Migration	Damage to Tourist Attractions and Recreation Amenities	Coastwide	x	x	x	x		x
EOEEA	DEP	Divert solid waste by increasing local capacity and infrastructure to reduce emissions and vulnerability and promote ~~increase~~ resilience	Solid waste disposal capacity is becoming increasingly limited in Massachusetts and throughout the Northeast US. As a result, more than 1/3 of Massachusetts' trash—about 2 million tons per year—is sent to landfills in other states for disposal. This waste is moved primarily by rail; even a brief rail outage could cause severe disruptions to solid waste collection and disposal. MassDEP would support the development of local	MEMA	High	In Progress	Existing funding sources include MassDEP's Sustainable	There is funding identified but not yet allocated	3-5 years			Damage to Rails and Loss of Rail/Transit Service		Reduction in State and Municipal Revenues	Losses from Commercial Structure Damage and Business	Statewide			x			x
EOEEA	DEP	Develop regulations to create a Clean Heat Standard for heating fuels	The 2025/2030 Massachusetts Clean Energy and Climate Plan (CECP) tasks MassDEP with developing a Clean Heat Standard. MassDEP will initiate a stakeholder process with	DOER, EOHED, EOEEA	High	Not started	Staff time; capital bond	There is funding	Less than 3 years	MassCEC, EOHED	Cognitive Effects from					Statewide				x	x	x
EOEEA	DEP	Complete buildout of Statewide Hydraulic Model	Create a Statewide River Hydraulic Model, using paper printouts, microfiche, and modern LIDAR. This project will allow for projection of future river elevations for both high and low flows and will aid in estimating the effects of projects on river flooding. Phases 1, 2, and 2a included a feasibility study, tool development pilot in the Squannacook River Basin, and model calibration at additional sites. The last project	EEA, DOT, DER, CZM, DCR, FEMA, USGS, UMass, and others	High	In Progress	This activity would be conducted with state personnel in	Potential funding	Less than 3 years		Loss of life or injury due to high vulnerability dams, hurricanes,	Damage to Roads and Loss of Road Service	Shifting Distribution of Native and Invasive Species	Increase in Costs of Responding to Climate Migration	Economic Losses from Commercial Structure Damage and Business	Statewide		x	x			x
EOEEA	DER / DFG	Update DER's Environmental Justice Strategy	Review and improve how DER integrates environmental justice into its grant programs, restoration practices, policies, and other activities, as approximately 60% of DER's restoration-adaptation projects are located in communities with EJ populations. The result of this action will be an updated DER EJ strategy consistent with DFG's and EEA's strategies. The strategy will identify new approaches and best practices and will guide	No comments.	High	Not started	Capital budget (Environmental Bond Bill)	There is funding identified but not yet allocated	Less than 3 years	EEA's Diversity, Equity, and Inclusion (DEI) Office	injury due to high vulnerability dams, hurricanes,	Damage to Roads and Loss of Road Service	Freshwater Ecosystem Degradation	Need for State and Municipal Policy Review and Adaptation Coordination		Statewide	x			x		x

EOEEA	DER / DFG	Identify and prioritize tidal restoration projects using the DER tidal crossing geodatabase	In 2020, DER developed a coast-wide geodatabase containing data on tidal crossings in Massachusetts. Through GIS analysis and field assessments DER will use the tidal crossing geodatabase to identify and prioritize new salt marsh restoration projects that consider multiple criteria including climate resilience, marsh migration potential, and future impacts of sea level rise.	CZM	High	In Progress	Capital budget (Environmental Bond Bill) / DER will also apply for FY25	There is funding identified but not yet allocated	Less than 3 years	Massachusetts Office of Coastal Zone Management	injury due to high vulnerability dams, hurricanes,	Damage to Coastal Buildings and Ports	Coastal Wetland Degradation	Damage to Coastal State and Municipal Buildings and Land		Coastwide		X		X		
EOEEA	DER / DFG	Transitional Crossings Year 1: Testing Standards for Evaluation, Feasibility and Design of Culverts and	Apply the draft Phase 1 climate resilience guidance developed for stream crossings in coastal and near-coastal environments, document the site assessment processes,	DCR	High	In Progress	SHMCAP Implementatio	Funds are committed	Less than 3 years		injury due to high	Coastal Buildings and	Wetland Degradation	Coastal State and Municipal		Coastwide		X		X		
EOEEA	DER / DFG	Municipal and other dam removals Year 1: feeding the project pipeline for strong ecological value and climate	Complete feasibility studies and develop preliminary designs for up to five high-priority dam removal projects, prioritizing high- and significant-hazard dams. This early-stage	DCR, DEP	High	In Progress	SHMCAP Implementatio	Funds are committed	Less than 3 years		injury due to high	of Dam Overtoppi	Ecosystem Deg radation	Coastal State and Municipal		Statewide		x		x		
EOEEA	DER / DFG	Understanding groundwater flow and associated water quality benefits of cranberry bog restoration projects	Support hydrologic and geochemical studies to better understand how effective cranberry bog restoration projects are at improving water quality, specifically looking at nitrogen. Restoration of former agricultural cranberry bogs alters groundwater flow and patterns of ground/surface water exchanges, but the nature and extent of altered flow patterns is likely site specific and potential reductions in nitrogen export are not well understood and difficult to characterize in the field. Increased frequency of high	No comments.	Medium	In Progress	Capital budget (Environmental Bond Bill) / Federal (Partnership with U.S.	Planned - There is funding identified but not yet allocated	3-5 years			Reduction in Clean Water Supply	Freshwater Ecosystem Deg radation			Regional		x		x		
EOEEA	DER / DFG	Develop culvert replacement project pipeline to advance high priority ecologically sensitive restoration projects	Advance strategies to help communities and partnering agencies identify and prioritize ecologically sensitive culvert replacement projects. This effort provides early phase planning services to prepare high value ecological projects for future implementation assistance. DER will build on criteria developed to score projects for its Culvert Replacement Municipal Assistance Grant Program with a particular focus on high value ecological projects and municipalities/regions that have historically had less culvert projects in partnership with DER. DER will work with landowners of potential sites which	DCR, MassDOT, local municipalities, regional organizations, and please describe other partners here.	High	In Progress	Capital budget (Environmental Bond Bill)	Planned - There is funding identified but not yet allocated	Less than 3 years		injury due to high vulnerability dams, hurricanes, wildfires, extreme	Damage to Roads and Loss of Road Service	Freshwater Ecosystem Deg radation	Damage to Inland State and Municipal Buildings and Land		Statewide		x		x		
EOEEA	DER / DFG	Division Restructuring and Expansion	DER will implement a division restructuring and expansion plan with the following goals: Expand and improve DER's ecological restoration work; Strengthen DER's internal capacity; Expand external capacity; Learn and share knowledge about restoration outcomes and best practices. The expansion plan includes specific actions related to hazard mitigation and climate adaptation including: promoting ecological restoration as	No comments.	High	In Progress	Operational budget (annual appropriation) / Capital budget	There is funding identified but not yet allocated	Less than 3 years		injury due to high vulnerability dams, hurricanes,	Damage to Inland Buildings	Freshwater Ecosystem Deg radation	Need for State and Municipal Policy Review and Adaptation Coordination		Statewide	x	x		x		
EOEEA	DER / DFG	Increase Regional Capacity Building to Help Communities Plan and Implement Climate Resilient Ecological Restoration Projects	DER will increase its regional capacity building efforts by partnering with 3-5 new regional partners through its Regional Restoration Partnerships Program. The new regional partners will receive technical and funding assistance from DER to plan, design and implement aquatic ecosystem restoration projects that increase climate resilience for human and natural communities.	Regional organizations	High	In Progress	Capital budget (Environmental Bond Bill)	There is funding identified but not yet allocated	Less than 3 years		injury due to high vulnerability dams, hurricanes,	Damage to Inland Buildings	Freshwater Ecosystem Deg radation	Need for State and Municipal Policy Review and Adaptation Coordination		Statewide	x	x		x		
EOEEA	DMF	DMF Ocean Bottom Temperature database	Advance the utility of the DMF Bottom temperature database in addressing ocean warming	EEA IT, DFG IT	Medium	Not started	Operating; SHMCAP	Potential funding	3-5 years	EEA IT, DFG IT, others?	Cultural Resources				Marine Fisheries and	Coastwide	X	X	x	X	x	x
EOEEA	DMF	Support Ocean Acidification monitoring efforts	Advance the development of an Ocean Acidification monitoring network through collaborations with locaal shellfish departments and shellfish aquaculturists	DAR, SAP	Medium	Not started	Operating; SHMCAP Implementation	Potential funding	3-5 years	Local municipalities. DAR, SAP	Reduction in Food Safety and Security				Decrease in Marine Fisheries and Aquaculture Productivity	Coastwide	X	X	x	X	x	x
EOEEA	DMF	Enhance environmental monitoring cabibilities for HAB's and shellfish borne illness	Improve monitoring cababilities for HAB's and shellfish borne diseases.	local municipalities	Medium	In Progress	SHMCAP Implementatio	There is funding	3-5 years	municipalities. DAR, SAP	Food Safety and Security		Distribution of Native and		Marine Fisheries and	Coastwide	X	X	x	x	x	x
EOEEA	DMF	Increase fishing vessel tracking program support	Support for research and implementation for vessel tracking for monitoring and assessing shifts in fishing effort	EEAIT, DFG	High	In Progress	Staff Time	There is funding identified but not yet	3-5 years	commercial fishing industry (MLA?)	Damage to Cultural Resources		Distribution of Native and Invasive Species		Marine Fisheries and Aquaculture Productivity	Coastwide	X	X	X	X	x	x
EOEEA	DMF	Increase training and workforce diversificaiton	Support training and work force diversification programs for fishers and farmers	Urban Harbors Institute?, MLA, Fisherman's Wives Assn. , etc..	Medium	In Progress	Staff Time	There is funding	Greater than 5 years	fishing industry (MLA?)	Food Safety and Security		Distribution of Native and		Marine Fisheries and	Coastwide	X	X	x	x	x	x
EOEEA	DMF	Increase Program Support	Enhance support for existing programs such as BIG / CVA. Provide support to industry through grant opportunities for shorebased seafood processors and dealers for renewable energy and clean energy conservation improvements to their business		Medium	In Development	Staff Time	There is funding identified but not yet allocated	Greater than 5 years	Commercial fishing sector	Reduction in Food Safety and Security				Decrease in Marine Fisheries and Aquaculture Productivity	Coastwide	X	x	X	X	X	X
EOEEA	DPU	Resilient siting of new or modified jurisdictional transmission facilities	Ensure that new or substantially modified jurisdictional electric transmission facilites are designed, built, and operated for resiliency regarding flooding/sea level rise; severe weather events; and physical/cyber security threats. Refine use of forward-looking approval conditions that require periodic review of updated data and science, potential mitigation measures; required actions/modifications.	No comments.	high	In Progress	capital budget; SHMCAP Implementatio n	Potential funding	Less than 3 years	MEPA, DEP, RMAT, CZM, GBRAG, FEMA, Army Corps		Damage to Electric Transm ission and Utility Distribut ion Infrastructure			Reduced Ability to Work	Statewide		x			x	x
EOEEA	EEA	Increase funding, eligibility, and focus on environmental justice to and within municipal and agency resilience action	Launch MVP Planning 2.0 program and develop update to MVP 2.0 Action Program that addresses stakeholder feedback and improves program access and support to best practices.	No comments.	High	In Progress	Capital budget (env bond bill)	Potential funding	Less than 3 years	N/A				Demand for State and Municipal Government S		Statewide				x		
EOEEA	EEA	Increase access to state resilience funding	Develop a one stop grant clearinghouse that streamlines climate/environment grant application process for applicants and ensures efficiency in the distribution of funding to local projects. In coordination, update and maintain the resilientma.mass.gov website based on stakeholder feedback; build out new pages and resources related to example projects, funding sources, metrics, and topic-specific toolkits; and revise and expand data and GIS maps and tools to better serve stakeholders.	MEMA	Medium	In Progress	Operating; SHMCAP Implementatio n	Potential funding	3-5 years					Increase in Demand for State and Municipal Government S ervices			x	x	x	x	x	x

EOEEA	EEA	Increase Efficiency of Water Use	Provide technical and financial assistance to cities and towns to develop better water conservation plans and drought management plans that meet state guidelines provided by EEA, establish water rate structures that promote conservation and efficiency, conduct statewide water/sewer rate surveys, enhance local capacity to perform system wide water audits; address and minimize outdoor water use; invest in enhanced education and outreach to the public and water suppliers and in particular to EJ communities and under-resourced communitites on water efficiency and water conservation.	No comments.	High	Not started	Operating; SHMCAP Implementation	Potential funding	3-5 years			Reduction in Clean Water Supply					x	x	x	x		x
EOEEA	EEA	Develop a statewide database and dashboard of water resources data	Develop a statewide database on water use and management in multiple sectors, such as municipal, district, commercial, institutional, industrial, public sector to help with water needs forecasts, streamflow analysis, TMDLs, etc. This would pull data from across agencies (such as DEP) to increase efficiency and timeliness of compilation and analysis of water capacity, allocations and use.	Is this intended to be a statewide or global action? Response by VR: this statewide action would require close coordination with DEP and DCR-OWR.	Medium	Not started	Operating; SHMCAP Implementation	Potential funding	3-5 years			Reduction in Clean Water Supply					x	x	x			
EOEEA	EEA	Ensure resilient current and future water supplies: i. Assess vulnerability of groundwater resources to drought, ii. Identify and Protect recharge areas	Launch a study to assess and map vulnerability of private wells and public water supply wells to stresses such as droughts.This project will assess and map these contributing areas for use as a criteria in EEA land conservation programs.	Statewide action collaboration in partnership with DEP, and DCR-OWR.	High	Not started	Operating; SHMCAP Implementation	Potential funding	3-5 years			Reduction in Clean Water Supply						x	x			
EOEEA	EEA	Identify causes of low streamflows (therefore decrease water availability) during a drought.	Launch a study to identify the causes for low streamflows such as land use change, climate change, water use, etc to identify and prioritize mitigation measures.	EEA, MassWildlife, DEP, DCR-Maybe this is a statewide or global action given the scale and statewide importance. Response by VR: yes, this will include key water staff from our 3 envtl	High	In progress	Operating; SHMCAP Implementation	Potential funding	Less than 3 years			Reduction in Clean Water Supply						x	x	x		
EOEEA	EEA	Enhance and make more robust and comprehensive hydrologic monitoring networks	Assess monitoring networks used for the Drought Indices to make them more robust, and comprehensive (e.g., spatial representation, regional representation, hydrogeologic representation). Conduct a network analysis and expand the network by acquiring and installing new equipment.	Local and regional municipalities and organizations.	High	In Development	Operating; SHMCAP Implementation	Potential funding	Less than 3 years			Reduction in Clean Water Supply						x	x			
EOEEA	EEA	Prioritize mobile solar energy systems for emergency response.	Shift from generators to investments in mobile solar energy storage systems that can be used during emergencies.	DOER, MEMA (potential funding)	High	Not started	Operating; SHMCAP Implementation	Potential funding	Less than 3 years		Health Effects of Extreme Storms and Power Outages	Loss of Energy Production and Resources				Statewide					x	
EOEEA	EEA/DCR-OWR	Address flooding through better understanding of changes in flooding due to climate change; impacts of flooding to infrastructure, natural resources and groundwater; better planning and management; decrease in Flood Vulnerability	i. Address Flood Vulnerability: Develop flood map overlays to show increased flood vulnerabilities across the commonwealth and in particular where these intersect with EJ populations; Identify areas of repeated flooding across the state, overlaying with EJ, overlaying with potential causes (e.g., geology, land use/IS) and overlaying with potential mitigation options such as upland recharge areas, improved stormwater infrastructure, and removing impervious surfaces or similar. Advance implementation	Statewide action collaboration	High	In Development	Operating; SHMCAP Implementation	Potential funding	3-5 years			Reduction in Clean Water Supply						x	x			
EOEEA	MassWildlife	Coastal erosion Adapation Project for endangered birds: Restoration of Ram Island Wildlife Sanctuary	This project would stabilize and restore Ram Island for the benefit of rare terns and saltmarsh habitat. The island in Buzzard's Bay is a state-owned wildlife sanctuary that supports 20% of the N. American population of the federally endangered Roseate Tern as well as MA's second-largest Common Tern (MA-listed: Special Concern) colonies. Maximum elevation of 3-ac island is <9 ft above MLW. It is rapidly eroding and	CZM	High	Not started	Operating; SHMCAP Implementation	Potential funding	Greater than 5 years	Partner with Trustees and other resource management agencies			Coastal Erosion			Regional	x	x	x	x		x
EOEEA	MassWildlife	Restoring water quality and habitat connectivity in coastal streams	This action will seek to assess cultverts in tributaries to Buzzards Bay, complete upgrades or replacements of culverts in Fresh Brook (Wellfleet, MA) and Red Brook, as	No comments.	High	Not started	SHMCAP Implementatio	Potential funding	Less than 3 years	Conservation Commissions,			Ecosystem Deg radation			Regional	x	x	x	x		x
EOEEA	MassWildlife	Priority dam assessments and dam removals	MassWildlife has identified several projects important for restoring habitats for cool-water and warm-water fisheries. These include the removal of Salmon Brook dam	Dam Safety Program, DCR, DER	High	In Progress	Partially funded (In Lieu	There is funding	Less than 3 years	Conservation Commissions			Distribution of Native and			Statewide	x	x	x	x		x
EOEEA	MassWildlife	Restoring Forest Ecosystem Health to bolster climate change resiliency	MassWildlife will continue to coordinate forest health projects with sister agencies such as DCR and DEP. However, MassWildlife projects may be developed and prioritized		High	In Progress	Operating; SHMCAP	Potential funding	Less than 3 years	DCR, USGS, NIACS			Forest Health Degradation			Statewide	x	x	x	x	x	x
EOEEA	MassWildlife	Great Marsh Ecosystem Recovery Project	Project partners have begun restoration of some of the Great Marsh Ecosystem. However, only a fraction of the ecosystem has been restored. This action will continue monitoring and restoration efforts to reestablish marsh elevations and tidal connections to the system.	CZM	High	Not started	America the Beautiful grant	There is funding identified but not yet allocated	3-5 years	Trusteees, NPS, MasAudobon, Town of Essex, many more			Coastal Wetland Degradation			Regional	x	x	x	x		x
EOEEA	MassWildlife	Lake level management recommendations to abate cyanobacteria blooms	MassWildlife has been working with partners (e.g., USGS, UMass-Amherst) to model how lake levels and climate change are likely to affect cyanobacteria blooms. However, little on-the-ground data has been collected to drive the models. This action would seek to collect empirical data in lakes throughout the state to validate and populate models. MassWildlife will coordinate with DCR and DPU when shared goals exist.	DEP, DCR	High	In Progress	NECASC funding; SHMCAP Implementation	Secured – Funds are committed	Less than 3 years	Partners with USGS, Univeristy of Michigan, UMass-Amherst,			Freshwater Ecosystem Deg radation			Statewide	x	x	x	x		x
EOEEA	MassWildlife	Protecting aquatic biodiversity: fresh water mussels	Freshwater mussels provide critical ecosystem services and yet are some of the most threatened animals in the state. Six of the 12 species found in Massachusetts are listed under the state's Endangered Species Act. They are critical to protecting water quality in freshwater systems. Each mussel can filter up to 15 gallons of water per day. As climate change continues to stress freshwater systems through increases in pollutant concentrations and algal blooms, freshwater mussels provide a nature-based solution	No comments.	High	Not started	NECASC funding; SHMCAP Implementation	Secured – Funds are committed	Less than 3 years	with USGS, UMass-Amherst, NECASC and biolgists from all 6 New			biodiversity, habitats, and native species due to climate change impacts.			Statewide	x	x	x	x		x
EOEEA	MassWildlife	Implementation of regional conservation plans for turtle SGCN	Restoring turtle species in Massachusetts is important for improving forest health. Terrestrial turtles are prolific seed dispersers for many plants, inlcluding trees, and fungi, because they are long-lived, widespread, and travel between habitats. Their eggs are also an important food source for other species, such as snakes and small mammals. Unfortunately, six of the ten native terrestrial and aquatic species are listed under the Massachusetts Endangered Species Act. The factors threatening the	Statewide action? I'm not sure it would fit as such.	High	Not started	America the Beautiful grant; SHMCAP Implementation	Potential funding	3-5 years	Northeastern state biologists			Loss of biodiversity, habitats, and native species due to climate change			Statewide	x	x	x	xx		x

EOEEA	MassWildlife	Assessment and management plan for invasive plants	Invasive species are the biggest threat to ecosystems in the state, after habitat destruction and degradation. Their impacts are getting inceasingly worse as a result of climate change. Habitats important for carbon sequestration (forests, salt marshes), clean water, and protection from inland flooding are all threatened by the pervasive and largely uncontrolled impacts from invasive species. Management and eradication of invasive species takes early detection, years of treatments, and continued funding	DCR, CZM, DEP, tribes	High	In Progress	SHMCAP Implementation Funding	Potential funding	3-5 years				Shifting Distribution of Native and Invasive Species			Statewide	x	x	x	x		x
EOEEA	MassWildlife	Monitoring and restoration of climate refugia aquatic ecosystems	Climate change refugia are habitats naturally more resilient to climate change as they change at a much slower pace than the habitats around them. They are important as anchors to restoration efforts because individuals will recolonize restored areas from these habitats. This action will collect streamflow and temparature data necessary to evaluate impacts to climate change refugia (e.g., at headwater ponds and streams flowing into coldwater habitats). Three projects have also been identified as important	DCR, DER, local towns	High	Not started	Partially funded	Secured – Fund	Less than 3 year	DCR, Conservation Commissions, USGS			Loss of biodiversity, habitats, and native species due to climate ch				x	x	x	x		x
EOEEA	MDAR	Climate Smart Ag Program, Sustainable Soil Management and Grant Programs	MDAR's Climate Smart Ag Program helps farmers transition to sustainable approaches to soil management such as reduced or no-till planting; the Agricultural Soil Health program that funds AFT to provide TA to farmers around soil health through the Coordinated Soil Health Program. The Farm Viability Programs provide farmers with technical assistance, business planning and funding to ensure that the farms remain productive and viable. Climate Smart Ag grants and FSIG grants assist farmers with	No comments.	High	Not started	Currently funded through the Environmental Bond Bill	Secured – Funds are committed	Less than 3 years		Increase in Mental Health Stressors		Soil Erosion	Increase in Need for State and Municipal Policy Review and Adaptation Coordination	Decrease in Agricultural Pr oductivity	Statewide						x
EOEEA	MDAR	MDAR: Grants for private APRs	The APR program is not legislatively authorized to fund private entity acquisition of APRs. Establish a grant program for acquisition and stewardship of APRs by private entities. This will aid in significantly increasing the pace of farmland conservation and the associated public benefits and protections of food security and agricultural production, water supply, soil erosion, freshwater ecosystems, biodiversity and habitat, avoidance of damages to tourist attractions. An increase in the number of APRs will	No comments.	high	Not started	Possibly through ARPA funds.	Potential funding	Less than 3 years		Reduction in Food Safety and Security	Reduction in Clean Water Supply	Soil Erosion		Damage to Tourist Attractions and Recreation Amenities	Statewide	x	x	x	x	x	x
EOEEA	MDAR	MDAR: Improve Mapping to Enhance Resilience and Emergency Preparedness of Agricultural Land.	Utilize and build off hydrologic data and modeling to design, develop, and maintain a mapping tool of "climate vulnerability corridors" for agriculture The model will identify existing and projected coastal and inland river floodplains that intersect with agricultural land. This will enable users to observe existing hotspots for high probablility soil erosion and freshwater ecocsystem degredation as well as predict future areas of concern based on projected changes to precipitation and flooding due to climate	DCR, CZM, DEP	high	Not started	SHMCAP Implementation Funding; Capital Budget (bond)	Potential funding	3-5 years	Agency partners - DCR, DFG, federal partnets			Freshwater Ecosystem Deg radation		Decrease in Agricultural Pr oductivity	Statewide	x	x	x	x	x	x
EOEEA	MDAR	MDAR: Farm Climate Resiliency Program	While there are existing and emerging Agricultural Best Management Practices (BMPs) to address climate change, a major barrier to implementation is the cost associated risk to farmers. Such practices often involve use of additional equipment, letting less productive land go fallow, and come with legitimate fears of risk of reduction in crop production. Another major barrier is the time it takes for farmers to learn and understand the practices, assess how they may be incorporated into their operation, and then figuring out how to implement it. These grants will provide free "climate	No comments.	High	Not started	Currently funded through the Environmental Bond Bill	Secured – Funds are committed	Less than 3 years				Loss of biodiversity, habitats, and native species due to climate change impacts.		Reduction in the Availability of Affordably Priced Housing	Statewide	x	x	x	x	x	x
EOEEA	MDAR	MDAR: Model future challenges for specific agricultural commodities.	Predicting specific climate related challenges to specific agricultural sectors and commodities and linking that with a projected timeline will enable producers and	EEA and MEMA	high	Not started	SHMCAP Implementatio	Potential funding	3-5 years	Agency partners - EEA, MEMA					Decrease in Agricultural Pr oductivity	Statewide	x	x	x	x	x	x
EOEEA	MDAR	MDAR: Farmland Prioritization	Develop and maintain a farmland prioritization tool similar to BioMap. Agriculture is the only natural resource in the Commonwealth that does not have a prioritization tool. The Farmland Action Plan recommends development of such a tool. MDAR will consult with agricultural and natural resource experts, review existing prioritization tools and develop, maintain, and dissmeniate a tool for prioritizing agricultural land for protection. It will incorporate climate risk and resiliency considerations and	No comments.	high	Not started	SHMCAP Implementation Funding; Capital Budget (bond)	Potential funding	3-5 years	EEA,			biodiversity, habitats, and native species due to climate change impacts.		Decrease in Agricultural Pr oductivity	Statewide	x	x	x	x	x	x
EOPSS	EOPSS	Integration of climate change adaptation into EOPSS agencies' programs, policies, and procedures.	EOPSS in coordination with MEMA will work with all EOPSS agencies to establish a process by which agencies can consider climate change to the maximum extent possible. The following approaches could be considered, trainings, strategic planning, and other approaches to effectively integrate climate change and hazard mitigation into EOPSS agencies. A final product will be a how-to guide that can be used across all executive branch agencies to integrate climate change adaptation.	EEA and MEMA	High	Not started	Staff time and SHMCAP Implementation Funding	Potential funding	Less than 3 years		Emergency Service Response Delays and Evacuation Disruptions			Increase in Demand for State and Municipal Government S ervices			xx	xx	x	x		
EOPSS	MEMA	State Government Continuity of Government Plan	In coordination with the Governor's Office and EOPSS, MEMA is leading the development of the whole of Government Continuity of Government (COG) plan. This plan will provide direction to the Executive, Legislative, and Judicial Branches of Government in the event governmental services are heavily impacted by an emergency including natural disasters and those that are exacerbated by climate change. The COG will provide all Branches of	All three branches of government inclusing all relevant agencies lead by MEMA in coordination wtih EOPSS and the Governor's Office	High	In Progress	Staff Time	Secured – Funds are committed	Less than 3 years	Governor's Office and Cabinet Secretaries, EOPSS				Inability to carry out mission and services due to damage, disruption, or loss of state		Statewide	x		x			
EOPSS	MEMA	Integrate Climate Resilience considerations into the FEMA Public Assistance Program	The Climate Resilience Design Standards Tool will be integrated into FEMA HMA programs starting in FY23. MEMA will then work to Integrate the Tool into FEMA's PA	No comment.	High	In Progress	Staff time will be used to	Funds are committed	Less than 3 years	local communities		Roads and Loss of Road Service				Statewide			X	X		X
EOPSS	MEMA	Acquisition/Buy-out Program Study	Acquisition/Buyout programs are one method of property acquisitions in which private lands are purchased, existing structures demolished, and the land maintained in an undeveloped state for public use in perpetuity. Acquisition of a property in a floodway is intended to reduce the risk of future flooding for the property and/or those adjacent.	DCR, State Floodplain Coordinator	High	In Progress	Staff time	Secured – Funds are committed	Less than 3 years	DCR, State Floodplain Manager; local communities	Service Response Delays and Evacuation	Damage to Inland Buildings		Reduction in State and Municipal Revenues		Statewide	X	X	X	X		X
EOPSS	MEMA	Program Administration by States (PAS)	MEMA will seek Federal Emergency Management Agency (FEMA) PAS designation which will allow MEMA/State to review and approve Local Hazard Mitigation Plans at the State level. This will greatly expedite the review process. MEMA will need additional resource to establish and maintain the program.	No comments.	Medium	In Progress	Staff time or FEMA HMA Management Cost	Potential funding	Less than 3 years	FEMA,		Damage to Inland Buildings				Statewide	x			x		x
EOPSS	MEMA	STORM Act	MEMA will review other state agency revolving loan funds to identify which, if any, revolving loan funds can be partnered with to support the STORM Act requirements. MEMA will also identify best practices from other states which have successfully implemented the STORM Act to replicate those processes where possible within existing MA structures.	No comments.	Medium	In Progress	Staff time	Potential funding	Less than 3 years	State agencies with SRLF						Statewide	X			X		X
EOPSS	MEMA	Statewide EM Training Needs Assessment	MEMA recently launched the Northeast Emergency Management Training & Education Center (NEMTEC), designed to strengthen regional response to emergencies including those due to natural hazards exacerbated by climate change. This comprehensive training program will provide advanced education and expanded resources to New England's emergency management professionals, who face evolving challenges due to	No comments.	High	In Progress	Staff time; SHMCAP Implementation	Potential funding	Less than 3 years		Service Response Delays and Evacuation Disruptions					Statewide	X					X
EOPSS	MEMA	Dam Safety Planning Improvements	This is a stand alone action as it is for emergency response not maintenance plans.	DCR DSO	High	In Progress	Staff time	Funds are committed	Less than 3 years	Dam Safety; EEA		of Dam Overtoppi				Statewide	X		X			X

EOTSS	EOTSS	Continue to identify and to migrate business applications and systems to the cloud.	Migrate the MA21 mainframe-based system into the cloud for the resiliency of a key One Health Integrated Eligibility system.	No comments.	High	In Progress	IT Capital Bond Bill	Planned - There is funding identified but not yet	3-5 years		Disproportionate impacts on unhoused populations from extreme			Inability to carry out mission and services due to damage,		Statewide			X			
EOTSS	EOTSS	Enhance the mobility of the state workforce through the continued deployment - and refresh - of devices to implement COOP plans impacted by climate.	Deploying laptops can help the state and employees by enabling remote work during extreme weather events, reducing energy consumption and generating less heat when compared to legacy desktop systems, facilitating paperless work, and supporting sustainable procurement practices. By using laptops, the state can reduce our carbon footprint, support environmental sustainability, and improve the overall climate resilience	No comments.	Medium	In Progress	IT Capital Bond	Potential fundin	3-5 years			Damage to Inland Buildings		Inability to carry out mission and		Statewide			X			
EOTSS	EOTSS	Expand MassGIS capabilities to map land for wind farms or space for other transformative climate adaptation infrastructure	MassGIS can collaborate with agencies, including MEMA and EEA agencies, to harness the MassGIS skills and existing mapping capabilities to meet the strategic objectives and requirements of climate adaptation projects. In particular, MassGIS is able to gather relevant data on topography, land use and infrastructure. This may involve using tools such as sustainability analysis, spatial analysis and 3D representation.	EEA and MEMA	High	Not started	IT Capital Bond Bill	Potential funding	3-5 years							Statewide		X				
EOTSS	EOTSS	Explore the feasibility of creating a competitive State and Local IT Climate Resilience AND/OR Awareness Program	Explore the feasibility of creating a new competitive State and Local IT Climate Resilience and/or Awareness Program, and explore the possibility of adding IT climate resilience as either a Community Compact IT Best Practice or an eligibility area for the Community Compact IT Grant. Based on the funding/program source, EOTSS may provide technical guidance to municipalities regarding the climate impacts on local IT infrastructure.	EEA, MEMA and Division of Local Services (DLS)	High	Not started	IT Capital Bond Bill	Potential funding	3-5 years							Statewide	X					
EOTSS	EOTSS	Utilizing TSS videography team to professionalize climte coordination training videos and other digital products	Utilizing TSS digital services, including strategy, digital, data and videography experts, to work with cross-agencies content creators and subject matter experts to create professional-level content. The EOTSS videography team to produce professional-level training videos and other digital awareness products that can significantly enhance the quality and impact of these materials. The video team can work with cross-agencies content creators and subject matter experts to develop a production plan that aligns with the goals and objectives of the campaign, and bring technical expertise to ensure high quality of work. They can also use editing techniques to polish the final product that effectively communicates important messages to the intended audiences.		Medium	Not started	IT Capital Bond Bill	Potential funding	Less than 3 years													
EOED	CPRO	Incorporate climate resilience into the Commonwealth's sustainable development principles	Incorporate climate resilience into the Commonwealth's sustainable development principles, resulting in further integration of resilience goals into EOHED funding programs that support housing production and economic growth, including capital grant programs offered through the Community One Stop for Growth	No comments.	Medium	Not started	Staff time	Potential funding	Less than 3 years						Reduction in the Availability of Affordably Priced Housing	Statewide				X		
EOHLC	DHCD	Implement resiliency strategy at state-aided public housing	[Action from Round 2 drafted properly. It's additive and similar to other Actions for DHCD because DHCD is far ahead of most agencies, and is already implementing construction projects. This goal simply puts a number to that goal: DHCD identified 194 developments that are at high-risk to climate hazards like flooding. To address all of these by 2050, DHCD must move 7 projects into construction annually between now and 2050.] Funding is limited to SHMCAP grants for resiliency actions. New process is to develop feasibility studies to prepare for limited timeframe of grant funding and request grant funding for those projects which will complete in the time period. Currently five projects are in the study phase preparing to request grant funding when study is completed. Limitations are increased due to staff capacity to implement along with other capital projects. Ideally 3 studies can be initiated annually to roll out for a grant request the following year. Specific limited funding from A&F is also used on projects being planned to incorporate more resilient design practices into routine capital projects. This funding is also used for sustainability projects and so is limited in nature.	EEA and MEMA	High	In Progress	SHMCAP Implementation Funding	Potential funding	Less than 3 years	EEA & MEMA, DPH				Damage to Coastal State and Municipal Buildings and Land		Statewide		x	x	x		x
EOED	EOED	Incorporate climate resilience criteria into Seaport Economic Council (SEC) capital grants	Incorporate climate resilience criteria into Seaport Economic Council (SEC) capital grants to promote local adaptation projects that reduce climate risks for ports, harbors, and maritime assets in Massachusetts. Utilize the Commonwealth's Climate Resilience and Design Standards Tool to apply these criteria to grant evaluations.	MEMA, CZM, EEA	High	In Progress	Seaport Economic Council Capital Grant Program, currently funded by the	Secured – Funds are committed	Less than 3 years			Damage to Coastal Buildings and Ports			Decrease in Marine Fisheries and Aquaculture Productivity	Coastwide		x		x		HED via the Seaport Economic Council could potentially be a support agency in actions
EOED	MOTT	Incorporate climate resilience criteria into capital grants for tourism assets	Incorporate climate resilience criteria into capital grant programs that support the construction, resilience, or renovation of tourism assets, such as the Massachusetts Destination Development Capital Grant Program. Utilize the Commonwealth's Climate Resilience and Design Standards Tool to apply these criteria to grant evaluations.	DCR, CZM, Mass Historic Commission	High	In Progress	Massachusetts Destination Development Capital Grant Program, currently funded by the Commonwealt	Secured – Funds are committed	Less than 3 years						Damage to Tourist Attractions and Recreation Amenities	Statewide				x		

EOHHS	DPH	Host DPH Internal Climate Equity Working Group	Convene internal agency working group tasked with assessing disproportionate impacts of climate change on program-specific assets and functions and developing an agency-wide rubric to guide pilot assessments and intervention projects that address inequities and promote climate justice in vulnerable populations served by DPH. Climate hazards and risks to be assessed include extreme temperatures, extreme weather (e.g., hurricanes), and inland and coastal flooding. Action may address food safety and security, chronic disease, and increase in vectorborne disease, depending on which offices, bureaus, and programs engage in climate resilience activities through the DPH working group.	EEA and MEMA	Medium	In Progress	State Operating	Secured – Funds are committed	3-5 years	DOC, MDAR	Loss of life or injury due to high vulnerability dams, hurricanes, wildfires, extreme flooding, or extreme temperatures.					Statewide	x	x	x			x
EOHHS	DPH	Develop Outreach Materials for Climate Change and Health	Leverage existing educational content, data tools, and resources to develop new web-based and public-facing outreach materials focused on prevention of climate-related health impacts in high-risk populations. Topics to include extreme heat and poor air quality, extreme storms and power outages, tick- and mosquito-borne diseases, worker health and safety, and the presence of harmful bacteria and algae in recreational waterbodies. If sufficient funding becomes available, this Action will include convening a DPH Stakeholder Advisory Group that supports representatives from community-based organizations in Environmental Justice areas to evaluate and provide feedback on DPH outreach materials and messaging about climate and health. This Action will include equitable community engagement activities that centers the lived experience of community members and elevates the knowledge and expertise of community-based organizations in Environmental Justice communities in the development and dissemination of culturally and linguistically appropriate DPH outreach materials and messaging about climate and health.	EEA, MEMA, local municipalities, regional organizations, DCR, MBTA, and other state agencies with physical assets and spaces that could be used to share this content and information.	Medium	In Progress	State Operating	Secured – Funds are committed	3-5 years	DOC, MDAR	Health and Cognitive Effects from Extreme Heat					Statewide	x	x				
EOHHS	DPH	Strengthen DPH capacity to address health impacts of moisture and mold in public buildings, including schools	Develop focused outreach materials for operators of public buildings and schools that describe interventions for preventing and safely remediating moisture and mold growth inside the building envelope during extended periods of hot, humid weather, acknowledging the impact of climate change. The culturally and linguistically appropriate materials will be made publicly available on the DPH website and distributed according to a robust dissemination plan, which includes building managers as part of public building inspections and reports produced by the DPH Bureau of Environmental Health, Indoor Air Quality Program and other DPH tools and resources, including the DPH Bureau of Community Health and Prevention's Clearing the Air Toolkit: An Asthma Toolkit for Healthy Schools.	DHCD, EOE, DCAMM	Medium	In Progress	State Operating	Secured – Funds are committed	3-5 years		Health Effects from Aeroallergens and Mold					Statewide	x	x	x	x		x
EOHHS	DPH	Provide Municipal and Local Health Climate Equity Training and Technical Support	Produce a Massachusetts-specific training module for local health officials to increase awareness about the disproportionate health impacts of exposure to climate change hazards, including impacts on mental health and unhoused populations, leveraging DPH's existing relationships with local public health officials and experience and meaningfully engaging communities most vulnerable to climate impacts. The training module will cover a variety of climate hazards, including extreme temperatures, flooding, and mold, and will provide examples of environmental health interventions that local health officials can leverage as part of their work.	EEA, municipal and regional partners and organizations.	High	In Progress	State Operating	Secured – Funds are committed	3-5 years	DOC, MDAR	Disproportionate impacts on unhoused populations from extreme temperatures or extreme flooding.					Statewide	x	x		x		x
EOLWD	DLS	LWD Climate Change Impact Risk Assessment	Assess the risk to Labor and Workforce Development (LWD) operations faced from climate change. Through a vendor, assess risk to operations and facilities posed by climate change. Prioritize risks and develop mitigation strategies. Estimate costs of capital mitigation measures.	No comments.	Medium	In Progress	SHMCAP Implementation Funding	Secured – Funds are committed	Less than 3 years	EEA				Inability to carry out mission and services due to damage, disruption, or	Reduced Ability to Work	Statewide	X		X			X
EOLWD	DLS	Workforce Heat Exposure Outreach	Develop and provide annual outreach information to employers and employees on the dangers of exposure to environmental heat, and stategies for minimizing the risks posed by such exposures. Outreach to be done by email, and in-person and virtual presentations. Collaborate with internal and external stakeholders on the efforts.	Statewide action for heat	Medium	In Progress	Operating Bud	Secured – Funds are committed	Less than 3 years	DPH, AGO	Health and Cognitive Effects from Extreme Heat				Reduced Ability to Work	Statewide	X		X			X
MBTA - MassDOT	MBTA / EOEEA	Conduct Climate Vulnerability Assessments	Complete a Vulnerability Assessment of Critical Locations Across Commuter Rail System (esp. Historical flood locations), and assess the vulnerability of all 3 major Commuter Rail Facilities. Finish conducting Cabot Yard Vulnerability Assessment, and complete additional bus facility vulnerability assessments (in coordination with the Bus Modernization Program).	No comments.	High	In Progress	Capital Budget; Operating; Grant funding	Potential funding	3-5 years			Damage to Rails and Loss of Rail/Transit Service				Regional			X			X

MBTA - MassDOT	MBTA / MassDOT Security & Emergency Management Dept	Updating the MBTA's Emergency Response Plans and GIS viewer for real-time storm response	The MBTA will revise and update its Severe Weather Operations Plan, as well as its Snow + Ice Plan to reflect both the latest climate science and expectations about operating in severe weather. The completion of an updated Comprehensive Emergency Management Plan (CEMP) is underway as part of the MBTA's Tunnel Flood Mitigation program. The updated CEMP, which accounts for all climate hazards, will directly inform an update to the Severe Weather Operations plan, as well as the Snow + Ice Plan. The Severe Weather Operations plan that is currently in place requires more robust coordination between different MBTA departments, and a verification that the resources that each department says it plans to rely upon, will be available in the event of a major storm. Having a GIS viewer for real-time storm response (a deliverable that is part of the Tunnel Flood Protection Program) will help with this coordination and revision of the plans.	EEA and MEMA	High	In Progress	Operating Budget; Capital Budget	Planned - There is funding identified but not yet allocated	Less than 3 years	MassDOT (MBTA and MassDOT share an Office of Security & Emergency Management)		Damage to Rails and Loss of Rail/Transit Service				Regional		X	X			X
MBTA - MassDOT	MBTA / Office of the Chief Engineer	Tunnel Flood Mitigation Program	The MBTA's Tunnel Flood Mitigation program, begun in 2021, is presently working on conceptual designs for flood protection of the Alewife Storage Tracks and the Airport Portal. The program is also seeking to address- presently through initial scoping - and next into design and construction - upgrades to track dewatering pump rooms. By protecting portals the MBTA is seeking to keep coastal flood water out. By improving the pump rooms that handle everyday water on the tracks, these will help us from flooding internally. The next steps in this program will be addressing the D Street Portal on the Silver Line in the Seaport (designing flood protection), and addressing flood protection for the MBTA's lowest critical flood locations (especially the ones exposed to coastal flooding in the near term), such as vent shafts, manholes, emergency egresses, etc.	No comments.	High	In Progress	Operating Bud	Secured – Funds are committed	Greater than 5 years			Damage to Rails and Loss of Rail/Transit Service				Regional			X			
MBTA - MassDOT	MBTA / Office of the Chief Engineer	MBTA Design Standards Update	The MBTA Office of the Chief Engineer is in the process of updating its design standards for the entire system. The design standards have been drafted to incorporate climate resiliency in all of the standards. However going into this year significant editing and revisions will be needed, as well as stakeholder engagement from departments across the MBTA. When this project is finally complete, the goal is to have climate resiliency considerations such as designing for extreme temperatures, managing stormwater for both improved water quality and resilience, addressing coastal flooding, designing for high winds, etc, incorporated into the design requirements. These will be the requirements that all new construction at the MBTA (and retrofits) must adhere to.	No comments.	High	In Progress	Operating Bud	Secured – Funds are committed	3-5 years			Damage to Rails and Loss of Rail/Transit Service				Regional		X	X			
MassDOT	MassDOT	MassDOT: Develop the foundation for a Resilience Improvement Plan	Evaluate and prepare an outline for a statewide Resilience Improvement Plan, building upon asset resilience information in the Climate Adaptation and Vulnerability Assessment (CAVA), Massachusetts Project Intake Tool (MaPIT), and other sources. Coordinate with other agencies as applicable to identify opportunities to collaborate.	CZM, EEA, DCR, local munipalities and regional organizations	Medium	In Progress	Evaluating PROTECT funding	Planned - There is funding identified but not yet allocated	3-5 years	CZM, EEA, DCR, local municipalities and regional organizations	Emergency Service Response Delays and Evacuation Disruptions	Damage to Roads and Loss of Road Service				Statewide		x	x			x
MassDOT	MassDOT	MassDOT: Resilience Improvement Prioritization	Screen for and prioritize resilience improvements in vulnerable roadway/bridge assets utilizing information from the Resilience Improvement Plan evaluation, CAVA, MaPIT, and similar sources. Coordinate with other agencies and engage stakeholders, as applicable, through the project development process. Ensure transparency to communities on process.	Local municipalities and jurisdcitions, regional organizations, MVP program	Medium	In Progress	Operating Budget; Capital Budget	Planned - There is funding identified but not yet allocated	Greater than 5 years	Local municipalities and jurisdictions, regional organizations,	Emergency Service Response Delays and Evacuation Disruptions	Damage to Roads and Loss of Road Service				Statewide	X	x	x			X
MassDOT	MassDOT	MassDOT: Resilient Design Research and Planning	Research best practices and leading examples of transportation asset resilient designs and standards to inform future MassDOT initiatives and design guidance. Prepare a summary of findings.	No comments.	Low	In Progress	It is anticipated that this action item will be able to be advanced	Potential funding	3-5 years	This action will benefit from collaboration with various agencies, both	Emergency Service Response Delays and Evacuation	Damage to Roads and Loss of Road Service				Statewide		x	x			x
MassDOT	MassDOT	MassDOT: Climate Change Adaptation Training and Guidance	Invest in internal and external training, including continuation of the fluvial geomorphology based "Rivers & Roads" training program which provides guidance on bridge and culvert design interaction with emerging fluvial geomorphology practices. Coordinate with resource agencies on this effort, as needed. Update existing guidance documents to ensure proposed bridge and culvert projects are appropriately sized. Conduct internal staff training to ensure compliance with the Massachusetts Stream Crossing Standards.	DCR, EEA, DEP	Medium	In Progress	It is anticipated that this action item will be able to be advanced internally by MassDOT staff.	Potential funding	3-5 years	DCR, EEA, DEP		Damage to Roads and Loss of Road Service				Statewide	x	x	X	X		X
MassDOT	MassDOT	MassDOT: Enhance Resiliency Screening in Project Development	Evaluate opportunities along the project development process to track or screen climate resilience, climate mitigation, hazard mitigation, and environmental justice data elements to support climate-informed project design, and ensure alignment with funding sources and MassDOT goals. This includes evaluating the MassDOT MaPIT application inputs. Collaborate with EEA on similar efforts.	MEMA and EEA- statewide action across sectors?	Medium	In Progress	It is anticipated that this action item will be able to be advanced internally by MassDOT staff.	Potential funding	3-5 years	MEMA and EEA		Damage to Roads and Loss of Road Service				Statewide		x	x	x		X
MassDOT	MassDOT	MassDOT: Utilize TRB's Self-Assessment Tool in Project Development	Review the Transportation Research Board (TRB)'s self-assessment tool to identify opportunity to incorporate components into the project review process. This will focus on incorporating opportunities for reducing hazards and climate change concerns into the project screening and implementation process.	No comments.	Medium	Not started	It is anticipated that this action item will be able to be advanced internally by MassDOT staff	Potential funding	3-5 years			Damage to Roads and Loss of Road Service				Statewide		x	x	x	x	x

Secretary of Sta	MHC	Promote best practices when planning for historic and cultural resources	Promote to other organizations and property owners, and use internally, best practice guidance to reduce risk to historic and cultural resources from current and future hazards. Best practices have been developed by organizations such as the National Park Service and their Guidelines on Flood Adaptation for Rehabilitating Historic Buildings and Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings. Incorporate a disaster response section into the sample local historic district bylaw produced by the MHC based on guidance from the National Park Service and National Alliance of Preservation Commissions. This would allow for faster response to disasters in local historic districts while still protecting historic resources.	Statewide action? Or collaborate with CZM, tribes, and DCR.	Medium	Not started	MHC's regular c	Potential fundin	3-5 years		Damage to Cultural Resources					Statewide	X	X	X			
Secretary of Sta	MHC	Update grant scoring to prioritize underrepresented and threatened resources	Explore amending the scoring for the MHC's Survey & Planning Grant program to encourage the documentation of underrepresented and threatened resources. This might include additional points for projects focused on environmental justice areas, floodplains, and cultures and resources currently underrepresented in the MHC's *Inventory of the Historic and Archaeological Assets of the Commonwealth* and the Massachusetts Cultural Resources Information System (MACRIS).	No comment.	Medium	Not started	MHC's Survey &	Potential fundin	3-5 years		Damage to Cultural Resources									x		
Umass Amherst	Massachusetts	Update and produce a landslide inventory for Massachusetts to help identify vulnerable resources and infrastructure.	With the availability now of 1 m LiDAR statewide and delivery of 1/2 m LiDAR in eastern MA shortly, it might be time to do a complete inventory of this hazard. The landslide susceptibility map we did in 2012 is a bit old now. We never did a comprehensive inventory of landslides statewide. This hazard will be exacerbated by climate change.	DCR, DEP, MassDOT	High	Not started	MassDOT Stat	Potential fundin	3-5 years			Damage to Inland Buildings				Statewide			x			
Umass Amherst	Massachusetts	Identification of rockfall hazards.	Identification of rockfall hazards. This has never been done in MA particularly along the major state roads. With increased rainfall and more cycling of freezing and thawing under climate change, this poses an increased risk. There are hazard rating systems that could be employed to identify and prioritize this risk.	DCR, DEP, MassDOT	Medium	Not started	MassDOT Stat	Potential fundin	3-5 years			Damage to Rails and Loss of Rail/Transit Service				Statewide			xx			
EOEEA	EEA	Conduct a Climate Migration Assessment	Based on Massachusetts's lower relative climate risks compared to other parts of the country and world it is likely that the Commonwealth may experience in-migration due to climate change. Conduct an assessment that include the following analysis: (1) Likely sources of in-migration from other states within the USA and outside of the country; (2) Likely settlement sites within Massachusetts based on housing availability and job centers, as well as support services.; (3) Effects of in-migration on natural environment, utilities, schools, and other community resource needs; (4) Effects of in-migration on affordability of housing, and potential displacement of environmental justice and other priority populations; (5) Effects of in-migration on Massachusetts industries, sectors, and jobs. Opportunities to grow economy, new workers, and innovation for growing industries such as climate, technology, and healthcare; and (6) develop two to three likely climate migration scenarios and the adaptation pathways to prepare for each scenario. Example adaptation pathways would include ways to reduce the risk of sprawl damaging ecological and cultural resources, ways to protect affordable housing and priority populations from displacement, potential locations for new housing, and considering how to establish new workers into existing industries and/or how to prepare the Commonwealth to accommodate innovation and growth of new industries.		Medium	Not started	SHMCAP Impler	Potential fundin	Greater than 5 years							Statewide		x	x	x		
EOEEA	EEA	Prioritize project proposals within the Food Security Infrastructure Grant Program (FSIG) that specifically support climate change mitigation and proposals that seek to address long-term resilience to drought or extreme weather events	In the FY24 round, $1million and $2million respectively was set aside for project proposals that specifically support climate change mitigation by reducing equipment energy use or generating renewable energy and for project proposals that seek to address long-term resilience to drought or extreme weather events, including by reducing water use or enhancing a water supply. For future rounds: conduct a survey to determine the affects of climate change on each sector and their food production and build out RFR to require projects to meet at least one of these objectives.		Medium	Not started	Staff Time	Potential fundin	Less than 3 years													
EOEEA	DOER	Increase energy resilience of critical assets identified in State Energy Security Plan	Work with state agencies responsible for critical physical assets to develop strategies to increase energy resilience. Consider including non-state assets that carry out critical statewide functions such as schools, hospitals, and public safety agencies. Fund vulnerability assessments for critical facilities and identify high priority energy resilience projects to fund and implement.		Medium	Not started	Staff Time and D	Potential fundin	3-5 years													

EOEEA	DOER	Integrate adaptation goals in clean energy projects	Assess Massachusetts's clean energy projects to determine opportunities to increase adaptation and reduce risks by including hazard mitigation and climate adaptation goals wherever possible.		Medium	In Progress	Staff Time	Potential fundin	3-5 years													
EOLWD	LWD	Investments to take advantages of opportunities presented by climate change	• Provide workforce training assistance and funding to help workers gain skills, reskill, and upskill in an evolving workplace and labor market in the pursuit of climate ready goals. • Collaborate with the Massachusetts Clean Energy Center (MassCEC) to leverage opportunities to blend and braid state-funded workforce initiatives through EOLWD and MassCEC. Combined funding will augment recruitment, wrap-around support services, and technical and on-the-job training experience to build a talent pipeline for the Commonwealth's clean energy industry. • Increase coordination with labor unions to assist in climate-critical training and to retrain workers transitioning from other sectors and/or fossil fuel-based roles. • Increase integration across industry, academia, and workforce programming through	EOLWD, Commonwealth Corporation, and MassCEC, EOEEA, EOE, EOHED	High	Not started	State Operatiing	Secured – Funds	Greater than 5 y	FutureSkills and Comm Corp					Economic Losse	Statewide	x				x	x
EOEEA	DOER	Update the State Energy Security Plan	The DOER would propose to update the 2023 State Energy Security Plan in 2026 to include updating the state energy profile, the energy sector vulnerability and risk assessment, hazard mitigation approach and energy emergency response plan. This update will allow the Commonwealth to capture changes to the energy system (electric, natural gas and delivered fuels) as we work to decarbonize the economy, highlight shifting vulnerabilities and risks based on those changes, in addition to climate risks, and further develop a hazard mitigation approach as we get closer to 2030. As part of the SESP update process, DOER would propose to work with DPU and MEMA on the update and development of a table-top exercise in 2026 to validate the plan.	EOEEA, DPU, MEMA, DOER	High	Not started	Staff time and p	Potential fundin	3-5 years	EOEEA, DPU, MEMA and potentially DEP for completion in fall 2026												
EOEEA	DCR	Wildfire Management Infrastructure Improvements	DCR will undertake a modernization of wildfire facilities and infrastructure used to support local fire departments with wildfire suppression and wildfire risk mitigation (prescribed fire). Project will include design and construction of a Wildfire Management Operations Facility at Hopkinton State Forest, Wildfire Management Operations Facility at Douglas State Forest, and a comprehensive facility climate resiliency needs assessment. The existing Hopkinton facility was destroyed by snow loads in 2013. The existing Douglas facility is incompatible with the growing need for wildfire support services and lacks basic sanitary facilities. Design of the Hopkinton facility create a standard plan set for Douglas and additional future facility replacements. Climate smart building materials including local engineered hemlock cross laminated timber developed by EEA, UMass, UNH, UMaine and the USFS will be used to demonstrate building with long lived wood products in support of the Clean Energy and Climate Plan.	DCAMM	High	Not started	SHMCAP Implem	Potential fundin	3-5 years	Local municipalities, FEMA, M		Damage or los	Forest Health Degradation			Statewide	X		X			X
EOEEA	DPU	Ensure electric sector modernization plans consider climate impacts	On September 12, 2022, the DPU directed the investor-owned electric distribution companies' electric sector modernization plans that will be filed with the Grid Modernization Advisory Council in September 2023 and with the DPU in January 2024 consistent with the requirements of the 2022 Climate Act (St. 2022, c. 179). The electric sector modernization plans will include a five-year plan for preparing for future climate-driven impacts on the transmission and distribution systems, including proposed improvements to the electric distribution system to increase reliability and strengthen system resiliency to address potential weather-related and disaster-related risks. The DPU will review the plans when filed in January 2024 and issue a decision within seven months of the submission of the plan.		Medium	Not started	Capital/Operat	Potential fundin	Less than 3 years													
EOEEA	DPU	Work with electric utilities to assess critical infrastructure for climate vulnerability	Ensure that investor-owned electric utilities continue to appropriately assess critical infrastructure, high risk hazards, and system vulnerabilities in vegetation management plans, pre-storm assessments and through their emergency response plans.		Medium	In Progress	Staff time	Potential fundin	Less than 3 years													
EOEEA	DPU	Work with utilities to ensure solar and storage proposals address climate risk and vulnerability	Work with investor-owned electric and gas utilities to review geotargeted solar paired with energy storage proposals developed pursuant to the 2021 Climate Act (St. 2021, c. 8, section 77) designed to assist a municipality, including those with environmental justice communities, at high risk from the effects of climate change. The proposals must be supported by the municipality and designed to improve climate adaptation and resiliency.		High	In Progress	Staff time	Potential fundin	Less than 3 years													

2023 SHMCAP Cross-Government Actions

Exec Office	Lead Agency	Action Title	Action Description	Inter-Agency Coordination needed? If so, state which.	Funding Source	Funding Status *(drop down)*	Completion Timeframe *(drop down)*	Action Priority *(drop*	Partners	Action Category	Climate Assessment Priority Impacts and additional vulnerabilities: (*drop-down)*					Scale	2023 SHMCAP Goals *(mark "x" on all the goals relevant to the action)*					
											Human (#1)	Infrastructure (#1)	Environment (#1)	Governance (#1)	Economy (#1)		Goal 1: Collaboration, Communication, and	Goal 2: Science-based and Informed Decision-Making	Goal 3: Resilient State Assets and Services	Goal 4: Implement Adaptation Actions for Communities and	Goal 5: Climate mitigation	Goal 6: Resilient and Equitable Infrastructure
EOEEA, EOPSS	EOEEA, MEMA	Convene a climate resilience stakeholder	Create a ResilientMass Action Team subgroup to increase		Staff Time; SHMCAP Implementation	Potential funding	3-5 years	Medium		Outreach and				Reduction in		Statewide	x					
EOEEA, A&F	EOEEA, A&F	Increase funding to support municipal and	Identify new and sustainable revenue streams to increase	DPH	Staff Time; SHMCAP Implementation	Potential funding	Less than 3 years	High		Funding and				Reduction in		Statewide	x					
EOEEA, EOPSS	EOEEA, MEMA, A&F	Develop a framework for statewide resilience progress tracking	Through a stakeholder process, identify statewide climate resilience goals and associated metrics that the Commonwealth		Staff Time; SHMCAP Implementation	Potential funding	Less than 3 years	High		Outreach and education				Increase in Demand for		Statewide	x					
EOEEA	EOEEA	Launch a statewide Climate Communications Campaign	Launch a statewide Climate Communications Campaign targeting climate action for decarbonization and resilience, key findings		Capital budget	Planned - There is funding identified but not yet	Less than 3 years	High		Outreach and education				Increase in Demand for		Statewide	x					
EOEEA	EOEEA	Launch an Office of Climate Science	Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on	EOTSS, DOT, DMF	Operating budget	Planned - There is funding identified but not yet	Less than 3 years	High		Assessment, research, analysis,				Increase in Demand for		Statewide		x				
EOPSS	MEMA	Create a Tool for Loss Avoidance Studies and Future Mitigation Projects.	Create a tool for Loss Avoidance Studies that is utilized to understand the effectiveness of local and state level hazard	EOEEA	Staff time; FEMA BRIC, HMGP, SHMCAP Implementation	Potential funding	Less than 3 years	High		Assessment, research, analysis,				Inability to carry out		Statewide		x				
A&F	A&F	Expand evaluation of climate resilience for state capital investments	Expand utilization of the RMAT Resilience Design Standards Tool to ensure climate vulnerability and resilient design is an	EEA, MEMA, HED	Staff time	Potential funding	Less than 3 years	High		Capital planning		Damage to Inland Buildings		Inability to carry out		Statewide			x			
EOEEA	EEA	Formalize MEPA resiliency policy to ensure consideration of climate change during MEPA reviews	Expand application of RMAT Resilience Design Standards Tool to environmental permitting and reviews through MEPA process.	EEA, DCR, DOT, HED	Staff Time	Potential funding	Less than 3 years	High		Regulations, codes, and zoning								x	x			
EOHHS	HHS	Develop and implement a new Heat Flag System	Identify methods to obtain additional data on heat and ways to effectively communicate heat risk to the public across agencies.	LWD, DPH	Staff Time; SHMCAP Implementation	Potential funding	Less than 3 years	High		Outreach and education	Health and Cognitive Effects					Statewide				x		
EOEEA	EOEEA	Develop a coastal resilience strategy	Develop a coastal resilience strategy that considers climate	HED, DOT, DMF, DER	Staff Time, Capital budget	Secured – Funds are	Less than 3 years	High		Assessment,	Emergency	Damage to	Coastal Erosion	Inability to	Damage,	Statewide				x		
EOEEA	EOEEA	Protect 30 percent of land and ocean by 2030 (to align with the global 30x30 goal)	Implement EEA's Resilient Lands Initiative and incorporate the Healthy Soils Action Plan. Develop a statewide approach and	DCR, DMR, DER, DMF, DFG, MDAR, EEA	Capital budget	Planned - There is funding identified but not yet	Greater than 5 years	Medium		Natural systems protections and			Freshwater Ecosystem Degr			Statewide				x		
EOED	EOED	Identify regulatory opportunities to improve cooling standards in buildings to address extreme heat impacts, through review of	Assess the State Sanitary Code for opportunities to promote cooling in residential buildings and mitigate extreme-heat risks to renters and remote workers.	HHS, EOHLC, DHCD, LWD, DPH	Staff time	Secured – Funds are committed	Less than 3 years	High		Regulations, codes, and zoning	Health and Cognitive Effects from Extreme					Statewide				x		
EOE	EOE	Update school curriculum to include climate science and green workforce development.	To engage youth in climate and hazard mitigation more directly, implement pilot clean energy innovation pathway for high school students focused on helping students get applied learning	Workforce Skills Cabinet (EOHED, EOLWD,	Staff time; operating budget	Potential funding	Greater than 5 years	Medium		Outreach and education	Emergency Service Response Delays and	Damage to Inland Buildings	Shifting Distribution of Native and	Reduction in State and Municipal	Decrease in Agricultural Pr oductivity	Statewide						x
EOEEA	EOEEA	Develop a local option "Stretch Flood Code" for residential and/or non-residential construction	integration to the statewide building code - also referred to as a "Stretch Flood Code" - which municipalities may adopt at their choosing to prescribe more resilient standards for residential	DCR, EOEEA, HED, OPSI, DOER	Staff time/ SHMCAP Implementation	Potential funding	3-5 years	High		Regulations, codes, and zoning	Health Effects of Extreme Storms and Power	Damage to Inland Buildings		Increase in Demand for State and		Statewide		x				
EOEEA	EEA/DCR-OWR	Floodplain Regulatory and Coordination Framework	Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth	DCR, and many other agencies	No source identified as yet. Staff time will be committed.	Planned - There is funding identified but not yet allocated	3-5 years	Medium		Planning and policy		Damage to Roads and Loss of Road Service		Increase in Need for State and Municipal Policy Review	Reduced Ability to Work	Statewide	x	x	x			x

2023 Cross-Government Actions

2023 SHMCAP Cross-Government Actions

Exec Office	Lead Agency	Action Title	Action Description	Inter-Agency Coordination needed? If so, state which.	Funding Source	Funding Status *(drop down)*	Completion Timeframe *(drop down)*	Action Priority *(drop*	Partners	Action Category	Climate Assessment Priority Impacts and additional vulnerabilities: *(drop-down)*					Scale	2023 SHMCAP Goals *(mark "x" on all the goals relevant to the action)*					
											Human (#1)	Infrastructure (#1)	Environment (#1)	Governance (#1)	Economy (#1)		Goal 1: Collaboration,	Goal 2: Science-based and Informed	Goal 3: Resilient State Assets and	Goal 4: Implement Adaptation Actions	Goal 5: Climate mitigation	Goal 6: Resilient and Equitable
EOEEA, EOPSS	EOEEA, MEMA	Convene a climate resilience stakeholder	Create a ResilientMass Action Team subgroup to increase		Staff Time; SHMCAP Implementation	Potential funding	3-5 years	Medium		Outreach and				Reduction in		Statewide	x					
EOEEA, A&F	EOEEA, A&F	Increase funding to support municipal and	Identify new and sustainable revenue streams to increase	DPH	Staff Time; SHMCAP Implementation	Potential funding	Less than 3 years	High		Funding and				Reduction in		Statewide	x					
EOEEA, EOPSS	EOEEA, MEMA, A&F	Develop a framework for statewide resilience progress tracking	Through a stakeholder process, identify statewide climate resilience goals and associated metrics that the Commonwealth		Staff Time; SHMCAP Implementation	Potential funding	Less than 3 years	High		Outreach and education				Increase in Demand for		Statewide	x					
EOEEA	EOEEA	Launch a statewide Climate Communications Campaign	Launch a statewide Climate Communications Campaign targeting climate action for decarbonization and resilience, key findings		Capital budget	Planned - There is funding identified but not yet	Less than 3 years	High		Outreach and education				Increase in Demand for		Statewide	x					
EOEEA	EOEEA	Launch an Office of Climate Science	Launch an Office of Climate Science that serves as an authoritative resource and provides subject matter experts on	EOTSS, DOT, DMF	Operating budget	Planned - There is funding identified but not yet	Less than 3 years	High		Assessment, research, analysis,				Increase in Demand for		Statewide		x				
EOPSS	MEMA	Create a Tool for Loss Avoidance Studies and Future Mitigation Projects.	Create a tool for Loss Avoidance Studies that is utilized to understand the effectiveness of local and state level hazard	EOEEA	Staff time; FEMA BRIC, HMGP, SHMCAP Implementation	Potential funding	Less than 3 years	High		Assessment, research, analysis,				Inability to carry out		Statewide		x				
A&F	A&F	Expand evaluation of climate resilience for state capital investments	Expand utilization of the RMAT Resilience Design Standards Tool to ensure climate vulnerability and resilient design is an	EEA, MEMA, HED	Staff time	Potential funding	Less than 3 years	High		Capital planning		Damage to Inland Buildings		Inability to carry out		Statewide			x			
EOEEA	EEA	Formalize MEPA resiliency policy to ensure consideration of climate change during MEPA reviews	Expand application of RMAT Resilience Design Standards Tool to environmental permitting and reviews through MEPA process.	EEA, DCR, DOT, HED	Staff Time	Potential funding	Less than 3 years	High		Regulations, codes, and zoning								x	x			
EOHHS	HHS	Develop and implement a new Heat Flag System	Identify methods to obtain additional data on heat and ways to effectively communicate heat risk to the public across agencies.	LWD, DPH	Staff Time; SHMCAP Implementation	Potential funding	Less than 3 years	High		Outreach and education	Health and Cognitive Effects					Statewide				x		
EOEEA	EOEEA	Develop a coastal resilience strategy	Develop a coastal resilience strategy that considers climate	HED, DOT, DMF, DER	Staff Time, Capital budget	Secured – Funds are	Less than 3 years	High		Assessment,	Emergency	Damage to	Coastal Erosion	Inability to	Damage,	Statewide				x		
EOEEA	EOEEA	Protect 30 percent of land and ocean by 2030 (to align with the global 30x30 goal)	Implement EEA's Resilient Lands Initiative and incorporate the Healthy Soils Action Plan. Develop a statewide approach and	DCR, DMR, DER, DMF, DFG, MDAR, EEA	Capital budget	Planned - There is funding identified but not yet	Greater than 5 years	Medium		Natural systems protections and			Freshwater Ecosystem Degr			Statewide				x		
EOED	EOED	Identify regulatory opportunities to improve cooling standards in buildings to address extreme heat impacts, through review of	Assess the State Sanitary Code for opportunities to promote cooling in residential buildings and mitigate extreme-heat risks to renters and remote workers.	HHS, EOHLC, DHCD, LWD, DPH	Staff time	Secured – Funds are committed	Less than 3 years	High		Regulations, codes, and zoning	Health and Cognitive Effects from Extreme					Statewide				x		
EOE	EOE	Update school curriculum to include climate science and green workforce development.	To engage youth in climate and hazard mitigation more directly, implement pilot clean energy innovation pathway for high school students focused on helping students get applied learning	Workforce Skills Cabinet (EOHED, EOLWD,	Staff time; operating budget	Potential funding	Greater than 5 years	Medium		Outreach and education	Emergency Service Response Delays and	Damage to Inland Buildings	Shifting Distribution of Native and	Reduction in State and Municipal	Decrease in Agricultural Pr oductivity	Statewide						x
EOEEA	EOEEA	Develop a local option "Stretch Flood Code" for residential and/or non-residential construction	integration to the statewide building code - also referred to as a "Stretch Flood Code" - which municipalities may adopt at their choosing to prescribe more resilient standards for residential	DCR, EOEEA, HED, OPSI, DOER	Staff time/ SHMCAP Implementation	Potential funding	3-5 years	High		Regulations, codes, and zoning	Health Effects of Extreme Storms and Power	Damage to Inland Buildings		Increase in Demand for State and		Statewide		x				
EOEEA	EEA/DCR-OWR	Floodplain Regulatory and Coordination Framework	Develop a statewide floodplain management framework that describes state floodplain development processes and coordination, as well as state agency collaboration for best floodplain management practices across the Commonwealth	DCR, and many other agencies	No source identified as yet. Staff time will be committed.	Planned - There is funding identified but not yet allocated	3-5 years	Medium		Planning and policy		Damage to Roads and Loss of Road Service		Increase in Need for State and Municipal Policy Review	Reduced Ability to Work	Statewide	x	x	x			x

2018 SHMCAP Actions

Action Title	Action Description	Action Category	Action Status (as of 12/31/22) - *please update*	Exec Office	Lead Agency	Scale (statewide, regional, local)	Region 1 *(select 1 region from dropdown that best applies)*	Region 2 *(select a 2nd region from dropdown that best applies)*	Progress Notes (status as of Fall 2020)	Progress Notes (since Fall 2020)	Other Notes
DCAMM: Incorporate hazard and climate change vulnerability into capital planning, master planning, and facilities management functions.	Incorporate climate change vulnerability, resilience, and adaptation standards into capital planning for new projects; refer to agency climate change vulnerability assessments in master planning exercises; and integrate climate change vulnerability assessments into a facilities management system.	Planning and policy	In Development	Executive Office for Administration and Finance	Division of Capital Asset Management and Maintenance (DCAMM)				DCAMM currently requires all of its capital planning and master planning efforts to include hazard and climate change vulnerability assessments. To incorporate this in planning efforts, DCAMM has developed a resilience checklist and a mapping tool to assist project managers in the assessment of vulnerability risks. Based on these assessments DCAMM is incorporating resilience measures into capital projects where appropriate. DCAMM is working closely with EOEEA and their technical assistance vendor, Weston & Sampson, to develop a resilient capital planning evaluation tool to inform the capital budget process and will integrate the guidelines and standards from that effort into its capital planning and master planning efforts.	DCAMM has transitioned the resilience checklist into a web-form that integrates with the state's asset management database software (CAMIS). This form requires that the user input the asset risk ratings from the RMAT Climate Resilience Design Standards tool to establish the relative risk of each facility to various natural hazards. DCAMM is continuing to update this web form to include additional information, including earthquake risk to unreinforced masonry structures. The information collected through these surveys is stored in CAMIS, where it is accessible by all DCAMM personnel. Non-DCAMM CAMIS users will have access to their own facilities in CAMIS. A report will be created so that all users will be able to easily search and filter the results of resilience surveys for all state facilities to which they have access, for use by project managers and for capital planning purposes.	
A&F: Budgeting, coordinating administrative functions, and planning.	Incorporate climate change vulnerability, resiliency, and adaptation standards into budgeting, coordination, and capital planning.	Capital planning	Complete	Executive Office for Administration and Finance	Executive Office for Administration and Finance (A&F)				A&F is working closely with EOEEA and their technical assistance vendor, Weston & Sampson, to develop a resilient capital planning evaluation tool to inform the capital budget process and will integrate the climate change guidelines and standards from that effort into its capital planning and master planning efforts.	Completed	
HRD: Incorporate hazard and climate change vulnerability into personnel and workplace policies, training, and guidance as appropriate.	Evaluate current policies and guidance regarding weather and other hazard-related emergencies, workplace rules, and other information and consider updates and other training opportunities about personnel readiness, workplace climate change vulnerabilities, hazard mitigation, and climate adaptation techniques, etc.	Administrative support	Complete	Executive Office for Administration and Finance	Human Resources Division (HRD)				HRD is updating its telework policy, which would better allow eligible state employees to work remotely in cases where weather events disrupt access to physical office spaces.	Completed	
EOE: Review and recommend changes to regulations and policy related to determine if changes are needed to address resiliency planning for the sites and providers who are licensed by the Commonwealth to care for children.	Collaborate with the Department of Early Education and Care (EEC) to review existing agency regulations and policies to determine if changes are needed to support licensed providers in resiliency planning. As possible, EOE will also work with EEC to support the education of licensed providers about resiliency planning.	Planning and policy	Modified or Deferred	Executive Office of Education	Executive Office of Education (EOE)				No actions taken due to COVID response.	Continues to be deferred	
DEP: Demand strategies educational campaign.	Pilot an education and outreach campaign aimed at reducing non-agricultural outdoor water use (e.g. lawn watering) in the Parker River and Ipswich River Watersheds, two of the state's most stressed basins. Work will be informed by municipal scale piloting by the Division of Ecological Restoration. DEP is also piloting demand management strategies in the Ipswich and Parker watersheds. Information gained may be useful in designing statewide conservation outreach and drought response strategies.	Outreach and education	Complete	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				The pilot studies have been completed. The project webpage can found at: https://www.mass.gov/service-details/water-conservation-pilot	Completed no update	
EOEEA: Accelerate implementation of priority actions identified through the Municipal Vulnerability Preparedness (MVP) program, increase municipal participation in planning program, conduct program review and revise planning and action grant program as needed.	Continue the high rate of enrollment of communities into the MVP Program so that at the end of the next four years close to 100% of the state's municipalities are MVP designated. Deploy additional action grant funds to advance implementation of priority municipal climate adaptation actions, particularly those actions with multiple benefits, transferability, and nature-based solutions. Conduct a program review of year 1 of action and planning grants to support a more robust program going forward and help to improve and revise the MVP framework. Establish metrics to allow EOEEA to monitor program performance over time.	Planning and policy	Complete	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)	Statewide			The MVP program is now accessed by 89% of municipalities across the Commonwealth, and has committed over $44M in planning and action grant funding. In fall 2019, EOEEA completed hiring six MVP Regional Coordinators to support a full time MVP Manager and municipalities in participating in the program.	MVP has enrolled 99% of MA municipalities, and invested $100M in municipal resilience planning and action. MVP is currently developing a 2.0 program to improve and revise the framework.	
EOEEA: Create and deploy a SHMCAP project database.	Deploy the SHMCAP Action Tracker, a customized tracking spreadsheet tool for reporting progress status updates on individual actions, as a consistent approach for updating and reporting in real-time and will be actively maintained on a restricted, password-protected file sharing site to be established by EOEEA. It will serve as the primary mechanism for the status updates on each action and will establish metrics to measure effectiveness.	Planning and policy	Complete	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)	Statewide			EOEEA and MEMA are receiving progress updates for the annual review of the SHMCAP plan, and updating this SHMCAP Action Tracker.	The SHMCAP Action Tracker is live at https://resilientma.mass.gov/shmcap-portal/index.html#/action-tracker/	Just a note that this URL will need to be updated before final plan is released.
EOEEA: In consultation with DCAMM, MassDOT, and EOHED develop climate change design standards.	Work with Climate Change Coordinators and agency staff across Secretariats to review and update design standards using Massachusetts climate change projections that will support best management and construction practices for new and improved agency structures, roads, parkways, parking lots, housing, and other facilities.	Planning and policy	Complete	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)	Statewide			EOEEA has hired a technical assistance vendor, Weston & Sampson, to support RMAT agencies in implementing the SHMCAP. The team is working with state agencies and a technical advisory group to develop a web-tool that provides recommendations for climate resilient design standards and a climate risk rating for state projects with physical assets. It is estimated to be launched on ResilientMA.org in early 2021.	EEA launched the Climate Resilience Design Standards beta tool in April 2021, and an updated version in July 2022 that provides preliminary climate exposure assessment and recommendations for design criteria and implementation at the project level. https://resilientma.mass.gov/rmat_home/designstandards/	
EOEEA: Maintain and enhance climate change projections and specific climate change data sets to support different groups of end users.	Maintain, update, and enhance climate change projections for temperature, precipitation, sea level rise, and inland hydrology through the end of the century to determine key data needs, and ongoing incorporation of advancements in the field of climate change science. Updated climate change data will be maintained and made available to the public on the resilient MA website.	Assessment, research, analysis, science, and mapping	Complete	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)	Statewide			EOEEA is maintaining and updating climate change projections on ResilientMA.org.	EEA has incorporated best available statewide climate data on ResilientMA.mass.gov, including the MA Coast Flood Risk Model, USGS-Cornell-Tufts Climate and Hydrologic Risk (Phase 1) precipitation and temperature projections, and MAPC statewide land surface temperatures. EEA is in the process of launching an office of climate science to ensure climate data is maintained, updated, and appropriately applied to policy and programs.	
EOEEA: Reassess and develop a climate change resiliency framework and criteria for all EOEEA agency land acquisition and grant funding for land acquisition to support natural resource conservation, wildlife, human health and public safety.	Review, assess and reprioritize resiliency criteria into land acquisition grant programs to ensure protection of multiple resiliency goals including critical ecosystem services, connectivity of wildlife, climate-sensitive areas, repeat loss of infrastructure and property, human health and safety, and habitats of climate-sensitive species.	Capital planning	Complete	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)				The Resilient Lands Initiative (RLI) will release its 10-year vision and strategy in November 2020. Over the past year, the RLI has gathered input from 16 public listening sessions and focus groups and 12 meetings of a steering committee with 40 participants from federal, state, municipal and NGO land conservation and stewardship practitioners and is now finalizing the draft 10-year vision and strategy. The plan includes eight strategies: No Net Loss of Farms and Forests; Focus on Food Systems; Focus on Urban Greenspaces and Community Health; Focus on Water Resources; Focus on Landscape Conservation and Restoration; Focus on the Green Economy; Focus on Natural Carbon Storage and Climate Resilience and Focus on Collaboration for Sustainable Solutions. EEA is also working with several NGO, municipal and federal partners to create a new forest resilience and carbon storage program that focuses on best practices to enhance carbon storage and resilience funded by an MVP grant, DCR Working Forest Initiative funds, private grants and a US Forest Service grant. This new program will be finalized and implemented on a pilot basis during 2021.	The Resilient Lands Initiative and Healthy Soils Action Plan were released in December 2022: https://www.mass.gov/info-details/resilient-lands	
MassWildlife: Dam removals at the Merrill Ponds Wildlife Management Area.	Advance efforts to remove two dams (Welsh Pond Dam and Putnam Pond Dam) and rehabilitate a third dam that provides significant recreational benefits. Each project will continue to improve the resiliency of the agency's resources by improving the hydraulic capacity of the roadway stream crossings, reducing solar heating of Singletary Brook.	Structure and infrastructure retrofits/new projects	Complete	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				Welsh Pond dam was removed in summer 2019. Putnam Pond dam was removed and a dry hydrant installed at Adams Pond.	Completed.	
MassWildlife: Identification of cold water climate refugia and transitional waters for protections of CFRs.	Improve existing mapping tools to incorporate additional watershed characteristics (e.g., flow management, including lake-level management and groundwater inputs) to support identification of cold water climate refugia and transitional waters and management decisions including prioritization of dam removal, instream flow protection, riparian vegetation management and location and timing of trout stocking.	Assessment, research, analysis, science, and mapping	Complete	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				Project results from phase 1 (identification of potential coldwater climate change refugia) were published in Frontiers in Ecology and the Environment 18(5):271-280 in June 2020. Additional field validation of refugia function continues through water temperature monitoring but the direct observation component (e.g., tagging of fish) was postponed due to COVID-19.	Completed. This work is being enhanced throught the identification of climate change refugia to both streamflow and temperatures. Work is ongoing in collaboration with USGS and other partners.	
MassWildlife: In partnership with CZM, improve management of beach nourishment projects and other shoreline protection strategies and incorporate habitat considerations into coastal storm disaster response habitat and infrastructure on barrier beaches.	Strengthen technical expertise in management of beach nourishment projects and other strategies (e.g. dune revegetation) to simultaneously enhance wildlife habitat and protect shoreline infrastructure, ensuring key habitat considerations are made in coastal storm disaster response.	Planning and policy	Complete	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				The Bird Island Restoration Project was completed in partnership with CZM. Work included rebuilding of a revetment, revegetation, and enhancement of tern habitat.	No new actions.	
MassWildlife: Study impact of climate change on fish hatcheries held by MassWildlife.	Perform a study to assess vulnerabilities and impacts of climate change on Division-owned fish hatcheries including Bitzer Hatchery (Montague), Sunderland Hatchery (Sunderland), McLaughlin Hatchery (Belchertown), Roger Reed Hatchery (Palmer), and Sandwich Hatchery (Sandwich), and determine next steps.	Assessment, research, analysis, science, and mapping	Complete	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				HDR completed a general study of climate change impacts as part of a greater evaluation of the hatcheries. The resulting report is currently under review. Further studies are now needed to understand and design specific climate adaptation actions to address recommendations in the HDR study.	Completed no update	
MassWildlife: Updates to BioMap2.	Incorporate newer predictions, finer-scaled climate change predictions as well as more recent species and habitat data collected following a rigorous analysis of the status and location of rare species and natural communities in collaboration with The Nature Conservancy. The resulting document, BioMap2, identified areas where conservation efforts should be focused in order to protect plant and wildlife biodiversity in Massachusetts.	Assessment, research, analysis, science, and mapping	Complete	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				MassWildlife is meeting with TNC monthly. Data needs and potential analyses have been identified. Preliminary products associated with aquatic biodiversity have been developed.	Project completed.	
DCR: Track and assess asset vulnerability by adding climate change/resiliency categories as part of the Asset Management Modernization Project.	Include climate change vulnerabilities and resiliency actions as part of a comprehensive database of property information.	Planning and policy	Complete	Executive Office of Energy and Environmental Affairs	Department of Conservation and Recreation (DCR)				EEA recently informed DCR of funding to conduct vulnerability assessments of two DCR properties as pilot project to develop methodology for statewide application. AMMP team will work with vulnerability team to coordinate information sharing.	Complete. DCAMM incorporated climate data into CAMIS and there is now a Resiliency Section under the Assessment tab in building records	
DCR: Upgrade and strengthen control systems for both the New Charles River and Amelia Earhart dams.	Review capital maintenance and modernization plans for the New Charles River and Amelia Earhart dams and incorporate relevant flood, tidal, and other hazard mitigation considerations to make them more resilient to flooding and severe weather events.	Planning and policy	In Progress	Executive Office of Energy and Environmental Affairs	Department of Conservation and Recreation (DCR)				Construction work at the New Charles River Dam to improve resiliency if it is overtopped is mostly complete, with all work expected to be done by the end of 2020. Construction documents to effect similar resiliency improvements are being prepared for the Amelia Earhart Dam. Long-term studies to investigate appropriate actions to take at facility with respect to climate change and sea level rise are envisioned and work toward this end is occurring.	Charles River Dam flood proofing construction work was completed in 2022. Long-term resiliency study led by USACE for New Charles River Dam is underway and expected to be completed by 2025. Floodproofing project at Amelia Earhart Dam is underway. The design and permmiting for elevating the AED to improve resiliency of Mystic River Watershed will begin Summer of 2023.	
DPU: Regional power grid planning and incorporation of climate change data.	Work with utilities to assess climate data and prioritize regional power grid improvements that will provide benefits of reduced outages, and lower long-term maintenance costs.	Planning and policy	In Development	Executive Office of Energy and Environmental Affairs	Department of Public Utilities (DPU)				DPU is examining regulatory issues related to microgrid development and is considering opening an investigation into the topic.	Have begun working with Utilities to gather data.	
EOEEA: Based on results of vulnerability assessment for EOEEA properties and vulnerability assessments from other agencies, use climate change projections to develop stormwater management actions and projects.	Work with EEA agencies to examine areas with the highest potential for best practice stormwater management projects, and develop a plan to implement these management actions.	Planning and policy	In Development	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)				The Resilient Lands Initiative GIS model has completed its flooding and stormwater phase and is now completing the development of a heat island mitigation model. The modeling has been delayed by the COVID pandemic restricting access to the bank of computers used to do this modeling at UMass but it is anticipated the model will be completed and piloted before the end of June 2021. This model will allow municipal officials, EEA agencies and NGO's to assess the benefits to communities in flooding and heat island effects of implementing (or not implementing) land conservation and restoration projects.	The Resilient Lands Initiative and Healthy Soils Action Plan were released in December 2022: https://www.mass.gov/info-details/resilient-lands	

EOEEA: Develop and implement a communications strategy to build state agency, municipal and public awareness of climate change resiliency issues and adaptation strategies.	Develop a communications strategy for the purpose of keeping state agency staff, municipal staff and volunteers, and residents informed of the risks, vulnerabilities and solutions as the impacts of climate change continue. EOEEA will use assets such as state parks to offer educational opportunities for residents across the Commonwealth and the resilient MA Climate Change Clearinghouse.	Outreach and education	In Development	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)	Statewide			EEA in coordination with MEMA will begin exploring this action in 2021.	EEA is in the process of launching a statewide climate campaign to drive individual and collective climate adaptation and mitigation action.	
DCR: Develop strategy to implement priority DCR infrastructure projects in its Coastal Inventory.	Develop implementation strategies for prioritized projects identified in 2014 Coastal Infrastructure Inventory and Assessment Report which covered 1,462 hard and soft structures located in 62 coastal communities.	Capital planning	Should be Modified	Executive Office of Energy and Environmental Affairs	Department of Conservation and Recreation (DCR)				DCR initiated a study to update the 2013 Massachusetts Coastal Hazard Inventory and Assessment to reflect existing conditions of publicly-owned coastal infrastructure. DCR has mapped locations of all publicly-owned natural, coastal structures (e.g. sand dunes) with condition assessments and ratings to reflect the extent that the listed structure protects critical assets.	Due to change in priorities and Covid-19 impacts, no progress has been made to date.	Still debating how this should be modified.
DCR: Incorporate climate vulnerability in all planning efforts.	Consider the impacts from climate change and natural hazards as part of all planning efforts agency-wide.	Planning and policy	In Progress	Executive Office of Energy and Environmental Affairs	Department of Conservation and Recreation (DCR)				DCR is currently developing a scope to a complete a vulnerability assessment pilot project on two properties to develop a methodology for statewide application.	The statewide DCR Climate Change Vulnerability Assessment was completed in September 2022. The tool is available for use, and continues to integrate the latest climate science and programmatic data to better inform DCR decision-making. DCR's Office of Cultural Resources and GIS department developed a GIS-based data layer and data collection app to enable DCR's cultural resources to be inventoried and mapped, with a goal of identifying those sites most vulnerable to climate change impacts. To date, DCR has collected data on over 1,100 historic buildings, structures, objects, landscapes, and burial grounds.	DCR will complete the Cultural Resources Inventory within the next 5 years, so we are carrying part of this over into the 2023 SHMCAP.
DCR: Revise current review procedures for DCR-managed dams and other flood control structures to incorporate climate change data.	Work through the Office of Dam Safety to incorporate data on climate change into standards used to review dam management plans, and conduct outreach to private dam owners about potential risks related to climate change and extreme weather events.	Planning and policy	In Progress	Executive Office of Energy and Environmental Affairs	Department of Conservation and Recreation (DCR)				DCR's ongoing repair plan for DCR owned state park dam includes design resiliency considerations based on the most recent hydrologic precipitation frequency data available.	The national industry standard for dam safety hydrologic and hydraulic analysis is to rely on the latest NOAA – Office of Water Prediction - Hydrometeorological Design Studies Center (HDSC) products. Therefore, the Office of Dam Safety uses the HDSC Probable Maximum Precipitation Estimates Document - Hydrometeorological Report no. 51 and NOAA Atlas 14 Precipitation Frequency Atlas Volume 10 Version 3.0 for Northeastern States. In late 2020, MEMA was awarded a federal grant, for which DCR was a sub-applicant, in the amount $378,009 based on a total project value of $581,553. DCR met the required 35% match of $203,544. In June of 2022 DCR awarded a contract to an engineering consultant to develop a screening level, risk-based, decision-making process to prioritize DCR-Office of Dam Safety's portfolio of eligible high hazard potential dams that are reported to be in poor or unsafe condition. The project is expected to be completed in the summer of 2023.	
DCR: Update the State Forest Action Plan to enhance climate change mitigation and adaptation strategies.	Update State Forest Action Plan to incorporate strategies to deal with future conditions presented by a warming planet. These concepts will be incorporated into the 2020 update of the Plan.	Planning and policy	Complete	Executive Office of Energy and Environmental Affairs	Department of Conservation and Recreation (DCR)				Final Draft of Forest Action Plan circulating for internal review prior to submission to US Forest Service.	Plan is complete.	
DCR: Work in strong coordination with EOEEA to monitor coastal shoreline sediment migration.	Continue to monitor sediment migration in order to understand and deal with the complexities of this natural phenomenon in a publicly and environmentally beneficial manner.	Assessment, research, analysis, science, and mapping	Complete	Executive Office of Energy and Environmental Affairs	Department of Conservation and Recreation (DCR)				DCR completed assessment report of sediment transport for North coastal communities of Salisbury, Newbury, and Newburyport including Salisbury Beach and the northern section of Plum Island including Reservation Terrace. Final draft report is under review by EOEEA.	Final sediment study was finalized in January 2021 and released publicly in April 2021. DCR partnered with USACE to implement beneficial reuse of over 200,000 cubic yards of dredge material as beach fill at DCR's Plum Island Reservation. As the Non-Federal Sponsor for the project, DCR obtained local permits for the project and acted as the conduit for the local cost share funding provided by HED.	
DEP: Develop a Statewide River Hydraulic Model.	**REVISED PROJECT DESCRIPTION** This project will create a Statewide River Hydraulic Model, using paper printouts, microfiche, and modern LIDAR. This project will allow for projection of future river elevations for both high and low flows and aid in estimating the effects of projects on river flooding. The Model will facilitate future updates to FEMA maps, including providing the ability to project the effects of changing and more intense hydrologic patterns on flooding elevations as well as project the river elevations during droughts.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				Phase 1: explore the feasibility of the tool is underway, funded through a Wetlands Development Grant from EPA. Depending on the results of Phase 1, the project would proceed to Phase 2: development of the tool and Phase 3: making the tool available to easily determine the needed size of crossings to meet standards.	Phase 1: Feasibility Study; 2019-2022; Completed; EPA Grant $244k Phase 2: Tool Development Pilot: Squannacook Basin; 2021-2022; Completed; EEA SHMCAP Grant $485k Phase 2A: Model Calibration at Additional Sites; July 2022 – June 2023; In-Progress; EEA SHMCAP Grant $330k Next Steps: Phase 3: Complete the Statewide Model Buildout; ~2023-2026; Pending funding – capital budget request pending. Can be funded in total (est. ~ $3-4 M) or in regional phases. (Western, Central, and Eastern MA)	PROJECT ONGOING, impacts can be captured in 2023-2028 actions see revised project description
DEP: Develop Future Extreme River Flow Projections.	Develop streamflows predicted for the Year 2100 using a downscaled Global Circulation Model (GCM) with standardized Representative Concentration Pathways (RCP) from Coupled Model Intercomparison Project Phase 5 (CMIP5). The future streamflows will be added to the web-based USGS StreamStats Methods to make them widely available. This project will allow new and rebuilt roadway crossings to be designed using future expected streamflows which will eliminate uncertainty in the methods that convert precipitation to streamflow. Ultimately, the project will increase the resilience of new or rebuilt roadway crossings to convey river flow, aquatic organisms, and roadway automobile traffic.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)	Statewide			MassDEP and EOEEA have begun a study with Cornell University, Tufts University and the USGS to produce updated and higher spatial resolution downscaled temperature and precipitation projections as a stand alone product and as inputs to a pilot basin model to produce future exteme streamflow projections.	EOEEA entered into a JFA with USGS and a contract with Tufts University who sub-contracted with Cornell University (Climate and Hydrologic Risk Project Phase 1). Cornell University developed climate projections considering thermodynamic changes and future IDF (intensity-design-frequency) curves for MA by scaling existing values using the Clausius-Clapeyron constant. Tufts University in conjunction with USGS developed a model to project streamflow in a pilot basin (Squannacook River Basin) using climate projections. The Climate Change Projections Dashboard was completed and data is available as of December 2022 (https://mass-eoeea.maps.arcgis.com/apps/dashboards/2e8534bc2a7849b0aa6f64d0f79a8937). A visualization product for the output of the Stochastic Watershed Model (SWM) for the pilot basin is in the design phase. The next Phase is to include consideration of dynamic changes in climate projections and extend the streamflow modeling statewide.	PROJECT ONGOING, impacts can be captured in 2023-2028 actions
DEP: Implement Updated Stream crossing culvert replacement guidance.	**REVISED PROJECT DESCRIPTION:** Continue to partner with the Department of Fish and Game, the Division of Ecological Restoration and others to implement a statewide goal of improving stream crossings for resiliency and aquatic organism passage. This project involves developing guidance for the Wetlands Protection Act implemented by MassDEP. DER is working to secure funding for culvert replacement projects. Both efforts will improve the resiliency of new structures, protect habitat and reduce flood damage.	Funding and financing	In Progress	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				On September 14, 2020 Secretary Theoharides announced $800,000 in grants to support culvert replacement projects and the release of a report titled, â€œRecommendations for Improving the Efficiency of Culvert and Small Bridge Replacement Projects,â€prepared by the Massachusetts Culverts and Small Bridges Working Group. This report highlights the safety and environmental challenges presented by over 25,000 road stream crossings across the state and the need for funding and technical assistance for municipalities and partners to address these issues. It also provides recommendations to address the barriers faced by municipalities to implementing this work. The Massachusetts Culverts and Small Bridges Working Group's report can be found here: https://www.mass.gov/doc/massachusetts-culverts-and-small-bridges-working-group-report/download	Draft Guidance (EPA grant deliverable) (Meeting the Massachusetts Stream Crossing Standards to the Maximum Extent Practicable) was completed/submitted to EPA October 2022. An associated Policy was developed to assist in implementation and use of Guidance. Guidance and Policy are planned to be finalized and made available to the public in the Spring 2023. Note: The updated Stormwater Handbook will be available for public comment in the Spring 2023, in parallel with stormwater/precipitation proposed regulatory amendments. Final Handbook is planned to be released in 2023. The Handbook will be used in designing stream crossing and culvert replacement work.	PROJECT ONGOING, impacts can be captured in 2023-2028 actions see revised project description
DEP: Improve Mapping to Enhance Resilience and Emergency Preparedness of Water Utilities.	Continue DEP's Water Utility Resilience Program (WURP) and Geographic Information Systems (GIS) Program collaborative efforts to develop a uniform approach in creating and tracking maps of public water systems and publicly owned treatment works. The project improves internal access to water utility critical infrastructure information, aids in identifying system vulnerabilities and local climate change planning, improves emergency preparedness and response capabilities, and develops consistently formatted, statewide water utility infrastructure maps for multiple uses. Continue to develop detailed GIS maps at the community scale as well as general service area maps to improve system resiliency for additional water utilities. Establish secure access to critical infrastructure information by DEP staff and collaborating agencies to enhance emergency response and recovery efforts.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				MassDEP WURP finalized a project contract with Tighe & Bond on June 25, 2019 to continue a third round of technical assistance that provides direct mapping assistance to 38 water utilities (24 PWS and 14 wastewater systems) with the flexibility of assistance for up to 40 water utilities total. This third round also includes tasks that provide water utilities with tailored Geographic Information System (GIS) needs assessments and on-site (or remote) GIS training, as well as continuation of the statewide service area mapping with enhanced outreach. In addition, this project round includes water utility flood mapping, which will be coordinated with grants awarded through the Municipal Vulnerability Preparedness (MVP) program to highlight water sector issues raised through the MVP planning process, and avoid any potential duplication of efforts. Due to the coronavirus pandemic, the 2019 project round was approved for extension through December 11, 2020 and will result in mapping for a total of 120 water utilities within 73 municipalities across the Commonwealth. Additional utilities have indicated interest in participating to develop GIS mapping of their respective systems, while the developed service area data for drinking water is being utilized in determining effective PFAS monitoring. The executed contract allows two renewal options of one year each for work related to the project scope until termination on or before June 30, 2022. Additional technical assistance through this project is contingent upon available funding/appropriation.	The WURP provided direct mapping assistance to 15 and 9 utilities in FY21 and FY22, respectively. From its start in 2017 the program provided a total of 156 direct mapping assistance project deliverables for 95 PWSs and 48 wastewater systems in 89 different municipalities; confirmed service areas for 83% of Community PWSs statewide and 68% of publicly owned treatment works; and collected interconnection information for approximately 70% of the PWSs. The program is developing a data dashboard that will serve as an MassDEP internal access point for service area data and certain critical infrastructure data. During FY23, staff are evaluating work completed during the first 5-yr project and preparing for enhanced FY24 activities, depending on available funding. A Capital spending request has been proposed for review by EOEEA in Capital Plan for continued support of this project. See related action above.	PROJECT ONGOING, additional funding needed. impacts can be captured in 2023-2028 actions
DEP: Promulgate wetlands regulations to establish performance standards for work in land subject to coastal storm flowage.	Promulgate wetlands regulations to establish performance standards for work in Land Subject to Coastal Zone Flowage. DEP Wetlands Protection Program is working to propose draft regulations that will establish performance standards for work in Land Subject to Coastal Zone Flowage. This resource area is critical for reducing coastal impacts from Storm event. DEP intends to align any proposed standards with FEMA mapping and the state building code for these areas.	Natural systems protections and enhancements (e.g., conservation, restoration, and management)	In Progress	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				The stakeholder group continues to meet and work on these regulatory standards.	Regulations have been developed and are planned to be released for public comment in Spring 2023, with final regulations promulgated 2023. The updated Stormwater Handbook will also be available for public comment in the Spring 2023, in parallel with stormwater/precipitation related proposed regulatory amendments. Final Handbook is planned to be released in 2023. Note priority area: Natural Environment - Inland and Coastal wetlands degradation; Natural Environment-Soil Erosion Natural Environment-Coastal Soil Erosion	PROJECT ONGOING, impacts can be captured in 2023-2028 actions
DEP: Regional water quality monitoring initiative.	Participate in a regional surface water quality monitoring initiative with the other New England states, EPA Regional offices, and tribes in the Northeast, Mid-Atlantic and Southeast. This effort monitors freshwater streams to detect climate-related changes related to temporal trends in biological, thermal, hydrologic, habitat and water chemistry data, and to gather information on response and recovery of organisms to extreme weather events.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				As part of the Northeast Regional Monitoring Network, MassDEP has established five sites in Massachusetts which have been designated for long-term monitoring for temperature regimes, flow characteristics, and stream macroinvertebrate communities.Â These sites are Hubbard Brook in Granville, Brown's Brook in Holland, Parker's Brook in Oakham, West Branch Swift River in Shutesbury, and Cold River in Florida.Â Since 2012 MassDEP has been collecting air and water time-series temperature data, as well as annual macroinvertebrate kick-samples.	In progress (ongoing regional effort). Two additional water bodies (2) in Massachusetts have been added to network. Monitoring of the new water bodies will begin May or June 2023.	PROJECT ONGOING, impacts can be captured in 2023-2028 actions
DEP: Update precipitation data used by wetlands program.	Update Precipitation projections (models) used by the wetlands program to condition work in wetland resource areas and design stormwater controls.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				The most recent stakeholder meeting was held on 9/22/2020. Progress continues. Precipitation projection/ model will need to be incorporated into regulations, stormwater handbook and hydrology handbook.	Regulations have been developed to update the precipitation model and are planned to be released for public comment in the spring of 2023. The updated Stormwater Handbook will also be available for public comment in the Spring 2023, in parallel with stormwater/precipitation related proposed regulatory amendments. Final Handbook is planned to be released in 2023. Note priority area: Natural Environment - Inland and Coastal wetlands degradation; Natural Environment-Soil Erosion Natural Environment-Coastal Soil Erosion	PROJECT ONGOING, impacts can be captured in 2023-2028 actions

DEP: Vulnerability assessment of hazardous waste sites.	**REVISED PROJECT DESCRIPTION** Conduct a vulnerability assessment of thousands of waste sites in state as part of the Massachusetts Contingency Plan (MCP). Prioritize high concern based on water resources and indoor protections. Pilot studies of at risk sites for adaptations/mitigation measures. Provide assessment results to MVP Planning. As part of the Massachusetts Oil Spill Prevention and Response Act (MOSPRA) program, conduct a project "Evaluating and Adapting Oil Spill Preparedness and Response Capabilities for a Changing Climate" that considers how future decarbonization and climate change scenarios may influence marine oil spill preparedness and response activities.	Planning and policy	In Progress	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				As prepared by EcoAdapt and Boston University with oversight by the Sustainable Remediation Forum (SURF) and MassDEP: 1) Vulnerability screening model was completed in April 2019.Â 2) Model and report of vulnerability assessments of 6K "high priority" wastes sites was published in December 2019 (https://www.cakex.org/sites/default/files/documents/MA%20Climate%20%26%20Contaminants%20Screening%20Report%20FINAL%206Dec2019.pdf).Â Ongoing efforts on this project by MassDEP include working with the Licensed Site Professional Association's technical practice group on the implementation of climate change vulnerability assessments at waste sites as part of the assessment, remediation and closure of such sites under the Massachusetts Contingency Plan.Â	Activities for the MCP are complete. Under the MOSPRA program, MassDEP's contractor completed an Interim Report "Marine Oil Spill Threats to Massachusetts Coastal Communities: Updated Assessment with Considerations for a Changing Climate" in August 2022. The interim report identifies preliminary considerations for future scenarios where climate change, adaptation and decarbonization may impact oil spill risks, preparedness, and response. A final report, expected by the end of 2023, will consolidate information and provide considerations to the MOSPRA program for the following: (1) climate vulnerability/oil spill risk analysis; (2) considerations for integrating newly legislated decarbonization target and policies to assess potential impacts on petroleum transportation patterns, volume and spill risks; and (3) findings from a workshop series with oil spill prevention response experts and stakeholders including climate experts to further identify and prioritize impacts of climate trends, projections and policies for oil spill risk, prevention, and response, and opportunities for proactive risk reduction.	PROJECT ONGOING for MOSPRA action item, impacts can be captured in 2023-2028 actions. New activities included in 2023 Proposed Actions see revised project description
Build Restoration Capacity – restructure and expand DER programs and services to strengthen the capacity of the Division, municipalities, non-profit organizations, regional organizations, and agencies to lead and support restoration and climate adaptation work.	DER is building out its programs into three branches: Habitat Restoration Branch – leads river and wetland restoration projects and develops cutting-edge restoration expertise; Technical Services Branch – houses and shares expertise including engineering, GIS, restoration planning, and knowledge management; and Capacity Building Branch – provides funding, training, tools, best practices, technical assistance, and other support to restoration partners. These three branches work together to increase the pace and scale of DER's restoration work and to build others' capacity to lead and support restoration across the Commonwealth. As part of this buildout, DER will expand its new Regional Restoration Partnerships Program that strengthens the restoration capacity of regional organizations and communities.	Capital planning	Should be Modified	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Statewide			DER hired an Ecological Restoration Partnerships Specialist in June 2020 to develop and manage our Regional Restoration Partnerships Program. By the end of 2020 we will complete an assessment of regional restoration partner capacity-building needs and develop and document a program framework. Our goals for 2021 are to finalize the program framework, prepare and issue an RFP for regional partnerships, select and complete contractual agreements for up to 3 pilot regional partnerships, and begin implementation of the pilot partnerships.	Since 2020 the Partnerships Program finalized its program framework, released an RFP for regional partnerships and selected three regional partnerships organizations (Housatonic Valley Association, Buzzard's Bay Coalition, and Merimack River Watershed Council), the selected partnerships have developed a comprehenisve restoration plan and hired restoration coordinators to support long-term restoration work in coordination with DER's partnerships program coordinator. DER recently inititiated a restructuring and is currently hiring multiple positions to build out its three branches.	**Priority Impacts and Vulnerabilities Addressed:** This action is focused on increasing regional and local capacity for restoration projects rather than a specific impact/vulnerability. By increasing regional capacity to plan for and implement restoraiton and climate adaptation projects, this action addresses all impacts/vulnerabilities relevent to DER's mission in the Infrastructure (e.g., Damage to Roads and Increased risk of Dam Overtopping) and Natural Environment (e.g., Freshwater Ecosystem and Coastal Wetland Degradation) Sectors. **2023 SHMCAP Goal Addressed:** 1) Collaboration, Communication, and Engagement
Remove Barriers From Cold Water Streams - Develop and implement priority restoration projects on cold water streams to reduce public hazards, improve ecological health, and increase the climate resilience of human and natural communities.	Collaborate with property owners and federal, state, and local organizations to identify, prioritize, design, permit, and guide the removal of dams and replacement of culverts on high-priority cold water streams that are most impacted by warming temperatures and changing hydrology. These projects benefit coldwater species and habitats while also providing significant co-benefits for public safety and municipal infrastructure resilience. Thousands of dams and culverts in Massachusetts obstruct fish passage, degrade water quality, and drown floodplain habitat. Environmental impacts of climate change are particularly severe on coldwater streams where sensitive species, such as eastern brook trout, are threatened by increasing temperature and changes in hydrology.	Natural systems protections and enhancements (e.g., conservation, restoration, and management)	In Progress	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Statewide			DER and partners from state and federal agencies, environmental non-profits, and academic institutions continue to participate in a dedicated coldwater habitat working group through the Mass Ecosystem Climate Adaptation Network (Mass ECAN) to evaluate and prioritize cold water stream habitats for conservation, restoration, and other management actions. DER uses criteria for prioritizing coldwater habitat in competitive processes for grants and project selection, when appropriate.	DER continues to participate in coldwater habitat related meetings and to include coldwater habitat criteria in its competitive grant and project selection process. From 2020 - 2023, DER provided technical and financial assistance for 16 projects that support removal of stream barriers in coldwater habitat. DER is partnering with MassWildlife to monitor eastern brook trout distribution and abundance following multiple stream barrier removals in Sucker Brook, Pepperell.	**Priority Impacts and Vulnerabilities Addressed:** Loss of biodiversity, habitats, and native species due to climate change impacts. Freshwater Ecosystem Degradation **2023 SHMCAP Goal Addressed:** 4) Implement Adaptation Actions for Communities and Ecosystems
Remove Municipal and Other Dams Statewide - Remove unwanted, obsolete municipal and other dams to reduce public hazards, improve ecological health, and increase the climate resilience of human and natural communities.	Work with municipal, state, and private dam owners and federal, state, and local organizations to identify, design, permit, and guide the implementation of dam removal projects that benefit public safety, build resilience to extreme weather, and restore riverine habitat.	Natural systems protections and enhancements (e.g., conservation, restoration, and management)	Should be Modified	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Statewide			DER's Dam Removal Practice continues to work state-wide to provide technical and financial assistance to municipalities and private landowners that want to remove their dams. From 2019 through August 2020, DER worked with partners to remove 3 dams, including the highly complex removal of the Mill Street/Tel-Electric Dam on the West Branch of the Housatonic River in Pittsfield. One additional dam will be removed in October 2020, and another 16+ dam removal projects are in various phases of development.	DER's Dam Removal Program continues to work state-wide to provide technical and financial assistance to municipalities, private landowners, and state agencies that want to remove their dams. Between 2020 and 2022, DER worked with partners to remove two municipally owned and two privately owned dams. DER provided assistance to an additional 19 priority dam removal projects in various stages of development, including two state owned dams. Using FY22 SHMCAP awarded funds, DER also completed assessments and preliminary designs for removal of eight municipally owned dams. This early phase work will increase the Commonwealth's dam removal project pipeline. Field investigations and preliminary designs for up to ten additional dam removal projects supported by SHMCAP funds will be completed by FY24.	**Very minor modifiation to description, progress notes updated for Round 2** **Priority Impacts and Vulnerabilities Addressed:** Increased Risk of Dam Overtopping or Failure Freshwater Ecosystem Degradation Loss of biodiversity, habitats, and native species due to climate change impacts. **2023 SHMCAP Goal Addressed:** 4) Implement Adaptation Actions for Communities and Ecosystems:
DER: Remove State-owned Dams - Remove unwanted, obsolete state-owned dams to reduce public hazards, improve ecological health, and increase the climate resilience of human and natural communities.	Assist and help build the capacity of state agencies to identify, prioritize, design, permit, and guide implementation of dam removal projects that benefit public safety, build resilience to extreme weather, and restore riverine habitat.	Technical support and assistance	Should be Deferred (	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Statewide			DER assisted the Division of Fisheries and Wildlife and Department of Fish and Game with the completion of a study that evaluated and prioritized DFG-owned dams for potential repair or removal, including development of preliminary cost estimates. In FY20 and FY21, DER has also assisted DCR, MWRA, and DCAMM with the planning and development for removal of agency owned dams.	After internal review and discussion DER recommends that this action be deleted and incorporated into the remaining Dam Removal Action which has been expanded to include state owned dams. DER continues to provide guidance and technical assistance to other state agencies that are evaluating state-owned dams and considering dam removal opportunities.	**Priority Impacts and Vulnerabilities Addressed:** Increased Risk of Dam Overtopping or Failure Freshwater Ecosystem Degradation Loss of biodiversity, habitats, and native species due to climate change impacts. Increase in Need for State and Municipal Policy Review and Adaptation Coordination. **2023 SHMCAP Goal Addressed:** 1) Collaboration, Communication, and Engagement
Restore Coastal and Transitional Wetlands - Prioritize, develop, and implement coastal wetland restoration projects that improve ecological health and increase the climate resilience of human and natural communities.	Partner with municipalities and private property owners as well as federal, state, and local organizations to identify, design, permit, and guide the implementation of priority coastal wetland restoration projects that benefit public safety, increase resilience to extreme weather and sea level rise, and restore coastal habitat as well as transitional habitat that will become coastal due to sea level rise. -The health and ecosystem services of coastal wetlands are projected to be significantly impacted by sea level rise and other effects of climate change. As sea levels rise upstream brackish and freshwater habitats (as well as the infrastructure in those habitats) will be exposed to tidal conditions and coastal storm surge impacts. This provides opportunity for salt marsh migration as well as a need to plan for changing conditions when designing coastal restoration projects. DER is actively working to identify and prioritize additional tidal restoraiton opportunities through the development of a tidal crossing geodatabase, and using remote sensing as well as field techniques to identify transitional crossing culverts that are likely to become tidal in the future.	Natural systems protections and enhancements (e.g., conservation, restoration, and management)	Modified or Deferred	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Regional	North and South Shores Region	Cape, Islands, and South Coast Region	In FY20, DER's Coastal Wetlands Practice Area completed development of a coast-wide geodatabase of potential tidal wetland restoration projects, including information and metrics for climate resiliency benefits. A Data Viewer is being developed in FY21 to help prioritize projects. Construction of one tidal wetland restoration project was completed in FY20 and construction is underway for a second in Yarmouth (60+ acres) in FY21. DER is also working to develop technical guidance for coastal municipalities interested in replacing undersized road crossings that carry freshwater flow, but will soon transition to tidal flow, due to sea level rise. In the Great Marsh, DER and partners continue to pilot new coastal wetland restoration treatments to address legacy impacts of marsh ditching and other historic alterations that impair marsh resilience to sea level rise.	DER continues to prioritize, develop and implement coastal wetland restoration projects. Since 2020, DER has constructed three wetland restoration projects (Crescent Marsh in Saugus, Parkers River in Yarmouth and Eagle Neck Creek in Truro) and selected three new coastal wetland restoration priority projects in Yarmouth and Chatham. DER is currently using the coast-wide geodatabase developed in 2020 to prioritize potential restoration projects based on ecosystem benefits, climate change, and feasibility criteria. DER was awarded SHMCAP funds in FY23 to continue to investigate "transitional" road crossings that are predicted to become tidal in the near future due to sea level rise.	**This action was modified to include specific projects underway since 2018. Round 2 edits are indicated in red.** Note this action includes all coastal areas in Massachusetts (Boston Harbor region in addition to the two regions identified as Region 1 and Region 2) **Priority Impacts and Vulnerabilities Addressed:** Coastal Wetland Degradation Marine Ecosystem Degradation Loss of biodiversity, habitats, and native species due to climate change impacts. Coastal Erosion **2023 SHMCAP Goal Addressed:** 4) Implement Adaptation Actions for Communities and Ecosystems
Restore Wetlands and Streams Within Retired Cranberry Bogs - Develop and implement priority restoration projects within retired cranberry bogs to improve ecological health, protect open space, and increase the climate resilience of human and natural communities.	Work with landowners, federal, state, and local partners and non-profit organizations to restore retired cranberry bogs to natural wetland systems to increase habitat resilience for fish and wildlife, enhance drought resilience, and improve flood storage and water quality for communities.	Natural systems protections and enhancements (e.g., conservation, restoration, and management)	In Progress	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Regional	North and South Shores Region	Cape, Islands, and South Coast Region	In 2019-2020, DER's Cranberry Bog Restoration Program applied for and was awarded $10 million from the United States Department of Agriculture Natural Resources Conservation Service (NRCS) to support a partnership-based effort to protect open space and restore streams and wetlands on former cranberry bog farmland in southeastern Massachusetts. Over the next five years, DER and 17 partner organizations will use the funding to work with landowners to protect and restore historic wetlands on retiring cranberry farmland. The partnership aims to restore 900 acres of wetlands and permanently protect 1,800 acres of open space. The proposed work will restore habitat for fish and wildlife, help communities adapt to climate change, and benefit cranberry growers. The Cranberry Bog Program's existing seven projects will be supported through this effort.	DER's Cranberry Bog Restoration Program continues to work with landowners, federal, state, and local partners to identify and implement cranberry bog restoration projects. Between 2020 and 2022, eight new priority cranberry bog restoration projects were accepted by DER. Construction of the Upper Child's River bog restoration in Falmouth and Foothills Preserve in Plymouth were completed. DER's $10 million award from the Natural Resources Conservation Service (NRCS) to support a partnership-based effort to protect and restore streams and wetlands on former cranberry bog farmland has kicked off. New projects are anticipated to be brought into this joint DER - NRCS program in 2023.	**Round 2 edits are indicated in red** Note this action is focused on cranberry bogs, which generally occur in southeastern Massachusetts and the Cape and Islands. Would also include Eastern Inland as a third Region from the choices. **Priority Impacts and Vulnerabilities Addressed:** Freshwater Ecosystem Degradation Loss of biodiversity, habitats, and native species due to climate change impacts. **2023 SHMCAP Goal Addressed:** 4) Implement Adaptation Actions for Communities and Ecosystems
DER: Upgrade Municipal Culverts - Build municipal capacity to replace undersized, deteriorated culverts with larger, safer structures that reduce public hazards, improve ecological health, and increase the climate resilience of human and natural communities.	Provide training, tools, technical assistance, and incentive grants for municipalities to replace undersized culverts with larger, safer structures that are resilient to extreme storms, reduce roadway flooding and infrastructure damage, and provide passage for fish and wildlife.	Technical support and assistance	In Progress	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Statewide			In FY20 and FY21, DER's Stream Continuity Program and its Culvert Replacement Municipal Assistance Grants provided technical and financial assistance to help local communities assess road-stream crossings and upgrade priority culverts. For FY21, DER awarded grants totaling $806,880 to upgrade road-stream crossings in 14 municipalities. Two of these communities also received Training Initiative status and will serve as case study sites, receiving additional technical support and hosting training opportunities for near-neighbor communities. DER also participated in the development and issuance of the joint EEA-MassDOT, Culverts and Small Bridges Working Group Report.	DER's Stream Continuity Program continues to provide technical and financial assistance to help local communities assess road-stream crossings and upgrade priority culverts to meet the Massachusetts Stream Crossing Standards. DER awarded $2.8 million to 26 municipalities in FY22 and $1.8 million to 13 municipalities in FY23. Seven culvert replacements supported through this grant program were constructed between 2021 and 2022. Additionally, DER's case study culvert replacement training sites in Ashfield, Ashburnham, and Brookfield continued to advance during this period. The training site in Boxford was constructed. DER finalized a new Culvert Replacement Toolkit along with a series of capacity building videos to help municipalities gear up for upgrading degraded culverts.	**Round 2 edits are indicated in red** **Priority Impacts and Vulnerabilities Addressed:** Damage to Roads and Loss of Road Service Freshwater Ecosystem Degradation **2023 SHMCAP Goal Addressed:** 6) Resilient and Equitable Infrastructure, Ecosystems, and Communities
DOER: Build energy resiliency.	Continue to prioritize investments in clean energy resiliency infrastructure projects at state, municipal, and critical private facilities.	Capital planning	In Progress	Executive Office of Energy and Environmental Affairs	Department of Energy Resources (DOER)				DOER promulgated the nation leading Clean Peak Energy Standard which took effect in 2020 and includes a 50% increased value for resilient energy projects. DOER updated the SMART solar program, doubling the program size, maintained support for energy storage paired with new solar PV, and added a requirement that energy storage be paired with large solar projects. DOER participated in regulatory dockets updating interconnection procedures for distributed generation, particularly facilities which include energy storage and can enhance a site's energy resilience.	DOER promulgated the nation leading Clean Peak Energy Standard which took effect in 2020 and includes a 50% increased value for resilient energy projects. DOER updated the SMART solar program, doubling the program size, maintained support for energy storage paired with new solar PV, and added a requirement that energy storage be paired with large solar projects. DOER participated in regulatory dockets updating interconnection procedures for distributed generation, particularly facilities which include energy storage and can enhance a site's energy resilience.	

DPU: Facilitate a program for sharing resources between municipalities for tree maintenance.	Investigate, encourage or facilitate a program for towns, regions and utilities to work together and share information and equipment to reduce potentially hazardous trees/limbs.	Planning and policy	In Progress	Executive Office of Energy and Environmental Affairs	Department of Public Utilities (DPU)				DPU closely reviews distribution company vegetation management plans in both rate cases and annual reliability filings to ensure that electric distribution companies are appropriately managing vegetation to minimize outages that may be caused by inclement weather and/or climate change.	DPU closely reviews distribution company vegetation management plans in both rate cases and annual reliability filings to ensure that electric distribution companies are appropriately managing vegetation to minimize outages that may be caused by inclement weather and/or climate change.	
DPU: Power system planning that incorporates climate change risk.	Assess how power system planning may incorporate existing climate models to assess risk and deploy cost-effective infrastructure to reduce outages, repair, and replacement. Utilities could also identify key data gaps for system planning and identify that to DPU/EOEEA to coordinate with ongoing research.	Planning and policy	In Progress	Executive Office of Energy and Environmental Affairs	Department of Public Utilities (DPU)				DPU carefully reviews all submitted filings to ensure that power system planning and proposed utility capital investments take into account potential climate change impacts. The grid-facing investments approved under the electric utilities' grid modernization plans continue to progress forward and are designed to reduce outages and improve the ability of the electric grid to self-heal. In addition, the DPU has spent the last year investigating ways to improve the Commonwealth's procedures for interconnecting distribution generation. As part of this effort, the DPU has identified cost allocation and distribution planning related to climate policies as areas that may be worthy of further investigation in the near term future.	DPU carefully reviews all submitted filings to ensure that power system planning and proposed utility capital investments take into account potential climate change impacts. The grid-facing investments approved under the electric utilities' grid modernization plans continue to progress forward and are designed to reduce outages and improve the ability of the electric grid to self-heal. In addition, the DPU has spent the last year investigating ways to improve the Commonwealth's procedures for interconnecting distribution generation. As part of this effort, the DPU has identified cost allocation and distribution planning related to climate policies as areas that may be worthy of further investigation in the near term future.	
DPU: Review storm preparedness best practices from other regional distribution systems.	Review distribution system adaptation methods adopted in areas which have historically been subject to the types of hazards which may increase in Massachusetts (e.g. precast distribution poles near the coast, such as those used in Florida).	Planning and policy	In Progress	Executive Office of Energy and Environmental Affairs	Department of Public Utilities (DPU)				DPU reviews all capital investment plans by the distribution companies to ensure that investments take these matters into account. Distribution companies have been proactive in their approach to reduce outages and make the necessary investments in more robust infrastructure in areas of the grid that are more vulnerable or subject to climate and/or weather related hazards.	DPU reviews all capital investment plans by the distribution companies to ensure that investments take these matters into account. Distribution companies have been proactive in their approach to reduce outages and make the necessary investments in more robust infrastructure in areas of the grid that are more vulnerable or subject to climate and/or weather related hazards.	
EOEEA: Incorporate information on climate change risk and vulnerability from the SHMCAP and subsequent studies into all capital budget planning.	Ensure all funding requests are consistent with vulnerability and risk assessments completed through the SHMCAP and subsequent studies so that future investments are resilient, do not increase exposure to climate change impacts, do not jeopardize life and safety, and seek to increase the resiliency of EOEEA's holdings.	Funding and financing	Complete	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)	Statewide			EOEEA has hired a technical assistance vendor, Weston & Sampson, to support RMAT agencies in implementing the SHMCAP. The team is working with state agencies and a technical advisory group to develop a web-tool that provides recommendations for climate resilient design standards and a climate risk rating for state projects with physical assets. It is estimated to be launched on ResilientMA.org in early 2021.	RMAT's Climate Resilience Design Standards Tool is in use across the statewide capital planning process as of February 2022, and in major infrastructure grant programs like MVP and Massworks. It was also launched for private and public projects undergoing MEPA review as of October 2021.	
EOEEA: Review habitat management, land stewardship, coastal zone management, agricultural and invasive species programs and policies to develop strategies that promote coordination among agencies and support climate change adaptation and mitigation goals.	Facilitate multi-agency review of habitat management, forest stewardship, agricultural best practices and invasive species programs and policies to recommend updates that reflect climate change data and projections and address opportunities to increase resilience while also reducing GHG emissions or increasing carbon sequestration.	Planning and policy	Complete	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)				The Resilient Lands Initiative (RLI) will release its 10-year vision and strategy in November 2020. Over the past year, the RLI has gathered input from 16 public listening sessions and focus groups and 12 meetings of a steering committee with 40 participants from federal, state, municipal and NGO land conservation and stewardship practitioners and is now finalizing the draft 10-year vision and strategy. The plan includes eight strategies: No Net Loss of Farms and Forests; Focus on Food Systems; Focus on Urban Greenspaces and Community Health; Focus on Water Resources; Focus on Landscape Conservation and Restoration; Focus on the Green Economy; Focus on Natural Carbon Storage and Climate Resilience and Focus on Collaboration for Sustainable Solutions. EEA is also working with several NGO, municipal and federal partners to create a new forest resilience and carbon storage program that focuses on best practices to enhance carbon storage and resilience funded by an MVP grant, DCR Working Forest Initiative funds, private grants and a US Forest Service grant. This new program will be finalized and implemented on a pilot basis during 2021.	The Resilient Lands Initiative and Healthy Soils Action Plan were released in December 2022: https://www.mass.gov/info-details/resilient-lands	
EOEEA: Review, evaluate, and implement revisions as needed to environmental and energy policies, regulations, and plans.	Review, evaluate, conduct outreach with stakeholders, and implement revisions that may be needed to key state environmental and energy policies, regulations and plans maintained by EOEEA and its agencies. This action has cross-cutting impact on risk reduction across the administration.	Regulations, codes, and zoning	Complete	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)				EEA plans to release the final Healthy Soils Action Plan in November 2020. The plan gathered input from several public listening sessions and regular meetings of a technical steering committee with experts and managers dealing with the four principal land use types: farms, forests, wetlands and developed lands. The plan also analyzed soil organic carbon measurements from hundreds of on-the-ground plots to provide a map showing soil conditions across the state. The plan includes recommendations for protecting and improving MA soils to improve productivity of plant growth, reduce drought impacts, reduce erosion and increase and safeguard the immense stocks of soil carbon.	The Resilient Lands Initiative and Healthy Soils Action Plan were released in December 2022: https://www.mass.gov/info-details/resilient-lands	
EOEEA: Update and maintain the resilientMA.org climate change clearinghouse site to include a Vulnerability Assessment Wizard for MVP communities, a clearinghouse to grant programs to fund MVP actions, and a dynamic version of the SHMCAP.	Continue efforts to maintain an online website through development of a Climate Change Vulnerability Assessment Wizard or tool to help cities and towns assess, track and address vulnerability, creation of a municipal portal for MVP communities to store data, submit reports, and save resources, creation of dynamic version of the state plan for interactive reading, searching, and resourcing, a clearinghouse of State grant opportunities to help MVP recipients address priority climate change actions identified in their planning process, and continual update to climate change projections and data, and ongoing curation of the repository of climate change literature, plans, and other documents.	Technical support and assistance	Complete	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)	Statewide			EOEEA has published a dynamic version of the SHMCAP, including an action tracker for public facing status and progress notes of all state agency actions. EOEEA has contracted with a new vendor for ongoing maintenance and development of resilientma.org. Current development in progress includes an MVP Portal with key program resourcesÂ andÂ toolkits, an EEA climate grant viewer, and a page to host deliverables from the RMAT Climate Resilient Standards andÂ Guidelines project.	The ResilientMA.mass.gov site now includes a new MVP Portal, 2018 SHMCAP Action Tracker, Resilient MA Action Team page, updated Maps and Data Center featuring interactive applications with the latest climate science and data for MA.	
EOEEA: Utilize available climate change projections and risk assessment data to assess vulnerabilities of all EOEEA properties. Support efforts across the administration to assess facilities held by other Executive Offices.	Utilize climate projections and data on site specific vulnerabilities, agency adaptative capacity and other information to assess climate change vulnerability at all of EOEEA's land holdings, facilities, parkways, fisheries, dams, and other properties. This vulnerability assessment would result in scores and information for each asset, as well as a system of GIS layers depicting exposure and sensitivity and final vulnerability scores to help EOEEA to understand the risks present at each site.	Planning and policy	In Progress	Executive Office of Energy and Environmental Affairs	Executive Office of Energy and Environmental Affairs (EOEEA)	Statewide			In FY21, DCR will be conducting a climate vulnerability assessment on an inland and coastal property that contain a variety of natural, cultural, and recreational asset types in order to develop a methodology for analysis of properties state-wide, to be completed as a phase II.	The Climate Resilience Design Standards Tool utilizes climate projections and data to assess preliminary climate exposure and provide guidance to capital funded projects. EEA utilized the tool to assess projects through the statewide capital planning process.	
MassWildlife: Evaluation of climate change impacts on common species.	Continue efforts to understand the direct and indirect effects of climate change on common species (e.g., yellow perch, pumpkinseed, chain pickerel, wild turkey, deer, bear,) and angler/hunter behavior which will allow the Division to foresee how management strategies may need adjustment to provide recreational opportunities to Commonwealth citizens into the future.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				The Division has had initial discussions on how to address the action (e.g., what are the target species?), perhaps as part of the updates being made to BioMap2. Estimated start date July 1, 2021.	Disccusions in progress for fish species in collaboration with NECASC and UMass-Amherst.	
MassWildlife: Great Marsh Pilot Ditch Remediation Project.	Explore cost-effective experimental pilot projects to assess the feasibility of larger-scale interventions in the future to enhance resilience of the Great Marsh for habitat and ecosystem services (such as buffering upland and infrastructure against waves, storm surges, and coastal erosion). In cooperation with The Trustees of Reservations (TTOR), researchers at University of New Hampshire, and other partners, fill select ditches on MassWildlife and TTOR properties with organic material and measure the effects on marsh elevation and rates of sediment trapping. Preliminary indications are that this technique may prevent further subsidence, reduce the rate of marsh loss, and possibly even gradually elevate the marsh bed through sediment trapping. The ditch remediation pilot is only the first step. This project will build a coalition of partners committed to additional adaptive management, including the possibility of experimenting with thin layer deposition â€" another technique that is more difficult to implement and permit, but also holds the promise of gradually raising the marsh elevation, while preserving marsh grasses and other marsh life. Planning for this second phase would occur during the 5 year implementation timeline for the project.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				DFW, TTOR and other colleagues participated in a week-long Strategic Decision Making workshop focusing specifically on Great Marsh restoration. Several meetings of Great Marsh managers were held at USFWS headquarters to plan landscape scale salt marsh restoration projects. TTOR started ditch remediation pilot projects at Old Town Hill Reservation. Their contractor mapped legacy agricultural features on 50 acres of salt marsh on William Forward WMA. This map was used in restoration design, including micro-runnels at selected mega pools. TTOR hired a project manager to initiate permitting. An ENF and NPC were filed with MEPA. CZM and DEP provided substantive comments, requesting additional information about the nature-based techniques (ditch remediation, micro-runnels, and salt marsh sparrow nesting habitat). The Secretary required a SEIR that will be filed in Fall 2020. MassWildlife filed an ILF grant pre-proposal, and conducted a site visit for grant committee members with Geoff Wilson, one of the Great Marsh advisory team members. TTOR filed a NAWCA grant application.	DFW, TTOR and other colleagues participated in a week-long Strategic Decision Making workshop focusing specifically on Great Marsh restoration. Several meetings of Great Marsh managers were held at USFWS headquarters to plan landscape scale salt marsh restoration projects. TTOR started ditch remediation pilot projects at Old Town Hill Reservation. Their contractor mapped legacy agricultural features on 50 acres of salt marsh on William Forward WMA. This map was used in restoration design, including micro-runnels at selected mega pools. TTOR hired a project manager to initiate permitting. An ENF and NPC were filed with MEPA. CZM and DEP provided substantive comments, requesting additional information about the nature-based techniques (ditch remediation, micro-runnels, and salt marsh sparrow nesting habitat). The Secretary required a SEIR that will be filed in Fall 2020. MassWildlife filed an ILF grant pre-proposal, and conducted a site visit for grant committee members with Geoff Wilson, one of the Great Marsh advisory team members. TTOR filed a NAWCA grant application.Work continues in partnership with USFWS, Trustees, and other partners.	
MassWildlife: Identification of areas with high native aquatic biodiversity to help prioritize aquatic adaptation actions as the climate changes.	The Division of Fisheries and Wildlife is responsible for the conservation of freshwater fishes and wildlife throughout Massachusetts. Efforts (i.e. BioMap2) have been made to rigorously analyze and map rare species and natural community data in terrestrial ecosystems. These efforts identified lands critical for protecting and maintaining wildlife and plant biodiversity in Massachusetts. However, similar efforts have not been completed for the river and streams providing habitat to aquatic species (e.g., fishes, freshwater mussels) managed by MassWildlife. Identification of water bodies with high native aquatic biodiversity would provide critical information necessary for effective management and conservation of aquatic species in the state.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				Fish species diversity has been analyzed at the watershed and stream order scale. Maps of species richness have been completed and indices of fish assemblage similarity to expected communities have been calculated. Next steps include incorporation of additional data (e.g., freshwater mussels, odonates), and a prioritization scheme to rank and identify areas with highest biodiversity.	Biodiversity strongholds have been identified for fish species. In progress for freshwater mussel assemblages.	
MassWildlife: Work with MassDOT to incorporate habitat and cold water fisheries considerations into MassDOT climate vulnerability assessments, adaptation projects, and community planning tools.	Build on the existing â€œLinking Landscapesâ€ MassWildlife/MassDOT partnership and MassDOT's pilot assessments of road stream/wetland crossings vulnerable to climate change, storm damage and flooding to: - Expand the pilot MassDOT Road Infrastructure Vulnerability Assessment statewide. Identify the important habitat areas that would benefit from improved stream and wetland crossing structures and that intersect with the most vulnerable road infrastructure (e.g. Rare Species key sites, Cold Water Fisheries priority areas, Natural Communities). - Conduct a comprehensive assessment that builds on existing models to (SHEDS-ICE) to map stream reaches in Massachusetts that are likely to remain cold water refugia under different climate scenarios and timescales (2030-2100). - Incorporate project results into an existing GIS-based project planning tool used by MassDOT staff and shared with municipalities and regional planning authorities. In addition to identifying vulnerable road infrastructure that intersect habitat features of statewide and regional significance the planning tool will make specific project design recommendations, and highlight available technical assistance and funding opportunities.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				Statewide culvert/bridge vulnerability maps were created and made available publicly. The results are being integrated with the MADOT Project Intake Tool and the Early Environmental Coordination Checklist.	Statewide culvert/bridge vulnerability maps were created and made available publicly. The results are being integrated with the MADOT Project Intake Tool and the Early Environmental Coordination Checklist. Work continues in collaboration with DOT.	
DEP: Enhance the Water Utility Resilience Program (WURP).	Enhance the Water Utility Resilience Program, a program which supports the efforts of public drinking water and wastewater utilities in building or enhancing resilience to and recovery from severe weather events, by providing additional technical assistance through DEP's regional offices for water utilities to improve asset management, address system vulnerabilities and support more outreach and provide educational materials and events for this sector.	Technical support and assistance	Not Started	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				Augmenting the WURP program is dependent on staffing and resources allocated for this work.	Not started as enhanced staffing was not funded. If approved, additional climate staff (proposed within an expanded budget proposal) may undertake some of these technical assistance tasks. A Capital spending request has been proposed for review by EOEEA in Capital Plan for continued support of the current project (no expansion). See related item below.	Funding needed. If funded, impacts can be captured in 2023-2028 actions
DEP: Resiliency Grants for Water Infrastructure.	Establish a resiliency grants program for public water systems and wastewater systems to make system improvements that will increase capacity to withstand the effects of climate change and recover after severe events. This program would build on "Gap Grants" that support energy efficiency and clean energy projects in this sector. The expanded program could support projects such as flood protection measures, elevation of critical components to avoid damage from sea level rise, flooding or extreme precipitation, providing backup power for critical services, anticipating rising temperatures, and replacing aging infrastructure that is increasingly vulnerable because of climate changes. These grants would be designed to support resiliency projects that are not being regularly supported by other financial incentive programs while being consistent with and complementing them.	Funding and financing	Not Started	Executive Office of Energy and Environmental Affairs	Department of Environmental Protection (DEP)				This work is dependent upon grant/program funding.	Not started. This new grant program was not funded. Note: New SRF funds from significant federal infusion of funding may provide funding for these purposes and MVP grants may also address this need.	If funded, impacts can be captured in 2023-2028 actions
MassWildlife: Evaluation of shifts in habitats and species distributions.	Work to understand the rate and extent of changes to ecosystems over different timescales in order to effectively manage resources. Species habitats and distributions are expected to shift with changing environmental conditions, resulting in changes to the function and structure of ecosystems. While the Division is already considering these shifts in management decisions, comprehensive spatially-explicit analysis (where, how) of impacts to ecosystems and vulnerable species and habitats has not been completed.	Assessment, research, analysis, science, and mapping	Modified or Deferred	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				MassWildlife and TNC staff have discussed the possibility of including this information in updates to BioMap2 (BioMap3). The process does not currently consider how these may shift in response to changing environmental conditions. The analysis may be completed in a subsequent phase of BioMap. Estimated start date July 1, 2021.	Postponed. Angency priorities have changed.	

MassWildlife: Mapping and control of invasive plant species.	Identify and map the extent of invasive plants on Division-owned and managed lands statewide. This information is necessary to determine the habitat quality and restoration potential of lands, as well as treatment methods for controlling or eradicating invasive species. Additionally, monitoring helps with early detection and eradication efforts to control for newly introduced invaders who may be able to spread north under climate change. Once invasive plants are mapped, treatment options for eradication or control can be determined and implemented. Because of the robust nature of most invasive species, treatment to eradicate or significantly control any one existing population can take 5-8 years.	Assessment, research, analysis, science, and mapping	Modified or Deferred	Executive Office of Energy and Environmental Affairs	Division of Fisheries and Wildlife (MassWildlife)				Control of invasive species has largely focused on habitats for imperiled species. Work in FY20 included efforts to control water chestnut at Russell Cove (Connecticut River) and Spofford Pond, Mile-a-Minute in western Massachusetts and near the Blue Hills, black swallowwort at Mt. Tom, and gray willow along coastal plain ponds.	Postponed. Angency priorities have changed.	
DER: Develop a Dam Removal Decision Support Tool - Develop and share a web-based tool that evaluates the potential removal of any dam for hazard reduction and ecological and climate resilience benefits.	Update and publish the web-based tool that evaluates dams for removal based on the expected ecological benefit to include risk reduction and climate adaptation benefits.	Technical support and assistance	Should be Deferred (	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Statewide			In 2019-2020, DER invested significant staff time to upgrade its Restoration Potential Model (RPM) tool, which can be used to evaluate the relative ecological benefit of removing any dam in the Commonwealth. This step must be completed prior to development of a web-based tool that includes climate adaptation benefits.	After internal review and discussion DER recommends that this action be deleted. DER has continued to invest staff time in upgrading the Restoration Potential Model (RPM) tool to evaluate the relative ecological benefit of removing a dam. At this time, a web-based viewer that incorporates climate adapatation benefits has not been completed.	**Priority Impacts and Vulnerabilities Addressed:** Increased Risk of Dam Overtopping or Failure Freshwater Ecosystem Degradation Loss of biodiversity, habitats, and native species due to climate change impacts. **2023 SHMCAP Goal Addressed:** 2) Science-based and Informed Decision-Making
DER: Restore Streamflow - Develop and implement priority streamflow restoration projects that improve ecological health and increase the climate resilience of human and natural communities.	Work with municipalities, water suppliers, NGOs, state agencies and others to restore more natural streamflow (the amount of water that flows through streams and rivers) as part of an effort to increase community resilience to drought and improve the health of aquatic habitats.	Natural systems protections and enhancements (e.g., conservation, restoration, and management)	Should be Deferred (	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Statewide			DER's Streamflow Restoration Program is working with many partners to explore and implement both physical and non-physical methods for increasing water conservation and reducing flow stress on aquatic systems and water supplies. Current projects support reductions in residential water use, modifications to impoundment management, and improvements to water supplier data systems that can increase water conservation.	After internal review and discussion DER recommends that this action be deleted. Since 2020, streamflow restoration has been integrated into DER's habitat restoration functions and is no longer a stand-alone program.	**Priority Impacts and Vulnerabilities Addressed:** Freshwater Ecosystem Degradation Increase in Need for State and Municipal Policy Review and Adaptation Coordination. **2023 SHMCAP Goal Addressed:** 1) Collaboration, Communication, and Engagement
DER: Restore Water Quality - Develop and implement priority water quality restoration projects that improve ecological health and increase the climate resilience of human and natural communities.	Work with partners to identify, prioritize, plan and complete projects that improve water quality and increase community resilience to water quality impacts stemming from climate change. Changes in precipitation associated with climate change are anticipated to increase runoff of pollutants into wetlands, rivers, and coastal embayments. Together with rising temperatures and water body eutrophication, these changes are anticipated to increase the prevalence of water quality impairments that impact aquatic ecosystems and multiple community interests, including aesthetics, water supplies, and recreation. Projects may include nature-based stormwater treatments; restoration of riparian buffer functions and values; support for developing local ordinances and stormwater utilities; and enhancing local and regional capacity to develop and implement solutions for identified water quality impairments.	Natural systems protections and enhancements (e.g., conservation, restoration, and management)	Should be Deferred (	Executive Office of Energy and Environmental Affairs	Division of Ecological Restoration (DER)	Statewide			DER has completed the first year of the Water Quality Restoration Pilot and is entering into the second year. The pilot partner, Ipswich River Watershed Association (IRWA), is working on a campaign to reduce nutrients in the Ipswich River through reductions or elimination of fertilizers on residential properties to improve water quality. This work is in partnership with the town of Middleton. In addition, DER's Priority Project for creation of a floodplain for lower Fearing Brook in Amherst is entering the permitting phase. This work will provide significant NPS treatment in addition to habitat and river function improvements.	After internal review and discussion DER recommends that this action be deleted. Since 2020, DER has moved away from focusing on water quality restoration as a stand-alone program and instead water quality restoration considerations have been integrated into DER's general habitat restoration projects.	**Priority Impacts and Vulnerabilities Addressed:** Freshwater Ecosystem Degradation Coastal Wetland Degradation Marine Ecosystem Degradation **2023 SHMCAP Goal Addressed:** 1) Collaboration, Communication, and Engagement
DPH: Strengthen environmental health programs to respond to climate-related impacts.	Strengthen environmental health programs to respond to climate-related impacts and support other state agencies and communities to conduct health impact assessments on climate.	Technical support and assistance	In Development	Executive Office of Health and Human Services	Department of Public Health (DPH)				In late 2019, an online tool, "Community Health Profiles," will be publically available to provide climate and health information for each of the 351 cities and towns in Massachusetts and can be found at https://matracking.ehs.state.ma.us/index.html. DPH will use federal funding from the CDC to develop a climate and health communication plan that identifies interventions that can be used to address climate change impacts. A particular focus will be given to environmental equity and populations that will be most vulnerable to climate change.	Deployed updated Climate and Health webpages on Mass.gov, taking advantage of searching capabilities within that system to provide both lay-friendly and professional educational content and climate equity resources, including links to DPH climate content pages on the Environmental Public Health Tracking website. Leveraged the Mass.gov platform to provide access to five DPH Climate Hazard Adaptation Profiles, which are hazard-based information briefs geared toward municipal officials and planners. https://www.mass.gov/climate-and-health. Engaged DPH Environmental Health staff in responding to requests for review and feedback on draft materials from the 2023 SHMCAP Project Working Group, within described content areas. Provided technical assistance and outreach to support residents, municipalities, and watershed organizations contending with cyanobacterial harmful algal blooms and bacterial exceedances identified in recreational waterbodies across the Commonwealth. Leveraged the DPH Environmental Public Health Tracking Program platform to post climate-related environmental health data, including historical monitoring results for bacteria detected at recreational beaches and downscaled climate projections data for temperature and precipitation. Participated in multi-agency efforts to conduct stakeholder outreach and address outbreaks of Eastern Equine Encephalitis, including collaboration with the DPH Bureau of Disease Surveillance and Laboratory Sciences to train directors of summer camps and recreation programs about EEE response efforts Conducted a climate and health training for all DPH environmental health staff providing an overview of climate and health activities funded under the FY22 EEA ISA in FY 2022 Provided technical assistance about indoor air, mold, and other climate-related health concerns through participation in RMAT working groups creating a climate resilience design standards tool: https://resilientma.org/rmat_home/designstandards/ Provided technical support to recent sanitary code revisions, incorporating measures for climate-related issues such as mold control, food safety, and other hazards with climate-related health impacts. Provided outreach to summer camps and recreational programs on staying safe during extreme heat events. Collaborated with the Massachusetts Health Officers Association to provide annual trainings on algae and recreational water quality for local health officials and other municipal staff.	
DPH: Provide support and direct care to vulnerable populations susceptible to climate change impacts.	Provide data with a social determinants framework to inform the Municipal Vulnerability Preparedness (MVP) Program and DPH preparedness plans. Identify adaptation and resiliency strategies that address health and racial equity. Strengthen the Environmental Public Health Tracking network and the Climate and Health Program in the DPH. Using DPH's current cross-state databases, perform data collection and needs assessment for particularly vulnerable populations (such as the homeless, the elderly, and people with mental illness or substance use disorders) and develop and implement adaptation and resiliency plans for these vulnerable populations. - Provide data with a social determinants framework to inform the Municipal Vulnerability Preparedness (MVP) Program and DPH preparedness plans. - Identify adaptation and resiliency strategies that address health and racial equity. - Strengthen the Environmental Public Health Tracking network and the Climate and Health Program in the DPH. - Using DPH's current cross-state databases, perform data collection and needs assessment for particularly vulnerable populations (such as the homeless, the elderly, and people with mental illness or substance use disorders) and develop and implement adaptation and resiliency plans for these vulnerable populations.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Health and Human Services	Department of Public Health (DPH)				DPH created an online Emergency Preparedness Population Planning Tool to assist municipalities in their planning preparation for extreme weather and climate change. The "Planning Tool" is available at https://matracking.ehs.state.ma.us/planning_and_tools/index.html.	Curated publicly facing environmental health data resources to inform assessment of exposure and health outcomes linked to the social determinants of disease and exposure to climate hazards. Conducted key informant interviews with other DPH programs that regularly engage with clinicians, community health workers, school nurses, etc. to identify collaborative outreach opportunities for deploying educational content on climate change for direct care providers. Evaluated data from a 2022 DPH Survey of Clinicians that assessed health care provider awareness and patient interest in environmental health topics including climate change. Developed case studies to inform educational content about climate hazards (e.g. extreme heat) for clinicians/direct care providers that are framed in the context of Environmental Justice and Social Determinants of Health. Developed educational content on the social determinants of climate related diseases and reframing health outcomes in the context of environmental justice, exposure to environmental stressors, and root causes. Training content included learning objectives and post-course quiz questions for peer review. Collaborated with the Massachusetts Nurses Association, the largest union and professional association of registered nurses representing more than 23,000 members across 85 health care facilities, to develop and deliver a Continuing Education Course on “Environmental Justice and Health Equity: Understanding the cumulative impacts of local environmental hazards and social determinants of health in Massachusetts”, which included relevant material for climate equity. This course was offered for a six-month period in the MNA Online Learning Platform (e.g., “Hippotlian CE Platform”). Learners were able to take a post-test assessment, obtain a certificate of completion as a CE-approved “contact hour”, providing a real incentive in adding the course to the learner’s portfolio of CE learning. Collaborating with the DPH Asthma Prevention and Control Program on educational content about climate change for specialized trainings tailored to the needs of direct care Community Health Workers. Activities include drafting training storyboards, preparing provider and patient materials, and conducting a survey of CHWs to better evaluate climate and health training needs. Educational content and training are scheduled to be deployed on MassAchieve training platform by the end of FY 23. DPH is also evaluating options for selecting a learning management system (LMS) platform to deploy climate change trainings for clinicians that offer continuing education (CE) credits to incentivize participation. Created a climate and health equity resource page on Mass.gov: https://www.mass.gov/info-details/learn-about-climate-change-and-health-equity.	
DPH: Strengthen DPH health care systems and services to prepare for climate impacts.	Include direct health care services and licensing of healthcare facilities and professionals. Train health care professionals on responding to climate impacts. Incorporate plans to address anticipated increases in patient and client volumes, changing health demands, and delivery of critical life-saving support during climate events.	Technical support and assistance	In Progress	Executive Office of Health and Human Services	Department of Public Health (DPH)				DPH is continuing to identify the climate-focused education needs of health care providers and has developed specific training materials to educate clinicians on the health impacts of climate change. An ongoing program of trainings and exercises for hospital preparedness in extreme weather can be found online here: (https://www.mass.gov/files/documents/2018/04/11/hpp-phep-training-and-plan.pdf) A list of DPH emergency preparedness and training resources is also available online here: (https://www.mass.gov/emergency-preparedness-exercises-and-training/need-to-know)	Responded to requests from DPH bureaus and programs for review of climate content and resources for assessment of climate and health impacts. Developing educational content for environmental health education for clinical providers, community health workers and public health professionals. Educational content and related materials focus on the critical role of social determinants of health and environmental justice in climate-related and environmental health impacts. Key features include reframing health outcomes in the context of environmental justice, exposure to environmental stressors, and root causes of health impacts, along with potential adaptation actions within control of patients and available community supports. Collaborating with academic nursing program at UMass Boston, MPH program at UMass Medical Center in Worcester, and with physicians at Boston Children’s Hospital to develop trainings for clinicians on climate and health.	

DPH: Update and expand DPH and DPH provider/vendor Emergency Operations Plans (EOPs) and Continuity of Operations Plans (COOPs) to address climate impacts.	Include all-hazards regional trainings for providers/vendors. These trainings cover, at a minimum, substance use, prevention, and treatment services including naloxone management; building communications redundancies for crisis intervention services; and health access, promotion, and prevention services for long-term resiliency.	Technical support and assistance	In Progress	Executive Office of Health and Human Services	Department of Public Health (DPH)				DPH has developed an ongoing program of trainings and exercises for hospital preparedness in extreme weather that can be found online here: https://www.mass.gov/files/documents/2018/04/11/hpp-phep-training-and-plan.pdf A list of DPH emergency preparedness and training resources is also available online here: (https://www.mass.gov/emergency-preparedness-exercises-and-training/need-to-know)	Developed and maintained Continuity of Operations Plans for DPH through the Office of Preparedness and Emergency Management. Updated and reviewed the DPH Infectious Disease Emergency Response plan (IDER), which details how DPH will approach the specific hazard of infectious disease outbreaks which are expected to become more prevalent as the climate changes. Lead Emergency Support Function 8 Health and Human Services (ESF-8) through the Office of Preparedness and Emergency Management (OPEM), who coordinates agencies for any disaster response requiring ESF-8. OPEM has collaborated with MEMA for preparedness planning during the COVID-19 outbreak and expanded plans on how to deal with natural hazards such as hurricanes and storms in an infectious disease outbreak. OPEM has been evaluating the effectiveness of plans during COVID and identifying opportunities to include CDC BRACE principles to build climate and health resilience. Developed, through OPEM, plans to deal with surge capacity planning at hospitals when an event creates a large influx of patients. As the COVID-19 outbreak demonstrated, hospitals can often be stretched beyond their capacity even in a resource rich state such as Massachusetts. Climate Change is anticipated to bring about more and stronger hazards so it is important to have planning conducted on how our medical system and state government will approach these hazards. Partnered, through OPEM, with Delvalle Institute Learning Center to provide free trainings on a variety of topics including those related to climate change. It is critical that staff and volunteers are trained prior to an event. https://delvalle.bphc.org/ Incorporating climate change and health issues into training exercises planned by OPEM through coordination with training and exercise administrators. Strengthened regulations regarding emergency and continuity of operations planning by the Bureau of Substance Addition Services (BSAS) requiring programs to bolster their emergency and all hazards plans to include preparing for and responding to all types of emergencies including natural disasters and currently identified threats such as cyber-attacks. Also, through the new regulations BSAS has implemented a new Central Registry System within the Opioid Treatment Program, including a disaster planning and response module which ensures continuity of treatment and immediate communication to patients and staff.	
MOTT: Research and assess and potential effects of climate change on Commonwealth travel and tourism industry and assets.	Research and assess and potential effects of climate change on Commonwealth travel and tourism industry and assets.	Assessment, research, analysis, science, and mapping	Complete	Executive Office of Housing and Economic Development	Massachusetts Office of Travel and Tourism (MOTT)	Statewide			MOTT will engage DCR to discuss opportunities for collaboration in the assessment of climate-change risks and vulnerabilities related to DCR assets. Additionally, MOTT will work with EOHED's Climate Change Coordinator and the Resilient Massachusetts Action Team (RMAT) to investigate funding opportunities for the research and classification of the state's tourism assets. Once the scope of assets is established, further research can be done to assess their vulnerabilities and identify priority actions for their protection and adaptation.	At HED's request, tourism was incorporated into the MA Climate Change Assessment within the Economy Sector. A full impact report was prepared for "Damage[s] to Tourists Attractions and Recreation Amenities." The impact ranked #4 (tie) in the Economy Sector state-wide, and ranked in the top two Most Urgent Impacts for the Economy Sector for the Berkshires and Hilltowns Region.	A successor action is included with HED's 2023 Proposed Actions. See action title, "Incorporate climate resilience criteria into capital grant programs for local tourism assets."
DHCD: Facilitate and coordinate development of guidelines and best practices for climate change adaptation and resilience for state-aided housing development.	Facilitate and coordinate development of guidelines and best practices for climate change adaptation and resilience for state-funded housing development, including state-aided public housing and affordable housing funded by quasi-public agencies.	Planning and policy	In Progress	Executive Office of Housing and Economic Development	Department of Housing and Community Development (DHCD)	Statewide			DHCD's Division of Housing Development has incorporated climate-change adaption and resilience criteria into the Commonwealth's 2020-21 Low-Income Housing Tax Credit Qualified Allocation Plan (LIHTC QAP). These criteria will take effect in the Winter Rental Projects Round and Mini-Competition Round. DHCD's Division of Public Housing has completed its CHARM study (Climate Hazard Adaptation and Resilience Masterplan) to support state public housing developments. Project outcomes include, but are not limited to: a ranking of state public housing developments based on climate-change exposure and vulnerabilities; a series of design tools to assist local housing authorities in the design of local hazard-mitigation capital projects; and in-depth climate resiliency assessments of nine priority public housing developments identified through risk-and-vulnerability analysis. The Division of Public Housing is also in the process of incorporating climate-resilience planning into its capital planning process. This was a recommendation of the CHARM study.	Findings from the CHARM study are now embedded into the Design Guidelines and Standards which inform all projects at state-aided public housing developments. This means that everyday, routine projects are now designed to more resilient standards than in the past. Additionally, DHCD provided funding for multiple resiliency-focused projects at highly at-risk developments which will quickly make the developments more resilient to a variety of climate hazards.	
EOHED: Incorporate climate change resilience/adaptation standards into grant programs including MassWorks.	Incorporate climate change resilience and adaptation criteria into major grant programs to enhance vulnerability of resulting assets to climate hazards and risks, to increase the resilience of the MA economy to climate risks, and to assist local governments in making local infrastructure more resilient. EOHED will begin with MassWorks program and use results to model best practices for other programs.	Planning and policy	In Progress	Executive Office of Housing and Economic Development	Executive Office of Housing and Economic Development (EOHED)	Statewide			EOHED's Community Planning and Resources Office (CPRO) anticipates the release of a new Resilient Capital Planning Evaluation Tool, which will be integrated into the applications of up to six capital grant programs beginning in FY21-22. In the interim, new temporary climate-resilience questions and criteria were incorporated into the 2020 Grant Round of the MassWorks Infrastructure Program. These questions and criteria were developed in consultation with EEA, MEMA, and ANF.	The MassWorks Infrastructure Program requires submission of a climate standards report with any project proposal. Reports must be obtained through the Commonwealth's Climate Resilience Design Standards Tool. Additionally, climate resilience questions and criteria have been incorporated into MassWorks applications and project evaluation forms. HED also assisted EEA with development of a project evaluator guide to support integration of climate standards reports into programs or regulatory reviews. MassWorks staff anticipate incorporating components of this guide in their evaluation forms in the next grant round.	An expansion of this action is included with HED's 2023 Proposed Actions. See action title, "Incorporate climate resilience criteria into Community One Stop for Growth capital grant programs."
OPSI: Review the state building code to assess feasibility of incorporating hazard mitigation and resilience.	Review the state building code to assess feasibility of incorporating hazard mitigation and resilience into standards.	Regulations, codes, and zoning	In Progress	Executive Office of Housing and Economic Development	Office of Public Safety and Inspections (OPSI)				In partnership with EEA, DCR, and MEMA, the Massachusetts Office of Public Safety and Inspections (OPSI) will investigate federal funding opportunities to not only assess the need for higher standards in or outside of the state building code to mitigate current and future flood loss, but also identify options and actionable steps to achieve such standards, either through potential amendments to the state building code or through local actions that will not conflict with the statewide code.	HED has received a FEMA BRIC grant in the amount of $98,250 for a climate-resilience assessment of floodplain standards in the MA State Building Code (MSBC), as well as development of a Local Floodplain Management Action Guide to assist municipalities in building local resilience to climate risks. The project is anticipated to kick off in March 2023, and is a collaborative effort between HED, EEA, and DCR. In addition to federal BRIC grant funds, the project is supported by a $42,000 grant in SHMCAP Implementation Funds awarded by EEA.	A successor action is included with HED's 2023 Proposed Actions. See action title, "Develop a local-option floodplain building stretch code." For this proposed action, EEA should be the Exec Office and Lead Agency, with "HED" (rather than "OPSI") acting as a partner agency. EEA would lead development of the code, with HED participation, as was done with the most recent revision of the MA energy stretch code
MPRO: Review Chapter 40A and existing regulatory framework to evaluate incorporation of feasibility and practicality of climate change hazard mitigation measures.	Review Chapter 40A + Subdivision control law and regulatory framework, including standards and possible mitigation measures such as street widths (less impervious surfaces), low impact development, and natural storm water sinks/systems.	Planning and policy	Not Started	Executive Office of Housing and Economic Development	Massachusetts Permit Regulatory Office (MPRO)				On behalf of the Massachusetts Permit Regulatory Office (MPRO), EOHED's Community Planning and Resources Office (CPRO) will engage the Department of Housing and Community Development (DHCD) to investigate the appropriate scope of work for reviewing the Commonwealth's Zoning Act and Subdivision Control Law.	No progress to date. Under MGL Chapter 40A, all zoning is local, with each municipality adopting its own unique zoning bylaws, subject to few limitations. However, potential exists to integrate climate resilient land use strategies into HED's Local Floodplain Management Action Guide, which is currently under development.	MPRO is a "paper office" and should be removed as an agency from future SHMCAP editions. Actions related to 40A should be discussed with DCHD, as they are responsible for development of the Commonwealth's zoning and land-use informational resources. Additionally, it should be noted that the Metropolitan Area Planning Council (MAPC) has compiled a Climate Resilient Land Use Strategies toolkit, which is designed to assist municipalities in using their regulatory authority to address climate risks: https://www.mapc.org/resource-library/climate-resilient-land-use-strategies/.
OPSI: Voluntary resilience audits for private property.	Program with voluntary (or incentivized) resilience audits that consider private property is exposure to hazards (natural and climate change) and make mitigation/adaptation recommendations.	Outreach and education	Not Started	Executive Office of Housing and Economic Development	Office of Public Safety and Inspections (OPSI)				OSPI will work with EOHED's Climate Change Coordinator to investigate local and/or private partnership opportunities for the planning and/or development of a resilience audit program for existing buildings.	No progress to date	HED found an equivalent initiative in the City of Boston's climate adaptation plan, "Climate Ready Boston." Initiative 10.1 proposes to "establish a resilience audit program for property owners." HED hoped to inquire whether the City had interest in collaborating; but progress towards another SHMCAP action item was prioritized (see action title "OPSI: Review the state building code"). Additionally, the status of this initiative with the City of Boson is given as "Not Started," based on the City's online CFB Progress Tool. This type of initiative is best piloted at the municipal level first. Its nearest equivalent at the state level is the MassSaves energy audit program(s). However, the MassSave model is not transferrable to climate resilience audits.
DLS: Review and consider updates to MASSsafetyWorks! resources given increased expectations of extreme weather events.	Review informational safety flyers for employers and employees to evaluate whether they should be updated in light of expectations of increased severity and frequency of extreme weather events.	Outreach and education	Complete	Executive Office of Labor	Department of Labor Standards (DLS)				This action has been completed.	Completed no update	
EOPSS: Create a statewide Threat and Hazard Identification and Risk Assessment (THIRA). In conjunction with the development of the THIRA conduct a statewide capabilities gap assessment.	Create a statewide Threat and Hazard Identification and Risk Assessment (THIRA) as well as a statewide capabilities gap assessment. EOPSS will integrate the Commonwealth's THIRA with the Risk Assessment, to the maximum extent practicable.	Assessment, research, analy:	Complete	Executive Office of Public Safety and Security	Executive Office of Public Safety and Security (EOPSS)	Statewide			THIRA plan has been submitted to FEMA as requested by 12.31.19.	THIRA was updated and submitted to FEMA 12.31.22.	Because this is ongoing work, should it be moved to the capabiltiies section?
EOPSS: Incorporate climate change resilience into business continuity planning for state government.	Work with ANF and EOTSS to update business continuity planning and to incorporate climate change hazards into plans and procedures across state government. This action has cross-cutting impact on risk reduction across the administration.	Planning and policy	Complete	Executive Office of Public Safety and Security	Executive Office of Public Safety and Security (EOPSS)	Statewide			EOPSS & MEMA have developed a framework for stakeholder engagement and a COOP template and COOP planning guidance to assist Executive Branch agencies with developing COOP. The COOP template and planning guidance includes considerations for climate change in both considerations for alternate locations and assessing and understanding risks and hazards. A priority for 2021 will be launching the COOP training program and providing additional technical assistance.	This action has been completed. The COOP planning guidance and documents including the template developed during this project are located https://www.mass.gov/info-details/continuity-and-safety-planning-guidance. These guidance and documents are for state agencies to develop a COOP and then submit a final electronic copy to MEMA in accordance with EO #490.	
MEMA: Develop Disaster Survivor Assistance Plans.	Develop and formalize plans, processes, and procedures for the direct and indirect delivery of services to citizens affected by man-made and natural disasters in the Commonwealth. To develop these, MEMA will convene one or more project management teams comprised of various local, state, and federal agencies, not-for-profit organization, and private sector partners.	Planning and policy	Complete	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)	Statewide			MEMA developed a Resource Recovery Center Plan and a Donations Management Plan which are in final draft form waiting for final approval. Once approved, the plans will be socialized amongst partners identified in the plan.	MEMA completed a Survivor and Family Assistance Plan which is located on mass.gov. The plan focuses on identifying resources and capabilities of local, regional, state, federal, non-governmental agencies, and private non-profit organizations, and on developing and setting forth a framework and organizational structure for the coordination of resources and capabilities in order to assist impacted communities in providing survivor and family assistance following a mass casualty or mass fatality incident.	
MEMA: Improved Local Comprehensive Emergency Management Plan (CEMP) Program.	Roll out and train local officials on the improved CEMP Program; CEMP Template, online document storage, and a mapping tool. The new mapping tool which will ingest the data from local communities using ArcGIS Online. This gives communities the ability to map critical infrastructure, hazardous facilities and routes, and points of interest, and provides a wider range of customization and mapping capabilities.	Technical support and assist	Complete	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)	Statewide			This project has been fully implemented. Several CEMP Program Trainings were conducted in each MEMA Region over the last year, and the CEMP Template is on our website, here: https://www.mass.gov/lists/local-emergency-management-planning-guidance.	This project has been fully implemented. Several CEMP Program Trainings were conducted in each MEMA Region over the last year, and the CEMP Template is on our website, here: https://www.mass.gov/lists/local-emergency-management-planning-guidance.	
MEMA: Encourage state granting agencies in the Commonwealth, such as the Massachusetts Department of Housing and Community Development's review of Community Development Block Grants, to work together with MEMA to assist in providing the Non-federal cost share in Disaster Recovery and Hazard Mitigation Grants to maximize the federal funding available to the Commonwealth and its communities.	Encourage state granting agencies in the Commonwealth, such as the Massachusetts Department of Housing and Community Development's review of Community Development Block Grants, to work together with MEMA to assist in providing the Non-federal cost share in Disaster Recovery and Hazard Mitigation Grants to maximize the federal funding available to the Commonwealth and its communities.	Funding and financing	In Development	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)				Through outreach and partnership MEMA continues to develop strong partnerships with state granting agencies to maximize the leveraging of federal funds in conjunction with other state and federal grant programs. To advance this ongoing effort MEMA continues to work with the Massachusetts MVP program to leverage state funds for FEMA funded local Hazard Mitigation Plans and other resilience actions. To leverage non-federal cost share and to also ensure mitigation is integrated across relevant programs MEMA will also continue to make outreach to the MA Department of Housing and Community Development regarding the following programs: Community Development Block Grant (CDBG), CDBG-DR, MassWorks and the Economic Opportunity Zone program.	MEMA continues to build cross agency partnerships to ensure maximum funding leverage. MEMA will coordinate with the new Office of Climate Change and Innovation to integrate federal funds with available state funds.	This is something that should move forward into the 2023 strategy

MEMA: Prepare hazard mitigation best practices and case studies.	Prepare hazard mitigation best practices and case studies.	Outreach and education	In Progress	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)				Best practices are being shared on a regular basis with public officials. Most notably during multijurisdictional post disaster grant briefings, of which there were 10 over the last year. Best practices are also provided during individual technical assistance visits with local officials and have also been featured in MEMA Reports. The MEMA Mitigation Unit is working with the MEMA PIO to create a Mitigation Monday social media campaign that will also feature best practices.	Best practices are being shared on a regular basis with public officials. Most notably during multijurisdictional post disaster grant briefings, of which there were 2 since Fall 2020. Best practices are also provided during individual technical assistance visits with local officials and have also been featured in MEMA Reports. The MEMA Mitigation Unit in conjunction with the MEMA PIO manage a Mitigation Monday social media campaign that also features best practices.	This is a capability as part of our normal day to day mission
MEMA: Update the State Hazard Mitigation and Climate Adaptation Plan and submit for FEMA review and approval every 5 years.	Update the State Hazard Mitigation and Climate Adaptation Plan and submit for FEMA review and approval every 5 years as part of the Commonwealth's commitment to the mitigation program.	Planning and policy	In Progress	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)				The first annual update of the Action Tracker has been completed and is scheduled to be available on www.resilientma.org by the end of 2018. The first Resilience Massachusetts Action Team (RMAT) quarterly meeting was held in October 2018.	Since Fall 2020 the RMAT has met quarterly. The RMAT kicked off the first 5-year updat of the SHMCAP in winter 2021. The first final draft is scheduled to be submitted to FEMA for review and approval. The SHMCAP expires September 17, 2023.	To be continued as a 2023 action which addresses impacts/vulnerabilities
MEMA: Apply for available federal HMA funding to implement and update the completed and approved multi-jurisdictional and local hazard mitigation plans.	Apply for available federal HMA funding to implement and update the completed and approved multi-jurisdictional and local hazard mitigation plans.	Funding and financing	In Progress	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)	Statewide			MEMA is dedicated to seeking FEMA funding to assist communities to update existing or develop new local hazard mitigation plans. There are 49 local hazard mitigation plans in development at this time. Â Additionally, there are 22 local hazard mitigation plans slated to begin in the next 6 months.	During normal daily operations MEMA's Hazard Mitigation Unit seeks funding for local hazard mitigation planning efforts. Since 2020 129 local hazard mitigation plans have received FEMA final approval. Currently 94 plans are being updated with FEMA HMA funding.	Because this is something we do with each grant cycle, shouldn't this be considered a capability?
MEMA: Enhance the effectiveness of 406 funding by working to further integrate mitigation into the FEMA Public Assistance Program.	Identify areas where 406 funding can be leveraged to maximize disaster recovery funding to build back better and more resilient infrastructure. This includes working on an interagency recovery group after a disaster to maximize efficiencies and reduce duplication for communities.	Funding and financing	In Progress	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)	Statewide			FEMA Hazard Mitigation 406 Public Assistance Program funding is available in conjunction with the repair of disaster-damaged facilities. Therefore, is limited to declared counties and eligible damaged facilities as the result of a presidentially declared disaster. The MEMA Recovery Unit works very closely with a FEMA Joint Field Office to ensure 406 mitigation is considered on all eligible projects. Of the two federally declared open disasters (DR-4372 and DR-4379) a total of 21 projects had mitigation measures incorporated totaling over $5.3 Million.	During normal post disaster recovery operations MEMA's Disaster Recovery Unit promotes the 406 Public Assistance Program when feasible.	This should be moved to the capabilities
MEMA: Partner with stakeholders in Massachusetts to develop and implement regional and local multi-hazard mitigation plans by providing training and technical assistance.	Work with local officials and regional planning agencies to provide technical assistance and funding for local hazard mitigation plans.	Technical support and assist	In Progress	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)	Statewide			MEMA's Mitigation Unit, the Department of Conservation and Recreation's Floodplain Management Office (DCR) and the Energy and Environmental Affairs Office of Climate Adaptation and Resilience (EEA) staff provided local communities with varying types of hazard mitigation planning technical assistance and trainings throughout the past year. For example, MEMA provided 71 communities receiving FEMA mitigation planning grants with mitigation planning overviews; DCR provided assistance to over 55 communities; and the EEA Municipal Vulnerability Program (MVP) staff and certified providers work with communities to incorporate FEMA local hazard mitigation planning elements into their MVP plan. In addition, MEMA has scheduled a FEMA Mitigation Planning G-318 workshop Nov 18, 2019, at the Pioneer Valley Planning Commission. There will be approximately 30 local officials in attendance.	MEMA continues to utilize a vendor to assist local communities with providing technical assistance with developing FEMA HMA applications.	MEMA's Hazard Mitigation Unit incorporates this work as part of their normal operations. Should this just be moved to the capabilities section?
MEMA: Perform a statewide risk analysis for all hazards to include in future updates to the SHMCAP and other related plans.	Address data deficiencies and improve analysis, when available, by partnering with federal, state, local, and other subject matter experts to inform future hazard mitigation plan updates.	Assessment, research, analy	In Progress	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)	Statewide			The next SHMCAP update process is scheduled to begin in 2021. The update will be designed to use data gathered during local MVP planning processes and key state and regional agency assessments.	The 2023 SHMCAP update is underway. The final draft will be delivered to FEMA in June 2023 and finalized by September 17, 2023.	
MEMA: Plan and host hazard mitigation grant workshops for state agencies and local governments after natural disasters, especially immediately following Presidential Disaster Declarations.	Conduct multiple grant briefings following declared disasters and upon release of PDM / FMA Notice of Funding Opportunities. In addition to the in-person briefings, MEMA will host webinars to provide increased opportunities for participation and speak at municipal meetings on the importance of mitigation.	Funding and financing	In Progress	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)	Statewide			Since August 2018 MEMA has held 10 multijurisdictional post disaster grant briefings across the Commonwealth with more than 200 public officials in attendance. In addition MEMA has conducted numerous individual technical assistance visits with local officials.	Since Fall 2020 MEMA held multijurisdictional post disaster grant briefings for the Covid disaster declaration and FY22 BRIC and HMA programs with more than 150 public officials in attendance. These briefings were recorded and posted on the mass.gov website. In addition MEMA provided hundreds of individual technical assistance with local officials in the form of email, phone calls, and Teams meetings.	This is a capability as part of our normal day to day mission
MEMA: Work with communities to implement cost-effective, environmentally sound, and feasible mitigation projects to severe repetitive loss properties. MEMA: In cooridnation with DCR Floodplain Management Office, establilsh a formal outreach strategy for acquisition and elevation projects throughout the State.	Advance funding for all eligible project types that reduce risk with a particular focus on nature based solutions. In addition, MEMA's Flood Hazard Management Program will continue to assist in focusing on mitigation or SRL and RL Structures through direct property mitigation or community flood risk reduction projects. MEMA in cooridnation with the DCR Floodplain Management Office, study the feasibility of establilshing a statewide formal outreach strategy for acquisition and elevation program.	Funding and financing	Modified or Deferred	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)				MEMA has been coordinating with massFM to investigate best practices on outreach for elevation and acquisition projects. Currently a small group is exploring the feasibility of developing a guidebook.	The focus of this project is being shifted to study the feasibility of establishing a formal outreach strategy for acquisitions and elevation program.	This would easily transfer to the 2023 list as it potentially addresses the following impacts: - Damage to Cultural Resources - Damage to Inland Buildings - Damage to coastal state and municipal buildings and land Damage to inland state and muni....
MEMA: Build out a mechanism to incorporate new data and recommendations from FEMA-approved regional and local mitigation plans into the SHMCAP, ArcGIS online and/or Climate Clearinghouse MEMA: Create a tool to enable the incorporation of new data and recommendations from FEMA-approved regional and local mitigation plans into the SHMCAP, ArcGIS online and/or Climate Clearinghouse.	Focus on locations of critical facilities and assessments of vulnerability and estimates of potential losses by jurisdiction. The intent of this tool will be to provide stakeholders the ability to obtain a statewide structure level risk analysis. Outputs will also provide a risk outlook and monetary damage assessment associated with the regulatory flood and projected future climate scenarios. In order to assist communities to develop FEMA BCA's for project development.	Assessment, research, analy	Modified or Deferred	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)	Statewide			Discussions continue to identify the best way to gather and provide information on local vulnerability. Developing tools on www.resilientma.org is one option that is being explored at this time.	MEMA in conjunction with a vendor are in the preliminary design phase. This is expected to be an ongoing project as new datasets become available with a tentative completion date of 2023.	See revisions to this action in red. This would be an action that helps local communities conduct more robust risk and damage assessments to help with their risk reducing planning efforts.
MEMA: Create an Earthquake Risk Reduction Program.	Develop a multi-jurisdictional/multi-disciplinary working group that will be convened and led by a facilitator hired by the Commonwealth utilizing NEHRP Direct State Assistance funding. Working group members will represent a wide variety of disciplines, levels of government, and sectors. The primary goals of this diverse group will be to establish a robust earthquake mitigation program for the Commonwealth that will develop and implement strategies to increase earthquake awareness, preparedness and education, and mitigate earthquake-related risks.	Planning and policy	Modified or Deferred	Executive Office of Public Safety and Security	Massachusetts Emergency Management Agency (MEMA)	Statewide			A multi-jurisdictional/multi-disciplinary working group was convened to begin the development of a earthquake mitigation program for the Commonwealth. A series of facilitated workshops have been conducted which resulted in recommended actions the Commonwealth can take to establish such a program. The next step is for the working group to reconvene to discuss and agree upon the most appropriate strategy to implement.	Due to the pandemic, forward movement on the actions were delayed. MEMA will reconvene the working group to discuss next steps.	
EOTSS: Migrate HRCMS/MMARS to the cloud.	Migrate the EOTSS Human Resources Compensation Management System and Massachusetts Management Accounting and Reporting System to the cloud, removing the need to maintain and protect on premise servers for these systems.	Changes to maintenance and operations, replacements	Complete	Executive Office of Technology Services and Security	Executive Office of Technology Services and Security (EOTSS)				With migration of the the Human Resources Compensation Management System (HRCMS) and the Massachusetts Management Accounting and Reporting System (MMARS) to the cloud completed in July of 2019 and September of 2019 respectively, the on premises physical servers in Chelsea and Springfield have been decommissioned - further reducing the Commonwealth's on premises hardware footprint.	Completed no update	
EOTSS: For Registry of Motor Vehicle systems that must remain on-premises (not cloud), evaluate migration options or relocations to third party on premises.	Work with Registry to evaluate and plan relocating servers to a 3rd party location.	Assessment, research, analysis, science, and mapping	In Progress	Executive Office of Technology Services and Security	Executive Office of Technology Services and Security (EOTSS)				EOTSS is working with DOT on their 3-year plan to improve network resiliency, shift certain applications to SaaS, and migrate priority enterprise applications to the cloud.	This remains in progress. MassDOT has additional critical equipment remaining at the MITC (Chelsea data center) and are currently in the middle of a project with a vendor to migrate data and information to the cloud.	
EOTSS: Migrate CommVault to the cloud.	Migrate CommVault system to the cloud, removing the need to maintain and protect on premise servers for this system.	Changes to maintenance and operations, replacements	Complete	Executive Office of Technology Services and Security	Executive Office of Technology Services and Security (EOTSS)				EOTSS continues to collaborate with Microsoft Professional Services to complete migrations by the end of Calendar Year 2021 as part of the Modern Workplace Program.	Completed no update	
EOTSS: Re-platform MA21 and MMIS to enable cloud migration.	Re-platform the Executive Office of Health and Human Services' critical systems MMIS (Medicaid Management Information System) and MA21 (MassHealth's eligibility system). This will facilitate their future migration to the cloud, removing the need to maintain and protect on premise servers for these systems.	Changes to maintenance and operations, replacements	Complete	Executive Office of Technology Services and Security	Executive Office of Technology Services and Security (EOTSS)				MA21 has been migrated to a significantly smaller mainframe, and re-platforming planning continues. For MMIS, EOTSS is actively collaborating with EOHHS to upgrade much of the front-end on premises applications and servers in preparation for migrations.	Completed no update	
EOTSS: Migrate Beacon, Meditech and FamilyNet to the cloud.	Migrate critical systems for the Department of Transitional Assistance (Beacon) and the EOHHS (Meditech and FamilyNet) to the cloud, removing the need to maintain and protect on premise servers for these systems.	Changes to maintenance and operations, replacements	Complete	Executive Office of Technology Services and Security	Executive Office of Technology Services and Security (EOTSS)				Approximately six Beacon-related applications have been successfully migrated to the cloud and on premises hardware has been decommissioned. EOTSS remains engaged with EOHHS to plan and collaborate on the remaining Beacon migrations. For Meditech, DDS is in the vendor selection phase of the procurement process. And, DCF is actively testing the FamilyNet proof-of-concept environment.	Completed no update	
EOTSS: Migrate critical operational systems to the cloud; move critical communications infrastructure to 3rd party provider - off site from MITC	Migrate Commonwealth servers to cloud hosting to the fullest extent possible (handful of exceptions.) Move critical communications infrastructure to 3rd party location (secure, local location). These migrations away from on premise hosting to cloud hosting reduce the risk of disruption due to sea level rise and extreme weather events.	Changes to maintenance and operations, replacements	Complete	Executive Office of Technology Services and Security	Executive Office of Technology Services and Security (EOTSS)				Cloud migrations remain underway in 2020 and the procurement process for core network modernization is moving forward.	Completed no update	
EOTSS: Migrate email to the cloud.	Migrate legacy Microsoft Exchange systems to cloud-based Office 365 services.	Changes to maintenance and operations, replacements	Complete	Executive Office of Technology Services and Security	Executive Office of Technology Services and Security (EOTSS)				Mail migration to the cloud has been completed for the following secretariats: Executive Office of Technology Services and Security, Executive Office of Education, Executive Office of Housing and Economic Development, Executive Office of Public Safety and Security, and the Department of Transportation. EOTSS is working to complete this initiative with the remaining secretariats prior to June 30, 2021.	Completed no update	
MassDOT: Pilot Deerfield Watershed Stream Crossing Resilience Project.	Produce GIS layers and a web viewer ranking the vulnerability of culverts and wildlife to climate change. The final report will document the methods used in the project. Next steps will include an evaluation of how to transfer the methods to the remaining watersheds in Massachusetts.	Assessment, research, analysis, science, and mapping	Complete	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				Project complete and is being used as an example assessing the vulnerability of culverts and prioritizing culvert replacement.	Completed no update	
MassDOT: Assess the feasibility of recommendations from the Commission on the Future of Transportation in the Commonwealth.	Assess the feasibility of recommendations from the Commission on the Future of Transportation in the Commonwealth.	Assessment, research, analysis, science, and mapping	In Progress	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				MassDOT's actions in the SHMCAP continue to support many of the Commission's recommendations and near term actions.	MassDOT is pursuing many of the Commission's recommendations including but not limited to: The Transportation Asset Management Plan which allocates 90% of Highway Division spending toward reliability and modernization investments; the Bicycle and Pedestrian Transportation Plans which aim to increase the percentage of everyday trips made by biking and walking; the Electric Vehicle Infrastructure Deployment Plan providing 5 years of funding to deploy fast charging along major highway corridors; numerous assessments and projects - described in the SHMCAP - to address transportation system resilience. Other parts of state government have addressed recommendations including a 2021 state law requiring multi-family zoning as-of-right in MBTA communities.	
MassDOT: Capture and document institutional knowledge on vulnerabilities from staff using the Mapping Our Vulnerable Infrastructure Tool (MOVIT).	Utilize the MOVIT tool to provide and store vulnerable asset data for project review and prioritization.	Assessment, research, analysis, science, and mapping	In Progress	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				MassDOT continues this ongoing effort to update previously collected information and to collect new information, particularly on Highway Division assets affected by precipitation, riverine, and coastal flooding. The information collected in the Mapping Our Vulnerable Infrastructure Tool (MOVIT) is located in GeoDOT and is ready to use.	MassDOT continues this ongoing effort to update previously collected information and to collect new information, which is accessible through GeoDOT.	
MassDOT: Develop climate change adaptation design guidance and provide resources and training for project managers and design teams on bridge and culvert design interaction with emerging fluvial geomorphology practices.	Develop a fluvial geomorphology based "Rivers & Roads" training program that will be initially offered to staff, including environmental analysts, project managers, bridge and hydraulic engineers, and construction and maintenance personnel. The training will eventually be offered to local government and the private consulting and construction sectors. The program will include three tiers that will increase in complexity.	Technical support and assistance	Complete	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				MassDOT's fluvial geomorphology based Rivers & Roads Training Program will help project managers and design teams better utilize emerging fluvial geomorphology practices to account for bridge and culvert design interaction. River and Roads training is underway with approximately 20 sessions completed. A more robust online training program is being developed.	The Massachusetts Rivers & Roads Training is now being offered by MassDOT Highway Division. The training is broken into three tiers. Tier 1 is an online overview of the fundamentals of fluvial geomorphology. Tier 2 is a classroom and field training that will advance the understanding of fluvial geomorphology and explore limiting river and road conflicts. Tier 3 is subject material details to support design review and implementation.	

MassDOT: Establish training to incorporate climate change awareness into project design, operations, and maintenance functions.	Establish MassDOT staff training to incorporate climate resiliency awareness into project design, operations, and maintenance functions. Training and activities will encourage better understanding of tools available to address climate resilient design and vulnerability, as well as assessment of current state and federal regulation impacts, policy, standard operating procedures, and design guides.	Technical support and assistance	In Progress	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				Training to staff is continuing and occurring on a project-by-project basis. More training will be developed in 2020/2021 using the Bay State Road program.	Training to staff is continuing and occurring on a project-by-project basis. More training was deployed in 2020/2021 using the Bay State Road program.	
MassDOT: Expand and improve the Boston Harbor Flood Risk Model to create the Massachusetts Coastal Flood Risk Model.	Expand the Boston Harbor Flood risk Model (BH-FRM) statewide (Massachusetts Coast Flood Risk Model) to create improved sea level rise and storm surge scenarios for the present tidal epoch, 2030, 2050, 2070, and 2100 time horizons; create northern and southern model grids; consider future shoreline changes; correct CZM/MassGIS shoreline mapping; assess the storm surge vulnerability of the coastal transportation network; and make data available to state agencies, coastal communities, and other interested stakeholders.	Assessment, research, analysis, science, and mapping	In Progress	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				This Action has been extended into 2020 due to computing challenges and extensive quality control/quality assurance reviews of the model output. To date, almost all coastal communities have been completed. A training program will be developed now in 2020/2021.	The model has been expanded to include all coastal communities. Certain model outputs have been incorporated into the publicly available RMAT Resilience Design Standards Tool and Resilient MA Map Viewer. A training program is planned for 2023.	
MassDOT: Incorporate climate change adaptation into the MassDOT Highway Division Transportation Asset Management Plan and coordinate Asset Management across divisions and partner agencies.	Conduct an asset management pilot project on the vulnerability of culvert and bridge assets. This information will be stored in MAPIT and will give an alert to proponent to coordinate with Hydraulics, Bridge, and Environmental departments.	Assessment, research, analysis, science, and mapping	In Progress	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				The MassDOT Project Intake Tool (MaPIT) application with climate change data will now be made available in the fall/winter 2020.	MassDOT completed a stream and river crossing vulnerability assessment including 1,100 department-owned culverts and 2,700 bridges. This information will be used to drive inspection and replacement efforts going forward.	
MassDOT: Incorporate climate resiliency into capital planning activities.	MassDOT is coordinating an effort to better account for climate resiliency in its overarching capital planning program and in project-level decision-making.	Capital planning	Complete	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				The MassDOT Capital Planning Program (CIP) estimates the percentage of projects in each of the CIP investment programs addressing climate change and resiliency.	Climate resilience questions are part of early project development through ProjectInfo, and climate resilience is one of the scoring criteria in the annual statewide transportation improvement program (STIP) process.	
MassDOT: Incorporate resiliency review items into the Early Environmental Coordination Checklist.	Revise the Environmental Early Coordination Checklist to include resiliency review items.	Planning and policy	In Progress	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				The Early Environmental Coordination Checklist (EECC) will be issued for use in Fall/Winter 2020.	MassDOT is currently continuing its update of the Project Development and Design Guide (PDDG), which will incorporate climate resiliency. The work to-date has involved determining the most appropriate back-end content management systems to host the PDDG, and coordinating with other ongoing design guidance development efforts. Additional updates currently underway for winter 2024.	
MassDOT: Incremental Development of Resiliency-Oriented Design Guidelines.	Work towards incrementally updating design standards across all Divisions for projects including roads, bridges, tunnels, and support facilities using the Massachusetts climate change projections.	Planning and policy	In Progress	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				MassDOT is currently continuing its update of the Project Development and Design Guide (PDDG), which will incorporate climate resiliency. The work to-date has involved determining the most appropriate back-end content management systems to host the PDDG, and coordinating with other ongoing design guidance development efforts.	This assessment continues. The finished project is expected in the first half of 2023. For assets identified as vulnerable, it will include estimates of damage and and repair costs, time estimates for repairs and considerations for the consequences from loss of service through 2070. The finished project will be incorporated into GeoDOT.	
MassDOT: State-wide Transportation Asset Vulnerability Assessment.	The study aims to provide a better understanding of which MassDOT's assets (infrastructure) are most likely to be at risk due to future inland flooding by utilizing the latest climate model results, suitable hydrologic and hydraulic tools, geospatial analysis and scenario planning methods. The study has delivered a prototype methodology for mapping out future climate-related inland flood plains at U8 watershed level and for assessing assets' vulnerability to extreme flood events. The study intends to produce results that will be useful for capital planning.	Assessment, research, analysis, science, and mapping	In Progress	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				The Statewide Climate Adaptation and Vulnerability Assessment (CAVA) moved into its next phase, developing and implementing the statewide, planning-level assessment of which transportation assets are at risk to inland flooding over the coming century. This study identifies inland flood exposure for in-state National Highway System (NHS) roads, bridges and large culverts, MassDOT and MBTA-owned rail, MassDOT facilities, and MassDOT-owned airports. It assesses damage and repair costs, time estimates for repairs, and considers the consequences from loss of service. This effort builds on work done under previous studies by refining developed methodologies, applying them statewide, and integrating other MassDOT analyses that are concurrently considering asset exposure to flooding. Ultimately, this effort is anticipated to provide critical planning-level statewide flood risk information for different types of transportation assets through estimates of â€œdo nothingâ€costs and qualitative consequences of at-risk transportation assets under future conditions assuming no intervention. This information can be used during the capital planning process to prioritize investments that avoid or reduce long-term climatic impacts associated with flooding.	This assessment continues. The finished project is expected in the first half of 2023. For assets identified as vulnerable, it will include estimates of damage and and repair costs, time estimates for repairs and considerations for the consequences from loss of service through 2070. The finished project will be incorporated into GeoDOT.	
MBTA: Complete system-wide vulnerability assessment.	Continue assessing vulnerability of MBTA systems, operations, and assets. Complete vulnerability assessments by operating line of the Rapid Transit system (Red Line, Orange Line, Blue Line, Green Line), including support facilities. Complete a vulnerability assessment of the bus network, bus garages and maintenance facilities, including the Silver Line. Complete vulnerability assessments of the Commuter Rail lines and the Commuter Rail maintenance facilities. Finally, complete an assessment of the Ferry system.	Assessment, research, analysis, science, and mapping	In Progress	Massachusetts Department of Transportation	Massachusetts Bay Transit Authority (MBTA)	Regional	Boston Harbor Region	North and South Shores Region	The MBTA continues to assess the vulnerability of our operations and assets. An assessment of the Blue Line has been completed, along with drill-down assessments of critical assets on Blue Line (Aquarium Station and the Maverick Portal, as well as the Orient Heights Maintenance Facility). Additionally, a system-wide pump assessment has been completed. The MBTA is currently conducting a follow-up to this pump room assessment to map its track drainage system to better understand how it interconnects with municipal systems. Currently underway are also climate change vulnerability assessments of the Red Line, the Orange Line and an assessment of the Power, Signals & Communications system for Rapid Transit. Lastly, this past year, the MBTA was able to get a system-wide GIS-based mapping tool developed which overlays the entire system (including track elevations) with the Boston Harbor Flood Risk model. The findings and recommendations of these reports, and the mapping tool are being used to inform system-wide modernization projects conducted by the MBTA through its capital programs.	The MBTA has now completed: a follow-up to the first pump room assessment to map its track drainage system; climate change vulnerability assessments of the Red Line, the Orange Line, and the Green Line. The MBTA has completed an assessment of the Power, Signals & Communications system for Rapid Transit. Using a system-wide GIS-based mapping tool MBTA has completed flood vulnerability screening reports of its bus facilities and all commuter rail facitilies including key layover and maitenance yards. The MBTA has also partnered with MIT to complete a system-wide flood model for rail rapid transit and has researched the cost of anticipated coastal flooding damage to the MBTA's rail rapid transit system. The findings and recommendations of these reports, and the mapping tool are being used to inform system-wide modernization projects conducted by the MBTA through its capital programs.	This action addresses the Priority Impact "Damage to Rails and Loss of Rail/Transit Service". To better address this issue, the MBTA's vulnerability assessments can expand beyond just a granular focus on the rail rapid transit system to address bus facility and commuter rail facility vulnerabilities, as well as the vulnerability of other MBTA services such as the RIDE and the Ferry Service. Examining the vulnerability of these additional MBTA services will depend on time, funding, and staff availability. One of the ways to assess the vulnerability of these additional services would be to partner with other state agencies (such as MassDOT) to share findings from any assessments that have been done on state roadways or other state-owned transportation assets (such as rail service in the Western part of MA).
MBTA: Incorporate climate resiliency into capital planning activities.	The MBTA's Strategic Plan and Focus 40 goals explicitly address climate resiliency as a key priority for the MBTA. The annual development of the 5-year Capital Investment Plan (CIP) will continue to incorporate climate resiliency as a factor in project scoring and evaluation. All ongoing and new capital projects will mandate consideration of current and future extreme weather and incremental climate change related risks into design and construction of each project.	Capital planning	In Progress	Massachusetts Department of Transportation	Massachusetts Bay Transportation Authority (MBTA)	Regional	Boston Harbor Region	North and South Shores Region	The MBTA has developed an approach to project selection that considers the proposed project's ability to respond to or protect against the impacts of climate change. When determining which projects should be included in updated Capital Investment Plans (CIP) each proposed project is reviewed and scored on a variety of factors, one of which is climate resiliency.	The MBTA has developed an approach to project selection that considers the proposed project's ability to respond to or protect against the impacts of climate change. When determining which projects should be included in updated Capital Investment Plans (CIP) each proposed project is reviewed and scored on a variety of factors, one of which is climate resiliency. We continue to update this scoring methodology each year. Now we have the capability of mapping each CIP project location to examine its flood risk, which better informs the project scoring for climate resiliency.	This action directly addresses Priority Impact "Damage to Rails and Loss of Rail/Transit Service". One of the ways to continue to improve this action item from 2018 would be to see what other agencies (both in MA and outside of the state) to score their capital projects for climate vulnerability. Regardless, the MBTA updates its capital investment plan scoring criteria every year, so addressing climate resiliency within capital projects is something that will be continuously examined year after year.
MassDOT: Coordinate with state and federal agencies to evaluate environmental regulation and permitting processes to address current roadblocks in climate change.	Notify and collaborate with the Coast Guard to explore the potential need for exemptions and minor modifications under the Surface Transportation Uniform Relocation Assistance Act. This action refers to collaborative work with the Coast Guard regarding potential future sea level rise impacts on the navigability of bridges over water. Construction of bridges over water includes notification to the Coast Guard for navigability concerns and review. As sea level rise continues, water levels impacting bridges may require Coast Guard attention over the next 20-50 years.	Planning and policy	Not Started	Massachusetts Department of Transportation	Massachusetts Department of Transportation (MassDOT)				Because the planning timeframe is projected to be 30+ years out, regarding bridges over inland and coastal waters that are used for navigation, federal partners including the U.S. Coast Guard are likely to take sea level rise into consideration at the time of permitting. The U.S. Federal Highway Administration is also involved when federal funding is used. MassDOT looks forward to working with federal partners to coordinate and determine how federal regulations will be applied in the future.	MassDOT had an initial meeting with U.S. Coast Guard Sector Boston (August 1, 2023) to participate in planning and design for sea level rise by both agencies. We look forward to working with these federal partners to coordinate…"	